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Foreword

The papers presented in this *Record* represent recent research in critical staff functions supporting public transportation operations. Each activity is often behind the scenes, not very visible to the customer but fundamental to successful service. Nonetheless, the results of such work clearly determine what operations are delivered to the public and utilized. Papers are based on presentations at TRB's Annual Meeting in January 1995 in Washington, D.C. They have been reviewed by peers (practitioner and academic) in the field of public transportation, in accordance with established Transportation Research Board procedures.

In Part 1, Planning, five topics are discussed. For small transit agencies, long-range planning is necessary (Martinelli et al.). Part of planning is determining how to measure benefits (Horowitz and Beimborn), and the relationship between finance and the national economy of the Netherlands is examined (Cheung). At the local level, household survey techniques are explored in Boston (Harrington and Wang) and bus metering, as a technique of congestion management for the Lincoln Tunnel in New York City, is studied (Pavis et al.).

Part 2, Management, contains five topics. Program versus transit performance is a growing concern (Taylor). In Montreal, Canada, transit financing equity is examined (Chapleau) and life-cycle costing in Hamilton, Ontario, is an important consideration in a technological decision (Sherman and Hide). In some situations, additional bus service may harm other transit services (based on research by Kaysi and Bassil in Beirut, Lebanon). Or, if facilities are converted—for example, busways or bus lanes to high-occupancy vehicle lanes—negative impacts occur (Vuchic et al.).

Part 3, Technology, offers four distinct situations for review. Modeling the costs of a proposed automated people mover system serving an airport helped define parameters (Manadalapu and Sproule). Combining two technologies, personal rapid transit and maglev, was examined for feasibility (Suppes). Electric bus operation feasibility in Austin, Texas, was also studied (Fowler and Euritt).

Part 4, Ridesharing and High-Occupancy Vehicles, reviews nine important subjects. Many businesses need to know what employee transportation Coordinators (ETCs) do, thus the ETC function is profiled (Chen et al). In New York State, employers are now benefiting from a new commute options guidebook (Saito et al.). The demographics of carpooling is still a basic question (Ferguson), and employer involvement does make a difference (Young). One of the larger challenges occurs in the suburbs, as experienced in the Lake-Cook (Illinois) corridor (Fish et al.). Transportation control measures are crucial to the success of ridesharing (Beaton et al.). Early progress can be expected from employer-based trip reduction programs (Burns), and site amenities also play a role in eliminating trips (Davidson). Finally, a 5-year study of employee commute options in Southern California provides a vital perspective (Young and Luo).

As the results of such research become available, decision makers, planners, and managers will have a stronger base of data and tools to help provide responsive public transportation service.

PART 1

Planning

Long-Range Planning Issues for Small Transit Agencies

DAVID MARTINELLI, ASVIN MANDADI, RONALD ECK, AND DARRELL DEAN

For small transit agencies to remain effective and to grow in service, they must respond to a number of national and local trends. The Intermodal Surface Transportation Efficiency Act, Clean Air Act, Americans with Disabilities Act, and local economic conditions are but a few of the recent events that mandate the use of long-range planning for small transit agencies. A research effort that identifies and discusses the key issues for strategic planning of transit agencies in small and medium-sized communities is outlined. Strategic planning can be a difficult undertaking, particularly for smaller agencies, because they either do not have the staff and time resources to carry out analysis of organizational practices, consumer needs, and political environment or do not feel the need for such formal processes because their organizations are simple enough and the strategy setting can be based on managerial experience and judgment. In addition, a case study of a recently completed study for the transit agency in Charleston, West Virginia, is presented.

The recently adopted Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) has empowered state and local governments with greater opportunities for involvement in transportation infrastructure and operations. In the signed version of the bill, $31.5 billion is authorized for transit over a 6-year period. A fundamental difference between ISTEA and prior transportation bills is that it gives states the flexibility to allocate federal dollars among highway and transit initiatives. Although funding flexibility for transit under ISTEA presents an opportunity for transit agencies to participate in the state programming process, it will be necessary for these agencies to develop comprehensive strategic plans. Many small transit agencies will be conducting strategic planning for the first time.

Transit agencies carry out strategic planning in different ways. Some perform long-range (10 to 20 years) service and capital plans, which are formal documents required externally, (e.g., transportation improvement programs, or TIPs). The focus is primarily on demand for service, service levels, capital needs, funding requirements, and fare structure. Some perform short-range (1 to 2 years) service plans or tactical planning, which is similar to long-range service and capital planning but has a shorter time horizon in which the focus is primarily on comprehensive operational analysis (*1*). The discussion in this paper addresses long-range planning for a horizon of 5 to 20 years, with a focus on strategic issues of importance to small transit agencies. Strategic planning can be a difficult undertaking, particularly for smaller agencies, because they either do not have the staff and time resources to carry out analysis of organizational practices, consumer needs, and political environment or do not feel the need for such formal processes because their organizations are sufficiently simple and the strategy setting can be based on managerial experience and judgment.

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It is expected that small transit agencies operating in small urban areas (population less than 200,000) will need guidance when confronted with complex issues such as funding, staffing, compliance with regulations, and evaluating service alternatives for the future. This is because, in general, small transit agencies do not have the internal infrastructure and planning experience necessary to develop long-range transportation plans. Instead, they may depend on externally developed service planning documents to form an internal comprehensive program. This may be attributed to lack of staff resources, lack of support for such activities, lack of training, and lack of perceived need. In large transit agencies, however, there is more likely to be a dedicated internal planning process infrastructure.

Much of an appropriate planning process of transit agencies within small urban areas will probably be area-specific. That is, much of the strategic planning process is governed by the following: local issues and policies, area travel and activity patterns, topography and geography, existing transportation infrastructure, proximity to major cities, and other factors (*2*). Although much is area-specific, there is a need to formulate the general issues that are necessary to address the unique needs and characteristics of small transit agencies. This paper addresses the major issues in long-range planning for small transit agencies. In addition, a case study is presented based on a recently completed study for the transit agency in Charleston, West Virginia.

The objectives of this paper are as follows:

1. To identify differences between small and large transit agencies,
2. To describe a methodology for developing an implementable long-range strategic plan for small transit agencies,
3. To identify planning issues most important to strategic planning for small transit agencies, and
4. To summarize long-range issues of a first-phase strategic plan for a transit agency in a small urban area.

DIFFERENCES BETWEEN SMALL AND LARGE TRANSIT AGENCIES

There are many differences between large and small transit agencies that have implications on the strategic planning process. A compilation of the primary differences between small and large transit agencies will serve as a precursor for designing a methodological approach for long-term strategic planning for small transit agencies. Although many of the factors that affect the planning process for large transit agencies also affect planning for small transit agencies, there are differences between small and large transit agencies that warrant special consideration for smaller agencies. These differences are enumerated here:

1. In most cases, small transit agencies do not have dedicated programs for developing strategic plans internally but rather rely on externally required planning processes, for example planning documents prepared by external agencies such as metropolitan planning organizations (MPO) and state departments of transportation and consultants, whereas larger transit agencies have organized planning divisions that perform planning studies on a regular basis (*3*).
2. A team planning approach is desirable and is used in most cases to develop a strategic plan for both large and small organizations (*4*). The only difference is in the composition of the team. Large transit agencies have separate departments for service planning, marketing, capital planning, corporate planning, and fare structuring. Executives from each department combine to form a team and to develop the required strategic plans for the agency, whereas small agencies must coordinate with other government and private agencies to form a team that would formulate and decide strategic decisions.
3. The availability of staff resources can have an important effect on the ability of a transit agency to implement a strategic planning process. Staff are needed to handle the logistics of such a comprehensive process, to coordinate discussion, to collect data, and to monitor implementation. Staff are also needed to conduct analyses, to synthesize findings, and to present options and their impacts. However, availability of staff resources is another factor that varies with agency size and therefore represents a limitation for smaller agencies.
4. Small transit agencies tend to have smaller fleet sizes, simple route structuring, and other characteristics of relatively small-scale operations. For this reason, few such agencies have conducted long-range plans and thus conduct strategic planning for the first time, whereas large transit agencies usually have a set framework for the strategic planning process. The complexity of the organization and its operations necessitate the development of long-range strategic plans, and availability of staff resources enables distribution of responsibility to implement and monitor the strategic plans.
5. Small transit agencies differ from large ones in the type of population they serve. Generally speaking, in large urbanized areas most of the population using transit are commuters and are motivated to use transit because of the high level of service (e.g., light rail), congestion on urban freeways and arterials, or limited parking within the city (*5*). There is usually little congestion in small urban areas, and ample parking space is usually available (*5*). This is a negative factor for transit operating in such areas because it has to serve principally the transportation disadvantaged and the elderly. Innovative ideas for improved level of service (LOS) are necessary to entice noncaptive riders to use transit in such areas.

APPROACH TO LONG-RANGE PLANNING FOR SMALL TRANSIT AGENCIES

"Strategic planning is the process of deciding on objectives of the organization or changes in these objectives, on the resources used to attain these objectives, and the policies that are to govern the acquisition, use, and disposition of these resources" (*6*).

In the context of transit, strategic planning is important to allow services to keep pace with demographic, social, economical, and political trends of a region. For example, in many metropolitan cities, some of the suburbs have emerged as employment centers. Therefore, trip patterns in these cities cannot be characterized as radial but rather are significantly more complex. Transit agencies must anticipate and/or respond to such trends if services are to be high and operations efficient. Strategic planning is also important in providing a framework of goals, objectives, and priorities respond (i.e., generate and evaluate alternative actions) to unexpected events such as funding cuts, labor strikes, facility closings, and government regulation.

Strategic planning for small transit agencies may not involve a rigid procedure. A formal strategic planning process usually contains methodological steps, formulation of alternatives, comprehensive analyses and evaluation, and documentation preparation. Small transit agencies do not have separate departments to conduct planning at different levels of the planning process, so a team planning approach may be adopted. This approach is mostly used in all transit agencies (small or large) and is thus recommended for small transit agencies. In team planning, a chief executive officer (CEO) uses line managers as staff to develop plans (*4*). For example, in a small city the mayor could act as the CEO, and his staff may consist of representatives from various organizations in the area including the transit agency. For the strategic plan to be applied as an effective management tool, the focus of the effort should be on only a few critical issues. Similarly, some small transit agencies may be able to integrate transit plans into other city plans, thus using scarce planning resources and coordinating government services with transit services.

There are typically four stages that are important in the decision-making process: problem identification and definition, debate and policy formulation, implementation, and evaluation and feedback (*5*). The purpose of the planning process is only to provide information that is most important to decision makers (*5*).

The first stage in the decision-making process is problem identification and definition. The critical issue here is the way in which the problem is perceived and thus defined. The interaction between decision-making and planning is assumed to occur in the diagnosis of internal and external factors affecting the agency's performance. The mission statement, goals, and objectives are established by the management team and planning staff in the first stage.

The second stage in the decision process is debate and policy formulation. The decision is a choice among alternatives. The interaction between decision process and planning is assumed to occur in analysis and evaluation of alternative strategies developed in the planning process.

The third stage is the implementation stage. The planning process constitutes the establishment of budget to implement the strategies proposed in the second stage.

The fourth and final stage in the decision process is evaluation and feedback. The interaction between the decision process and the planning process is assumed to occur in monitoring the strategic program results and the external environment. Monitoring is necessary to correct any changes that might occur during implementation, and a feedback is necessary for further diagnosis of the changes.

The strategic planning methodology developed herein for small transit agencies is based on a theory of organizational planning developed by Ferris (*7*). It has been modified to accommodate the mission and structure of small transit agencies. The following steps were identified by Ferris as most critical:

1. The agency should scan the overall environment to identify major trends, issues, problems, needs, and opportunities that affect the organization. This step is particularly important because small

transit agencies usually have more outside the agency's control that threaten the health and survival of the agency. Significant forces external to small transit agencies that may be considered major trends and issues include economic, demographic, social, political, technological, financial, and legal forces (*4*).

These trends and issues give rise to problems that need to be solved by strategically planning on a long-term basis. Because of these external forces small agencies have tended to be more reactive than proactive in their decision-making. It is important for these agencies to establish a role in the decision-making of local governments, state agencies, commerce groups, and other important organizations. Some of the issues raised, which have more or less similar implications on many small transit agencies, are: changes in Federal funds and programs, changes in state policies and their unforeseen circumstances, interagency competition and its impact on funding levels, importance of communication, serious implications of deteriorating external relations, and vulnerability of transit service to political conflicts (*1*).

Not all factors are external to the agency. Significant internal issues include financial viability, quantity and quality of service, managerial and organizational effectiveness, productivity of human resources, technological capability, and marketing effectiveness. The analyses of these internal factors should result in an examination of the organization's strengths and weaknesses (*4*). Small transit agencies should address in their strategic plans the following internal issues and opportunities: identifying the training needs of staff, assessing how new technologies such as microcomputers could benefit the agency, improving financial accountability and efficiency, and clarifying individual responsibilities and the agency's structure.

2. The agency should clearly define its goals and objectives. Analysis of internal strengths and weaknesses and examination of external influencing factors should be the basis for the mission statement. The mission statement should then be broadened and clarified by defining specific goals and objectives. For example, part of an agency's mission may involve improving the image of transit in the region. A corresponding goal might be to improve the system level of service. An objective should have a measurable end; hence a corresponding objective might be to decrease headways on selected routes. Small transit agencies should develop a specific strategy and action plan to deal with the external threats they face. A formal document that outlines internal needs and objectives and addresses service levels, capital plans, and other issues should be developed. The mission and goal statements should be communicated widely to create common expectations among financial contributors. Following a team approach and clarifying responsibilities among agency staff, a professional approach to management can be attained, and the agencies can handle any crisis (*1*).

3. The next step is the development of a strategy that defines how the stated objectives will be met. Strategies should be consistent with the stated mission and goals. The agency should attempt to delegate the resources necessary to implement the strategy. Key staff within the agency should be involved in the implementation. Strategies should be evaluated in terms of several criteria such as cost, personnel requirements, agencies and organizations involved, time frame, impact on the environment, and legal implications (*4*). In the case of small transit agencies strategies must be developed by key individuals who are familiar with the external environment. Market orientation should be the approach throughout strategy development, and the agency must segment its market in terms of users, geography, demography, and other criteria.

4. Implementation is the next crucial step to successful strategic planning. It is operational in nature and involves coordinating, managing, and motivating many individuals. For successful implementation, top managers must communicate with all employees what the strategic decisions are about. Strategies must not be poorly conceived; otherwise they will fail. A detailed implementation plan must be prepared that identifies specific tasks, responsibilities, and likely implementation problems. Also, no significantly implementable strategies should be approved without ample opportunity for public review and comment. Citizens, particularly those with specially affected interests, should have a say in choosing the forms and amounts of public transportation services they will have. Transportation should help to redress income differences, mobility should be available to all, and prices should reflect social costs.

5. The final task for strategy implementation is the monitoring and evaluation of the progress through periodic feedback. In monitoring, it is important to identify change in the external environment involving fundamental forces affecting the agency. It should also identify any unforeseen strengths and weaknesses of the agency and their implications. Subsequently, any modifications in the objectives are made.

SMALL URBAN AREA PUBLIC TRANSPORTATION CASE STUDY

The focus of this paper has been on the need and possible approach for long-range planning for small transit agencies. The Harley O. Staggers National Transportation Center at West Virginia University recently completed a first-phase in the development of a long-range transportation plan for Kanawha County, West Virginia. Though the study was not wholly strategic in nature, the identified issues incorporated several strategic planning elements. Some of the trends, initiatives, needs, and opportunities identified in the Kanawha Valley region had potential implications on the quality and scope of public transportation.

The population of Kanawha County is approximately 200,000 [Kanawha Valley Regional Transportation Authority (KVRTA), Charleston, West Va.] The heart of the county is the small urban city of Charleston. The city of Charleston is a Class I city and is the largest in West Virginia. It is the most populous with a population of approximately 60,000. Charleston has earned the reputation of a growing industrial area, and efforts are being made to redevelop the central business district (CBD) to attract more businesses. It is the home of several cultural groups and is the location of the state capitol, Capitol Complex, Cultural Center, the University of Charleston, community centers, and various neighborhood recreation centers. The city has a diversified activity system and thus also has major public transportation issues. Kanawha County comprises 908 mi^2 of hilly terrain bisected from southeast to northwest by the Kanawha River.

Most of the county's population and the commercial and industrial development are located in the floodplain of the Kanawha River and in the Elk and Coal river valleys. Major highways also follow these rivers. The county is well served by highway facilities with three Interstates converging in Charleston. The private automobile is well established as the major means of transportation. Parking is generally available in the Charleston CBD and other employment centers (Regional Intergovernmental Council, 1990). Public transportation is provided by the KVRTA for Kanawha

County. The impetus of the study was the confrontation of numerous regional, state, and national trends of the KVRTA with the quality and scope of the public transportation they provide.

A summary of the trends, needs, and opportunities identified by the study team is discussed here. The issues applicable to small transit agencies in general are discussed first followed by those issues that are more area-specific. The first-phase study involved the identification of long-range planning issues based on potential economic and social trends. The scope of public transportation options were examined based on the needs and opportunities. Several recommendations were provided under each issue, which required a detailed analysis and would constitute the second-phase study.

Some of the general issues identified by the study team include the Clean Air Act Amendments of 1990 (CAA), Americans with Disabilities Act of 1990 (ADA), and ISTEA. Passage of these laws has had a significant impact on the transportation planning and project development processes (*8*).

CLEAN AIR ACT OF 1990

The intended purposes of the CAA is to bring air quality nonattainment areas into attainment areas. Charleston is designated as a moderate nonattainment area for ozone. Consequently, all city and regional transportation plans and programs must perform additional analyses to show that their projects will result in pollution reduction. Also, at the state level, West Virginia must develop a state implementation plan (SIP) involving an inspection and maintenance program for vehicle emissions and other measures to reach attainment within 6 years. Four critical issues related to compliance were identified: hardware solutions, alternative fuels solutions, use of methanol fuel in public transportation, and behavioral changes on planning committees and the public to reduce both the level of traffic and the level of congestion on the highways. The key point here is not just compliance of agency with the guidelines of the act but its response to the changes in public attitudes and perception. For example, the public perception of the CAA is to have a clean, pollution-free environment, and hence the population would expect the transit agency to provide clean service. This may have implications on the transit industry if not considered.

AMERICANS WITH DISABILITIES ACT OF 1990

The intended transit purpose of the ADA is to allow access to all people with disabilities to public transportation services and public facilities without discrimination. ADA also requires that any public transit agency operating as a fixed-route system provide paratransit services for disabled individuals to access the system. KVRTA has submitted a paratransit plan that includes descriptions of a fixed-route system, existing and proposed paratransit systems, a proposed eligibility determination process, and a public participation process used to develop the plan.

INTERMODAL SURFACE TRANSPORTATION EFFICIENCY ACT OF 1991

The intended purpose of ISTEA is to promote a "more intermodal transportation system," and it attempts to shift responsibility for making fundamental transportation decisions from the Federal level to state and local levels. The changes allow for a greater flexibility in the role of state and local governments to shift resources between highway projects and mass transit. Greater flexibility in funding for transit provides an opportunity for transit operators to develop the efficient transportation system necessary to meet existing and future travel needs. Identification of future transportation needs through a long-range transportation plan is a prerequisite for the development of a TIP by the MPO, which is a major planning document for securing federal funds.

Small transit operators need to approach these issues by ensuring that they have a long-range strategic plan that addresses all three of the acts. Otherwise, given so many directions in which to plan, it might be a difficult task to comply with all the provisions of the acts.

DECREASE IN TRANSIT RIDERSHIP IN KANAWHA COUNTY

Most transit operating in the United States faces ridership crises or a potential decrease in ridership. In small urban areas such as Charleston, several causes for reduced ridership include declining population, rising unemployment, and abundance of downtown parking. Stabilization in fuel prices, improved fuel efficiency in vehicles, and sub-urbanization are causes, at the national level, for such decreases in transit ridership. A key aspect in the long-range transportation study for KVRTA was to identify these decreasing ridership trends and to possibly establish innovative approaches to increase ridership. Some strategic planning approaches suggested for small transit operators in general include: (*a*) an understanding of the decreasing ridership problem, (*b*) an analysis of the problem, (*c*) data collection for developing transit service alternatives, and (*d*) implementation and monitoring.

Some of the area-specific issues identified in the long-range transportation study include congestion on Interstate 64, economic developments in downtown Charleston, the proposal for a new southwestern West Virginia regional airport serving Charleston, Huntington, and Parkersburg, and decreases in transit ridership in Kanawha County (*8*).

CONGESTION ON I-64

The major Interstate highways I-64, I-77, and I-79 intersect in the Charleston metropolitan area. These Interstates provide local area communities access to the nearby metropolitan areas of Huntington, Parkersburg, Clarksburg, Beckley, and many other distant cities. The congestion problem identified was on I-64 between Charleston and Huntington. The traffic levels on the interstate often exceed the design level during weekday commuting hours, which results in congestion mainly at key bridges and interchanges. Public transportation use has been identified as a solution to the congestion problem on I-64. The use of public transportation on the interstate would add to the capacity and as a result there would be reduction in congestion. Generally speaking, the problem of congestion is present in most urban areas, and transit use has evolved as a major part of its solution. Some long-range strategic issues identified by the study team that can be combined with transit use include: (*a*) large and small scale improvements to the transportation system according to the local needs and nature

of economic and social growth, (*b*) priority facilities for transit and high-occupancy vehicles (HOV) in the form of HOV lanes on Interstates and priority entry control on freeway entry-ramps, and (*c*) integration of park-and-ride facilities with transit providing access to employment centers and the CBD. These issues need to be considered by small transit agencies in developing a long-range plan.

ECONOMIC DEVELOPMENTS IN DOWNTOWN CHARLESTON

Revitalization efforts under way in Charleston require the provision of a personalized, convenient, efficient, and safe internal ground circulation system to expand the capability of people to move about in a more active CBD. Some of the strategic planning elements of importance to small transit agencies that were proposed for KVRTA include (*a*) an understanding of the land use developments within the CBD, (*b*) an understanding of demand for public transportation because of existing and proposed land use developments, and (*c*) coordination between the transit operators and organizations involved in the land use developments. It is critical for the transit operator to understand the land use–transportation relationship before generating alternative transportation facilities. The activity system comprised the "activity centers" within a region. Activity patterns refer to the type of activity centers, which include employment, cultural, recreational, retail, and visitor bases. Travel decisions of people from the activity centers results in a variety of trips between the activity centers. This gives rise to demand for a transportation system that provides access within the activity system.

PROPOSED SOUTHWESTERN WEST VIRGINIA REGIONAL AIRPORT

The concept of a Southwestern West Virginia Regional Airport to serve Charleston, Huntington, and Parkersburg has been under consideration for several years. The provision of public transportation service to airports has received increased attention in recent years, so the study team identified the necessity to integrate transit with the proposed regional airport. Even though this is a location-specific issue, it can be considered a potential opportunity that needs careful attention of transit managers of small transit agencies. Two critical strategies identified in this issue are (*a*) a close coordination between the transit agency and the airport authorities *during* the planning stages of the airport construction, (*b*) proper planning by the transit operators for providing fast, convenient, and inexpensive transit services to air passengers, and (*c*) planning expansion of services for future increases in demand.

SUMMARY AND CONCLUSIONS

The summary of long-range planning issues addressed for KVRTA reflects some of the strategic planning issues important to a small transit agency. Recent legislative initiatives such as the CAA, ADA, and ISTEA affect the planning process of the small as well as large transit agencies. However, several differences between the large and small transit agencies, discussed earlier in the paper, make the approach to planning different for small transit agencies. The difference here is that small transit agencies depend on externally required service planning documents to develop an internal strategy. Dependence on externally required service planning documents can be overcome by assessing strategic factors affecting the agency's long-term success in terms of strengths, weaknesses, opportunities, and threats (*4,9*).

In developing a long-range plan, the agency should first assess its strengths and weaknesses. For example, compliance with the ADA would require coordination between transit and paratransit providers. An agency might do well in providing transit services to the local population, but lack of coordination with paratransit operators could result in inadequate performance. An agency must also explore opportunities that might lead to its future growth and success. Steps should also be taken to overcome factors that threaten the agency's ability to carry out its mission. Economic and social trends, demographic changes, and political influence within the agency's service area should be of primary concern to the small transit operator. For example, the revitalization process in downtown Charleston represents a potential change toward the betterment of the society and the economy.

Subsequently, travel patterns could be significantly altered possibly requiring a change in transit service characteristics and service levels. Thus, coordination among transit officials, local government officials, and other organizations was identified as a necessary tool to determine future needs of the area and a role of transit in meeting the needs of the population.

Some of the internal issues that may pose problems to a small transit agency include financial viability, quantity and quality of service, managerial and organizational effectiveness, productivity of human resources, technological capability, and marketing effectiveness. To overcome these threats, the agency should have a proper direction, and coordination within the agency is a key element. Development and implementation of strategies can be attempted only by overcoming these threats. In general, proper coordination, management, and motivation of individuals within the agency are solutions to overcome internal threats. The team planning approach, discussed earlier, is the best approach to strategy development by small transit agencies. Local government officials and representatives from other organizations are usually involved with the transit agency in developing a detailed implementation plan identifying tasks, responsibilities, and likely implementation problems.

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Methods and Strategies for Transit Benefit Measurement

ALAN J. HOROWITZ AND EDWARD BEIMBORN

Benefit assessment is done to make decisions, and a general discussion is given of how to view benefits for that purpose. Benefit assessment practices from many agencies in the United States are described. Agencies' reported benefits and their use of benefit measures in actual practice are compared. The political environment surrounding transit decisions was found to have a major effect on procedures that are adopted for benefit analysis. The paper also shows how consequences of transit can be illustrated through the use of a benefit tree, which allows planners to show how transit service provides an alternative means of travel, results in changes of trip making by automobile and transit, affects land-use activity, and leads to direct and indirect employment. Approaches are described for quantifying benefits. As an example, a method is presented for calculating the enhanced consumer surplus as a broad measure of user benefits of a project alternative. Recommendations are made on how to effectively use benefit measures for selection of project alternatives within a political decision-making environment.

Recently there has been increased interest in public transit by local units of government. Many urban areas have undergone substantial reviews of their transit services and have developed ambitious plans for expanding service and for constructing new fixed-guideway facilities. This increased local interest often coincides with budget shortages at all levels of government and with increased automobile ownership and usage. Under such conditions this support for transit usually means a larger commitment of local funds. Very often such support is manifested through a referendum or through a major grassroots effort. There is a local perception that the benefits of transit are great, so great that people will accept increased local taxes to pay for them. This has occurred in many cities, but the benefits of transit are still poorly understood.

Benefits can be viewed as those consequences that are valued by some segment of the population. Benefits exist because people believe they are important, whether or not they can be measured (or if seemingly objective measurement shows them to be nonexistent). Some communities place a high value on public transit even though it is difficult to find significant benefits by methods used for other means of transportation. These communities value transit highly and are collectively willing to pay a substantial amount of money to support it. The level of monetary benefits of a transit system in such places must be viewed as being at least as high as the total local expenditures (user costs plus subsidies) for transit, maybe substantially higher.

Benefits can be viewed in different ways, and it is essential to distinguish among approaches. Much of the debate about benefits stems from the chosen point of view. Three common viewpoints are financial, economic, or political.

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A financial viewpoint includes only those benefits that can be recovered as income. Benefits are those things that contribute to the rate of return on the investment in transit. Returns (benefits of transit) should go directly to the agency to pay the expense of providing service. External benefits have no value unless they can be captured by the transit agency.

The economic viewpoint of benefits is broader in that benefits can accrue to others and still be of value. This viewpoint uses a willingness-to-pay criterion for benefits; that is, how much are users and nonusers of a system willing to pay for a service regardless of its price? The difference between willingness to pay and price can be viewed as a benefit: consumer surplus. The economic view also assumes that the benefits can be converted into monetary units. Benefits are derived from an analysis of supply/demand equilibrium and from the behavior of individuals who make choices in an open market condition.

The third viewpoint of benefits is a political one. The political process in a democratic system provides a way for a community to express its opinion of what is and what is not important. When duly elected officials make choices, ideally they are expressing the collective feelings of society about the benefits of different governmental activities. The value placed on transit by voters, primarily nonusers, is an indication of the benefits beyond those accruing to users. Promotional materials from transit agencies, citizen groups, and referenda advocates often include environmental improvements, access to jobs, economic development, better mobility for others, emergency transportation, and enhanced community image as reasons to support transit.

The political process involves tradeoffs and choices, and it can be a good indicator of community values. However, there are factors that may cause the political process to represent opinion poorly. Lack of open debate, unfair competition between ideas, overrepresentation of special interests, or consideration of other unrelated issues (e.g., educational policy or low-income housing) can inhibit the interpretation of transit decision making as a means of measuring benefits. This paper presents a summary of a larger work (*1*) that provides a look at benefit issues from each of these viewpoints.

DECISION BASIS FOR BENEFIT MEASUREMENT

Benefit analysis is done so decisions can be made. A decision could be made for a specific purpose, such as the selection of the best alternative, or for more general reasons, such as to generate support for all transit services. Understanding the nature of transit decisions is the key to benefit measurement. Benefits can be analyzed by looking at both the product and the decision-making process itself.

Product: Cited Benefits

A list of benefits and impacts was compiled from a selection of alternatives analysis/environmental impact statements (AA/EIS) for major transit investments. Within the AA/EIS, the federal government requires certain impacts to be quantified; local agencies can add other factors to this list or can elaborate on required items to make their case more convincing. AA/EIS provide evidence of which benefits are of greatest importance to each community.

Fifteen alternative analyses, environmental impact statements, and economic impact assessments were reviewed. These particular cities were selected because they had had relatively recent projects and because their analyses appeared to be complete. Results from this analysis are given in Figure 1. Cited benefits are indicated, as well as whether an effort was made to quantify the benefits. A reading of the AA/EIS reveals that communities cite a wide variety of benefits. There are considerable differences among cities. None of the cities considered the option value of transit, and most considered the reduction in automobile trips, land preservation, and transit operations as benefits.

Process: Local Use of Benefit Measures

Cities around the country were visited to gain a better understanding of transportation decision making and the role of benefits analysis. Cities were selected where expansion of the transit system has been a significant local issue and where extensive analysis has been or is being made of the benefits of transit. Four cities were visited, each of which had undergone or is currently experiencing substan-

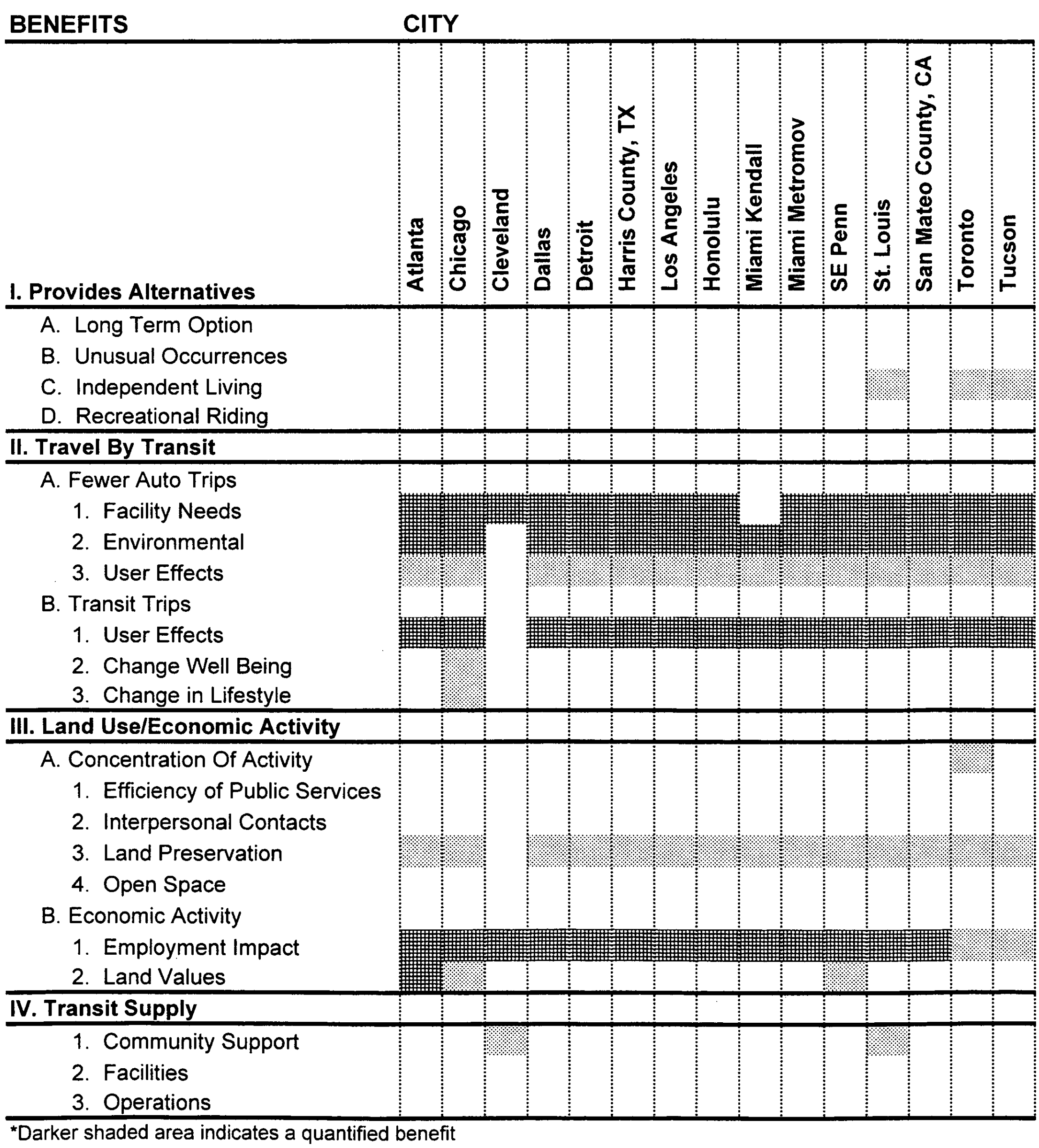

FIGURE 1 Cited benefits in AA/EIS.

tial discussion of local transit alternatives. The purpose of these visits was to examine how analytical estimates of benefits were used in decision making and to identify critical factors that lead to the choice of particular courses of action. This effort also looked into the role of referenda as a way to gain a community expression of transit benefits, that is, to determine whether one could estimate overall perceived benefits by looking at how much a community was willing to tax itself voluntarily to support transit.

In each community, interviews were conducted to understand better the technical and political arguments for and against the transit expansion. In-depth interviews were held with staff members of transit agencies, local government, and metropolitan planning agencies, and citizens and members of the academic community. A large number of documents were also obtained, including planning documents and promotional information that helped to understand the social, political, and philosophical history of transportation decision making. There was good agreement among those interviewed about the key political issues and the areas of dispute.

Issues of Debate

In the communities we visited we found diverse opinions on the general value of transit and even more disagreement on specific projects. This disagreement was especially evident when the issue of building a rail system was a point of local controversy. In these places transit, in general, may have widespread support, but particular parts of rail system proposals are seriously questioned. Debates over courses of action tended to center on benefit issues. Advocates believed there were substantial benefits of transit investment, and those people opposed doubted that such benefits exist. In most cases, these opinions existed independently of any attempts to quantify benefits. Studies that measured benefits were ignored or discredited or cited as authoritative depending on one's position on the proposed project. In most places we visited benefits were a matter of belief rather than an agreed fact. Furthermore, many benefits cited were intangible and difficult or impossible to measure.

The strongest criticisms came from those who believed that rail development cannot possibly be cost effective; that is, it cannot generate sufficient ridership and farebox revenues to justify the investment. In a role reversal, some critics accused political leaders of being too visionary, of not appreciating the obstacles to a successful system, and of placing too much faith in travelers' willingness to adapt to the changing transportation system. Technical analysis used to justify rail programs was challenged by opponents who said that the positive results were predetermined by the chosen methods. The critics have taken a conservative position relative to the potential benefits of a rail program, suggesting that most of the benefits are small and that overall nonquantified benefits do not exist. They say that it would be better to spend the money on bus services that can blend with the automobile-oriented life style of the community. Advocates, on the other hand, placed high weight on nonquantified consequences and were optimistic about other effects.

In the cities visited, those interviewed felt that the community supported transit principally because of the promise of congestion relief. Concerns about air pollution and energy consumption were also expressed in some locations. Supporters of transit included downtown interests, who believed that the center of the city could not experience any future growth without an increase in transportation system capacity. Comparisons to other "world class" cities were made in a few of the cities we visited. Transit was seen as an important factor in civil pride and prestige. However, it was also mentioned in some cities that transit was supported by people who feel that they would not personally use it. In other words, their view was that people want transit so that other people can ride it.

These reasons for transit support in some cities appear to be based on frustration with the highway system. Transit was presented as a palatable way of solving the seemingly intractable problem of traffic congestion. It was mentioned in some places that the city once had a fine streetcar system and things were better then. Lacking tangible evidence that a rail system would actually mitigate today's traffic problems, decision makers accepted this contention as an act of faith.

In some places the issue of socioeconomic status of riders was mentioned. There was a general agreement that trains have more status than buses. They can attract a better class of rider because of the promise of personal safety, comfortable seats, smoother ride, and attractive surroundings. Asked why these same attributes could not be given to buses, it was candidly stated by one person that a better bus environment could not be maintained, given the type of people taking the bus. A decision has apparently been made to create trains for affluent travelers, leaving buses as they were for poor people. Subsequent to these interviews, a lawsuit has been filed in one community concerning socioeconomic separation of train and bus riders.

Socioeconomic status is also affecting route alignments. There is a discernible tendency to locate rail lines away from richer areas and near poorer areas, somewhat undercutting the objective of increasing the proportion of affluent riders. The desire to serve poorer areas is understandable; poorer areas already have a demonstrated need for transit. The desire to avoid rich areas is not totally explained by population density or automobile ownership considerations. Interviewees suggested that the rich do not envision taking transit themselves but fear an increase in crime in their neighborhoods by "those" people who do take transit. Another impediment to providing rail transit in rich neighborhoods is a perception by some individuals that it is visually unattractive and noisy.

Role of Political Process

Transit planning, especially for new rail systems, is fundamentally a political process, assisted by technical analysis. Our interviews showed that most local planners do not believe that it is necessary to evaluate the benefits of its rail program because they have received a mandate for the program in the form of a clear political victory or successful referenda. The decision makers are all actors in the political process, and they decide which parts of the transit program receive funding.

Transit is seen by some elected officials as a means of revitalizing the community, containing sprawl, and encouraging growth in high density corridors. There is a strong belief in the cities visited that they have a dynamic community, rapidly changing in both its urban form and its demographics. The vision of rail transit development is that it can help reshape the community into a more efficient one and that it can overcome the almost complete dependence on highway transportation.

Transit relies on key elected officials for its support. If these key officials lose elections or leave office, there can be significant changes in direction. Projects are dropped or scaled back as other issues gain emphasis. The level of benefits may remain the same, but different people pursue other political objectives.

In some cases support for transit occurs because of a compromise among highway goals, environmental interests, and other factors. Some level of transit investment is needed to gain support for overall transportation programs that include substantial investment in other modes of transportation. Furthermore, support of advocates for environmental protection is obtained by promoting transit in exchange for compromises in development policy. Transit is another issue that mixes into an overall package of programs assembled by elected officials. When the overall picture is explained, the level of support for transit can make more sense than if transit is looked at by itself.

DECISION-BASED FRAMEWORK FOR BENEFIT ANALYSIS

A number of techniques can be devised to assess benefits of transit projects in a manner consistent with the decision process. This section focuses on just two techniques: the benefit tree and enhanced consumer surplus. They do not form a complete evaluation framework, but they indicate the needed breadth for transit decision making. Other techniques may be found in the original report for this study (*1*).

Benefit Tree

Despite the large amount of prior work on transit benefits, there have been few systematic efforts to deal with the interrelationships among different benefits nor have there been many attempts to provide a comprehensive picture of transit benefits. This section describes a framework that was developed for understanding the interrelationships among benefits of transit service. The framework takes the form of a tree diagram.

The benefit tree provides a display of what might happen as the result of a change to transit service. These consequences may not necessarily be benefits but merely impacts resulting from the improvement of a transit system. Impacts can be significant or insignificant depending on the chosen viewpoint, the scope of analysis, and the nature of the null alternative.

The benefit tree shows how consequences are related. The tree is divided into five branches. Vertically, the tree grows more specific from top to bottom. Double counting occurs when benefits are included at multiple levels on the tree. Some benefits can be quantified, others cannot. Nonetheless, the tree can provide a way to consistently compare alternative transit. The five branches are as follows:

1. Alternatives;
2. Travel by transit: fewer automobile trips;
3. Travel by transit: transit trips;
4. Land use/economic activity; and
5. Transit supply.

The tree has a total of 77 consequences, and it is too big to reproduce here in its entirety. Part of the tree is shown in Figure 2. The benefit tree can be used to identify and display the potential benefits of a transit alternative. The first step is to identify those boxes on the diagram where a transit alternative will be significantly different from the null alternative. Only those consequences generate benefits or disbenefits. Each remaining box would then be filled with numerical or descriptive information to describe the effect.

The example shows Branch 5 of the tree, transit supply, as filled out for a rail transit alternative compared with the null alternative, an all-bus system. Plan design and travel demand analysis lead to the determination that the rail alternative requires 30 light rail vehicles to operate on 32 km (20 mi) of track. Operations and construction require the resources shown in the tree. A fully filled out tree could illustrate all consequences and help focus decision making on key trade-offs among alternatives and aid in the selection of a locally preferred alternative. This example uses the viewpoint of a local decision rather than a national decision. As such, consequences that have differential effects at the local level are included. Decisions at other levels of government may use different assumptions and data.

A drawback to the benefit tree is that it is static. It is not possible to show how consequences occur over time. Should the timing of a consequence be an issue, then a suitable comment should be added to its box.

Broad Measurement of Travel-Related Benefits

The largest components of the consequences of transit are those that relate directly to travel. Travel-related benefits are those that result from increased accessibility when a transit system is improved. Benefits can accrue to a transit patron because a trip can be made with less time, cost, or inconvenience by transit than by some other alternative. Benefits can also accrue to an automobile driver or a passenger because there might be less congestion on some streets because of increased transit usage. Benefits can also accrue to traveler who might choose to make an additional trip by either mode or might choose to switch modes.

Many past benefits studies have determined that the largest single user benefit from a transportation system improvement is travel time savings. Additional user benefits include savings in costs of fuel, tolls, fares, vehicle ownership, and vehicle maintenance. Intangible user benefits can include the comfort of travel and the ability to make entirely new trips or to satisfy trip purposes by traveling to better but more distant destinations.

In the nation's largest cities, there has been an increasing interest in transit's impact on traffic congestion. There are two aspects to this impact: (*a*) the degradation of traffic flow associated with buses mixed with automobiles; and (*b*) the improvements in traffic flow that might occur if some drivers can be persuaded to take transit. Both of these effects should be components of user benefits.

When dealing exclusively with highway travel, it is sometimes possible to estimate user benefits by adding individual components. For example, by ignoring changes in mode or destination it is possible to compute time saving from a highway improvement by subtracting the "after" total travel time from the "before" total travel time. Transit benefits are far more complicated, so it is easiest to estimate them directly from the net consumer surplus of the system change. If calculated properly, net consumer surplus will include all the cited benefits, both tangible and intangible.

Essential Ingredient: Travel Forecast

User benefits in the form of net consumer surplus can be easily estimated, provided that a good travel forecast has been prepared for the transit alternative and the null alternative. It is important that the

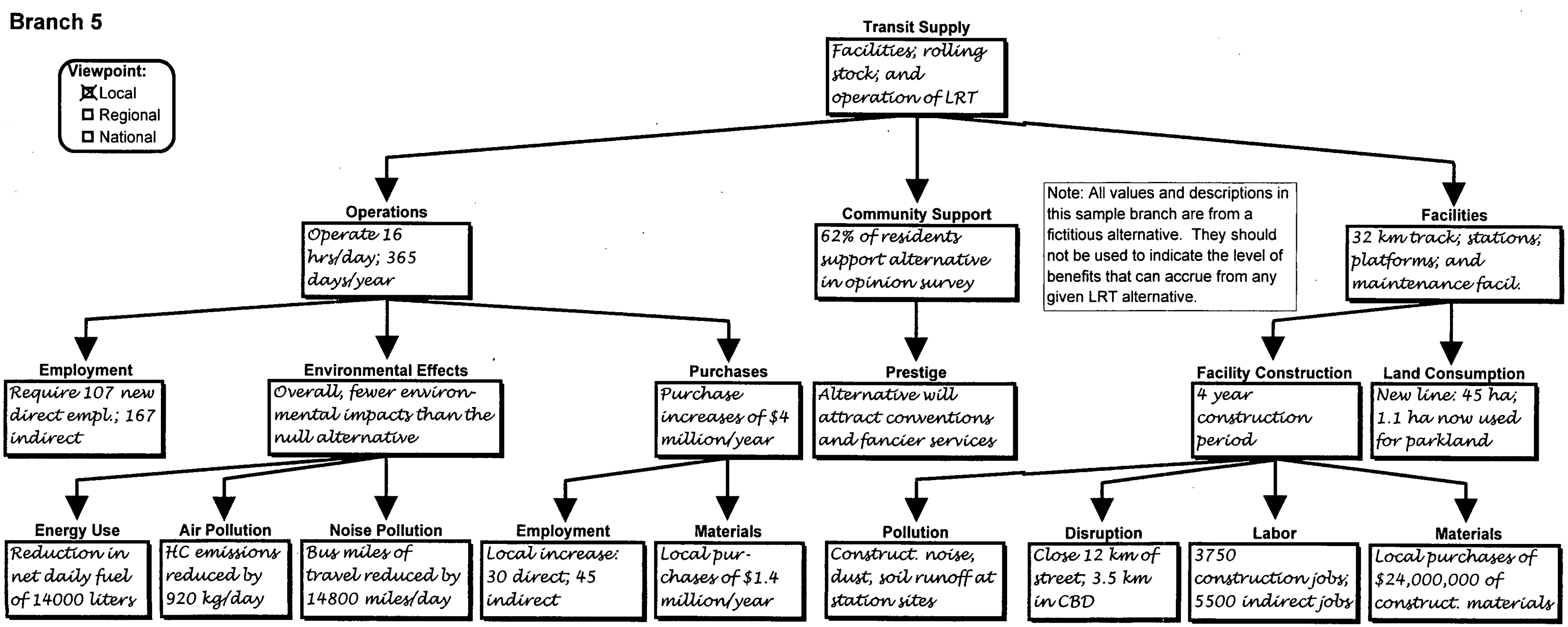

FIGURE 2 Example of one branch of benefit tree.

spatial distribution of trips within the forecast should be sensitive to the amount of transit service, enabling shifts in origin-destination patterns because of transit improvements. Most travel forecasting models do not provide this sensitivity; however, it can often be added with little difficulty. Furthermore, the spatial distribution of trips and mode split should be sensitive to the level of congestion on highways. Some travel-forecasting models can do this automatically, others cannot. Planners sometimes refer to a forecast with this property as having "elastic-demands."

Procedures for creating such a forecast have been developed over the past several years and are already available in off-the-shelf travel-forecasting packages. The essence of this approach is to use behavioral travel choice models as the indicator of willingness to pay and the basis for benefit measurement. Additional elements may be needed, depending on the nature of the transit system modification and its long-term effects on urban development.

Travel Benefits as Measured by Enhanced Consumer Surplus

Economists tell us that benefits of any public project can be ascertained by calculating net consumer surplus. Consumer surplus is the difference between the amount an individual is willing to pay for a good and the amount the individual actually pays.

For any given transit trip it is possible to calculate a comprehensive measure of its costs and inconveniences, called the trip's "disutility." Disutility is most easily interpreted when it is expressed in units of automobile riding time. A typical disutility function would look like:

Disutility = automobile riding time + (transit riding time)
· (transit riding weight) + (walking time)
· (walking weight) + (waiting time)(waiting weight)
+ (transfer time)(transfer weight)
+ initial wait penalty + first transfer penalty
+ second transfer penalty + fare/(value of time)
+ (tolls + parking costs
+ vehicle operating costs)/(value of time)
+ (vehicle ownership costs)/(value of time) (1)

In this equation, the value of time is the rate at which travelers would be willing to trade money for time savings. The weights, penalties, and values of time are easily extracted from mode split models or from psychological scaling studies. Equation 1 deals exclusively with time, cost, and convenience issues. Additional terms could be provided for other significant elements of comfort, such as protection from inclement weather and privacy, if they were factors in traveler choices.

The only vehicle ownership costs that should be included in Equation 1 are those that can be attributed to a single trip. It has been found that travelers do not correctly perceive the full value of their vehicle ownership costs while making mode choice decisions, so this term is sometimes omitted. However, it may be that a user regularly chooses transit to avoid ownership of a second car. In that case the ownership cost of an automobile should be included in the automobile disutility equation for those who qualify.

Travelers have a willingness to pay in units of travel time (*2*). They will choose to ride only if the disutility of travel (in time units) is less than their willingness to pay (in time units). Consequently, travelers possess a consumer surplus of disutility in time units. This disutility may be mathematically expressed as a time savings or maybe converted to monetary units by multiplying by the value of time.

Calculation of Enhanced Consumer Surplus

This enhanced measure of consumer surplus is illustrated in Figure 3 for a single trip. A demand curve shows the relationship between numbers of trips and trip disutility, expressed in time units. Point 1 represents the original disutility and number of riders taking the trip. Point 2 shows a new disutility and the number of riders after a service change, such as shortening the headway. Because of the service improvement, more people have chosen to take this trip. Some new riders switched from the automobile, some new riders have changed their choice of destination, and some new riders are making an entirely new trip. T_1 is the original disutility, and T_2 is the new disutility. All the old riders receive a windfall consumer surplus of $T_1 - T_2$. This windfall is illustrated as the shaded area *A*. New riders have a net consumer surplus shown in the shaded area *B*. Consequently, the total consumer surplus can be found from the roughly trapezoidal, combined area:

$$\text{Net consumer surplus} = -\int_{T_1}^{T_2} Q(T)dt \quad (2)$$

where $Q(T)$ is ridership as a function of disutility. Because of the integral sign, Equation 2 looks more complicated than it really is. Integral calculus is never actually used to perform such a computation. Instead, simply divide the service change into several small increments and approximate the net consumer surplus as a trapezoid as each increment is applied.

In a multimodal transportation system it is necessary to sum the net consumer surplus over all possible modes. Total net consumer surplus for the whole system can be found from this relationship,

$$\text{Net consumer surplus} = -\sum_m \sum_i \sum_j \int_{T_{1mij}}^{T_{2mij}} Q(t)dt \quad (3)$$

for all modes (m), all origins (i), and all destinations (j). As before, the integral is performed by summing the areas of flat, wide trapezoids.

The benefit tree does not require that benefits be converted to monetary units. If it is found to be necessary, enhanced consumer surplus can be converted to money by multiplying by the value of time.

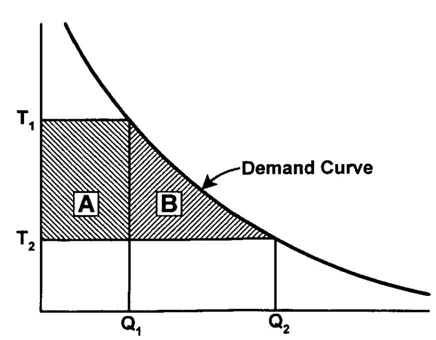

FIGURE 3 Calculating net consumer surplus from demand curve.

Technical Issues

A travel forecast that can properly measure enhanced consumer surplus is no more difficult to run than a conventional forecast, provided care is taken to compute the necessary values of disutility and demand for all modes. The types and amount of data, calibration requirements, and necessary expertise are essentially unchanged. However, there are certain technical and procedural questions that must be dealt with.

Composite Disutilities Most travel forecasts find the spatial distribution of trips throughout the community with a model steps that exclude information about the quality of transit service. Consequently, such a forecast will not be properly sensitive to changes in transit service. Forecasters have sometimes included transit service into the trip distribution step and the land use step by computing composite disutilities between origins and destinations that account for both highway and transit service. The following composite cost function has been found to provide the correct amount of sensitivity (*3*):

$$T_{cij} = \ln[\exp(-\alpha T_{bij}) + \exp(-\alpha T_{aij})]/-\alpha \quad (4)$$

where

- T_{cij} = the composite disutility from origin i to destination j,
- T_{bij} = the disutility by transit,
- T_{aij} = the disutility by automobile, and
- α = the coefficient for in-vehicle time in a logit mode split model.

The composite disutility is always smaller than the smallest value of its components.

Approximating Net Consumer Surplus Integral with Trapezoids Transit service changes can be either discrete or continuous. An example of a discrete service change would be the addition of a new rail station. An example of a relatively continuous service change would be an improvement in headways. It would make sense to compute the net consumer surplus of only part of a headway improvement, but it would make little sense to compute the net consumer surplus of only part of a new station. For discrete service changes, there can be only two possible valid forecasts: with and without the change. Consequently, net consumer surplus must be computed as a trapezoid, which will have a slightly larger area than an integral would find.

For continuous service changes, the calculation of net consumer surplus can be more precise. The service change can be arbitrarily divided into several increments, and the net consumer surplus can be computed for each increment as the area of a flat trapezoid. The sum of the net consumer surpluses for each increment is the total net consumer surplus. The major drawback to subdividing service changes in this manner is the added computation time necessary to evaluate each amount of intermediate service.

Need for Realistic Null Alternative Net consumer surplus is always calculated between a before case and an after case. The most relevant before case is the null alternative, that is, the most likely state of the community without the service change. The null alternative is not necessarily the current state of affairs. The null alternative could include growth or decline, redistribution of activities, or natural changes in the character of the community. Good null alternatives are difficult to construct, but they are essential to a valid calculation of consumer surplus.

A transportation system management (TSM) alternative is not a null alternative; a TSM alternative, by itself, can have significant benefits over the current state of affairs. It would be better to look at consumer surplus among different sets of alternatives; that is, TSM versus null, proposed versus null, proposed versus TSM, and so on. This way the net benefits versus costs can be determined.

CONCLUSIONS

The review of existing practice of benefits evaluation suggests that improvements are needed. It is essential that an evaluation be consistent with community values and with observed travel behavior. The following list of major findings and recommended procedures should serve as a set of guidelines for any benefits analysis.

Major Findings

Transit decision making is dominated by intangibles that do not easily lend themselves to quantification. Some of the most important benefits of transit are community pride, health effects of pollution, potential for urban redevelopment, equity of transportation service, and its option value.

The political decision process cannot be replaced by an objective technical evaluation scheme. The political process for transit decision making is firmly entrenched. Further, the political process is too complex, too fluid, and too subjective to be replicated by an objective evaluation procedure.

The political decision process is sensitive to good analysis but may not respond as the analyst desires. Good technical analysis is always worthwhile and is appreciated by many political decision makers. However, decision makers will reject any technical analysis that fails to confirm their beliefs or fails to convince them that their beliefs are incorrect. Given that the political process is not objective, it may be difficult to extrapolate on past experiences when assessing new project alternatives.

The results of any technical evaluation procedures must be intuitively correct. Any deviation from intuition will be quickly recognized and will undermine the acceptance of the analysis.

There are many interrelated benefits, leading to problems of double counting. Double counting can be explicit or implicit. It is the responsibility of the planner to avoid double counting and to indicate where unavoidable double counting occurs. This can be avoided by not aggregating measures and by using the benefit tree.

Evaluations of benefits in environmental impact statements or in alternatives analyses are limited. Agencies need to become more aware of good evaluation methodologies and to use the methodologies in their studies. Many agencies still need to recognize the importance of EIS and AA to their decision making.

Recommended Procedures

Use the benefit tree to identify important impacts and to help identify sources of double counting. The benefit tree is a comprehensive

listing of potentially positive impacts of transit service improvement. Not all impacts may be realized in any given community. Two impacts in close proximity on the benefit tree may constitute double counting, especially if one of the impacts is directly above the other.

Avoid aggregation of benefit measures. Aggregation destroys information. Transit decision making is complex, and that complexity must be apparent to decision makers. Each decision maker has a different way of weighing benefits; no aggregation scheme can possibly represent every set of weights.

Quantify as many benefits as possible. Quantification facilitates comparisons of alternatives, permits sensitivity analysis, and helps eliminate ambiguities.

Use a broad-based measure of consumer surplus for travel-related benefits. This report describes a direct measure of overall improvement in society, which is termed enhanced consumer surplus. It encompasses time savings, comfort, and convenience. Enhanced consumer surplus can be measured with readily available travel-forecasting methodologies. Because of the possibilities of significant congestion relief, all steps of the travel-forecasting model should be sensitive to changes in assigned travel times.

Examine changes in efficiency of land uses. Efficiencies occur because of regional changes in land use and because of local concentrations of activities. The effect of regional changes can be incorporated in enhanced consumer surplus. Local concentrations are difficult to predict, but their impacts of infrastructure efficiency may be significant.

Avoid using employment impacts as benefits, unless it can be clearly demonstrated that the employment would be greater than the null alternative. A common pitfall in benefits studies is to count employment shifts as gains. It would take a very sophisticated analysis to demonstrate a net increase in employment for most transit improvements:

Describe benefits that are not quantified. An objective description of a benefit should be provided, even if the benefit cannot be calculated. It is a mistake to omit valid benefits that do lend themselves to a particular evaluation scheme.

Tell how quantified benefits are calculated. The quantification of some benefits can be technically complicated. Nonetheless, it is important to explain the methodologies used in doing the calculation, including any assumptions made. Techniques must be explained in a manner understandable to a decision maker; otherwise it is best to avoid quantification.

Present information in a manner that facilitates decision making. It is important to treat decision makers with respect and honesty. Information must be presented in a clear and concise manner, avoiding hidden assumptions and highlighting those issues that are salient or controversial.

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Relationships Between Public Transport Finance and National Economy in The Netherlands

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In 1993, expenditure on all forms of public transport in the Netherlands amounted to 4.6 million Dutch guilders. This sum accounted for some 62 percent of all central government expenditures on infrastructure and transport. A research project was undertaken to examine the economic rationality of such expenditures and to study the relationships between government expenditures on public transport and the national economy. The primary objectives were to identify the economic linkages and to determine the extent to which money spent on public transport contributes to economic development. Phase 1 of the study consisted of a comprehensive review of the literature to gain insights into the complex relationships and to compile an inventory list of economic effects. In Phase 2 a conceptual framework was developed and a pragmatic methodology was designed so that identified economic effects can be quantified and monetized. In Phase 3, the Sector and the User Approaches devised in Phase 2 were evaluated. On the basis of the results of practical applications on the total public transport program and on the Rail 21 project, it is suggested that the methodology is capable of providing a coherent way for integrated estimations of economic effects to be attributed to public transport finance.

The maintenance of an efficient public transport system plays an important role in the Netherlands' Second Transport Structure Plan (SVV-2) and in the National Environmental Policy Plan 2 (NMP-2). In these policy documents, conditions are laid down for the future development of mobility to achieve four policy goals: improved accessibility, guided mobility, quality environment, and enhanced road safety. A shift in the modal split in favor of public transport is warranted, especially for journeys to work in areas where public transport offers a realistic alternative to car use. This relatively new role for public transport in strategic planning represents a shift in emphasis in recognition of the facts that continuous growth in travel demands cannot be met uninhibited and that efficient use of public transport will help to ease congestion on the roads. The proposition is that scarce road space can be better utilized for business trips and for road freight, both of which play an important part in promoting the country's economic well-being. Another consideration is that better use of public transport will help to promote the environmental goals to mitigate air pollution, reduce noise, and minimize severance (features that are often associated with the road program).

In the same period, the Dutch government has embarked on a program of reforms to strengthen the national economy, in particular by reducing the size of the public sector and cutting back the level of financial supports. In transport planning, the explicit aims are to reduce the amount of subsidies given to public transport and to increase the cost effectiveness of government-funded programs. In 1993, total expenditure on all forms of public transport amounted to 4.6 million Dutch guilders. This accounted for some 62 percent of all central government expenditures on infrastructure and transport. Conversely, transport projects, particularly investment in infrastructure, are seen as a way to promote economic prosperity because they provide employment and play an important role in strengthening the competitive position of the Netherlands as the gateway to an enlarged European Union.

In strategic transport planning and in the setting of priorities, there are political considerations, social arguments, and environmental reasons for supporting specific programs. It is important to recognize the raison d'état in the choice of projects, particularly those that require public funding and government support. The aim of this paper is to describe a project that has been undertaken in the Netherlands to study the economic relationships between government expenditure on public transport and the national economy. The primary objective is to identify the economic linkages and to determine the extent to which money spent on public transport contributes to economic development. The exercise will provide a first step toward defining the economic worth of public transport.

GENERAL DESCRIPTION OF STUDY

The central question is: can the effects of public transport expenditures by government on the national economy be determined? The primary research objectives are to develop a conceptual framework and to design an evaluation methodology for the assessment of the economic linkages. The process involves identification of economic effects, quantification of those effects, and placement of a (monetary) value on the effects so that they can be compared with the sum of public transport finance.

The research was divided into three phases. An interim report was prepared at the end of each phase to provide informed discussions and to assist in decision-making regarding the detailed work program in the subsequent phase. Phase 1 consisted of a comprehensive review of the literature available at home and abroad, including case studies. The objectives were threefold: (*a*) to identify the economic factors, (*b*) to study the modus operandi, and (*c*) to gain insights into the complex relationships of these factors.

The purpose of Phase 1 was to compile an inventory list of the types of economic effects that are associated with spending on public transport. The emphasis is less on the theoretical aspect and more on the practical application concerning how economic effects can be grouped, measured, and quantified.

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The aim of Phase 2 was to develop a conceptual framework and to design a methodology such that the economic effects could be quantified and valuated. The goal was to have an integrated framework for systematic and consistent evaluation of major public transport programs.

Phase 3 was a test to ascertain the methodology's strengths and weaknesses in practical application. The test was conducted in two stages. In the first stage the economic worth of the total public transport program was appraised, with the objective of giving a general estimation of the program's contributions to the national economy. The aim of the second stage was to assess the efficacy of the methodology when it was applied to a sizable public transport subprogram that would have significant impacts on travel demands at the national level. The chosen project was Rail 21, which is a proposal by Netherlands' Railways (NS) that contributes to the SVV-2 discussion on ways and means to improve the quality of public transport. Its main feature is a three-train system with international, intercity, and local services. To accomplish this goal, the NS calls for an investment of 17 million guilders (at 1992 price level) in 1993 to 2010, and the funding would have to come from the central government.

Three consultants were invited to submit proposals, and Netherlands Economic Institute (NEI) of Rotterdam was chosen to undertake the research. The project was supervised by a steering group made up of staff members from different departments of the Ministry of Transport and from NS.

Scope of Study

Evaluation is a technical process, and the method used will serve as a tool to assist in decision making. Therefore, it is vitally important to state clearly the terms of reference so that the context within which project evaluation must take place is firmly established.

Source of Funding

The primary aim of this study is to identify the economic effects associated with all kinds of public transport finance. It is useful to distinguish between different sources of funding: whether generated by internal sources (e.g., fares revenue or advertising incomes) or received from public authorities (such as grants and subsidies from central government, provinces or municipalities). In the Netherlands, subsidies and investment funding come almost exclusively from the central government. It is, therefore, an acceptable simplification in the early phase not to analyze the effects of alternative funding methods.

Evaluation of Total Program Versus Individual Projects

This particular exercise was conducted to provide an indication of the economic effects associated with the total public transport program. For the evaluation of individual projects of an incremental nature, other methods are available, such as cost-benefit analysis (CBA), cost-effectiveness appraisal, or multicriteria technique.

Revenue Versus Capital Projects

There is a basic difference between capital projects (e.g., investment in infrastructure or procurement of new rolling stocks) and revenue projects (e.g., extension of a local bus network or increase in service frequency). However, theoretical understanding of the structural effects of different types of projects is poor and technical knowledge of the interrelationship is even more patchy. For reasons of expediency, no clear distinction is made between the types of projects, provided that the spending will lead to substantial transport improvement.

Generative Versus Redistributive Effects

This project is geared only toward effects that have an impact on the national economy. Only generative effects create employment and stimulate economic growth, leading to a net gain in the National Income Account. If the positive effects are gained at the expense of another region, it will be treated as redistributive because the national economy in balance will not benefit from any net gain.

RESULTS AND FINDINGS FROM PHASE 1

This part of the study was not confined to public transport projects but had a more general character to cover all relevant literature on the subject. The survey (*1*) amounted to a statement on the state of the art at the time of reporting in December 1993.

Method of Research

Most studies were focused on the theoretical aspects of the relationship between transport spending and the likely impacts on the economy. In several cases, methodologies had been developed in the form of mathematical or econometric that were subsequently applied to published data to test the validity and robustness of the model. Some were case studies based on a comparison of the before and after situations or a documentary report on the historical development. A few were macroeconomic studies applying statistical analyses on cross-section or time-series data. Some studies took the form of prospective studies that made use of interviews with experts or relied on the results of questionnaire surveys. The revealed-preference approach was designed to examine what firms and individuals actually did. The stated-preference approach (sometimes utilizing simulation games) attempted to determine what firms and individuals would do in hypothetical situations. Scenario studies and investigations based on the Delphi technique provided some useful insights, even though such studies were largely speculative in nature and exploratory in character.

Outcomes from Impact Studies

Transport Programs in General

There are few published works on the economic effects of transport improvement on the economy. The interest of most studies was the traffic effects of infrastructure investment or changes in general mobility, rather than wider implications of improved accessibility effects on economic changes. When cases showing economic effects were singled out as a topic of interest, the results were often presented in qualitative statements which ranged from assertions or claims to platitudes with little evidence to support the case. With

regard to the importance of forward and backward linkages, the knowledge is limited (*2*). To take the case of the high-speed rail (HSR) projects in France (*3*), there were indications that the investment helped to stimulate the local economy and attracted newcomers to locate in the proximity of the HSR. But there was counter-evidence to suggest that the expected gains for the local economy did not materialize and, to the contrary, HSR worked as a suction tube, siphoning off benefits to other regions. A possible explanation is that transport improvement reduces the need for regional branch offices and has encouraged concentration of activities in the head office.

Public Transport Program in Particular

Even less is known about specific impacts of public transport programs. There are several studies on the effects of individual projects such as the Victoria Line Study in London (*4*) or the metro railway in Los Angeles (*5*). The former relied on CBA and the latter relied on effects on land use via changes in the rental values of property and land prices. The indication is that transport improvement in suitable circumstances can function as a catalyst to assist other policy measures to bring about the potential benefits or to hasten the process of change. However, research studies hitherto have not been able to establish any direct causal relationship between transport improvement and changes in the labor or capital productivity of firms located adjacent to the infrastructure. Another important issue is the extent to which it is possible to make generalizations on the basis of a small number of case studies in which local conditions often had played an important part. At present, there is insufficient evidence to make convincing generalizations.

Conclusions from Phase 1

The literature survey indicated that most appraisals were based on CBA, with permanent effects as the central focus, particularly user benefits associated with the investment project via journey time and travel cost savings. In some studies, the radiant effect was included, for example, trip generation by new users. Radiant effect refers to that group of indirect effects associated with forward linkages that could affect the economic structure over time. The proposition is that transport improvement will induce existing firms to expand and attract new firms to the area. Likewise, employees and workers will be influenced by improved accessibility to move into the neighborhood. In a few cases, attention was also given to the temporary effect. With a few exceptions, direct effects such as employment and value added in the transport sector were rarely discussed.

The radiant effect is the most controversial topic. In some research studies, particularly those specializing in marketing, it was argued that the effect is psychological in nature and is related to an improved image and a general increase in public confidence in the local economy. Some researchers tried to construct models to analyze the changes observed in regional economic development. A few attempted to adopt a more pragmatic approach and attributed the residual effects to such forces at work. However, no one has succeeded in producing a convincing and transparent method that can illustrate accurately the multiplicity of the interactions.

The consultant recommended the development of an integrated conceptual framework and (on the basis of this thinking model) an evaluation methodology that would suit the particular situations in the Netherlands. A pragmatic approach was proposed to take on board the knowledge gained from the state-of-the-art review and to allow for the quality of data available. These recommendations were endorsed by the steering group with a request that any vital gaps in knowledge should be identified so that future research can be programmed to strengthen the methodology.

RESULTS AND FINDINGS FROM PHASE 2

NEI has followed two different approaches simultaneously, regarding them as the spearheads for investigation. The conceptual framework is to view the problem from two different vistas: the producers' angle and the consumers' angle. In the Sector Approach, the central issue is the extent to which expenditure on public transport programs acts as a stimulant to the sector that is under discussion (including feedback repercussions). In the User Approach, the central issue is the extent to which improvement in public transport leads to better allocation and more efficient use of scarce resources from the society's point of view. An increase in the opportunity to make choices and in the range of possibilities is conceived explicitly as a plus point. The relationships between the two approaches and the place of the radiant effects are given in Figure 1. Because the two approaches have different theoretical foundations and philosophical perspectives, the two set of results should not be added together.

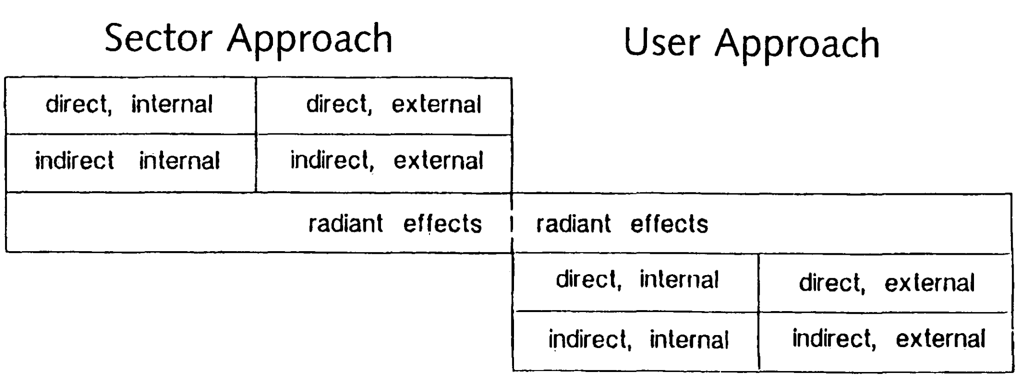

FIGURE 1 Relationships between sector and user approaches.

Sector Approach

Changes in value added and jobs creation are two major contributors to the gross national product in national income accounting. Input-output (I-O) analysis was considered to be the most appropriate method to measure the extent of such effects. Production statistics from the Central Bureau of Statistics (CBS) for the period 1988 to 1991 were used as a data source. In the I-O analyses, particular attention was centered on changes in final demands.

Temporary, Direct, and Internal Effects

Temporary, direct, and internal effects refer to values added and employment created in the construction and transport-supply industries. When values added against market price are corrected for indirect tax paid and for subsidy received, values added against factor costs are derived. These are made up of wages and salaries, social security tax, and other incomes such as interest and profits. Gross values added at factor cost are used to represent the economic effects for a comparison with the size of public transport finance. In principle, such effects can also accrue to engineering companies and consultants, but they are relatively small and thus are excluded. Another simplification is that all products are made and transport materials are supplied by companies located inside the country. Activities performed by foreign companies outside the Dutch frontier are discarded.

Temporary, Indirect, and Internal Effects

The categories temporary, indirect, and internal effects refer to impulses given to related industries, such as intermediary suppliers and delivery companies, and the chain reactions on delivery companies to the deliverers (third-order effect), and so on. To calculate these impacts, value-added multipliers and employment multipliers are used. They have been derived from statistical analyses of production statistics published by CBS. An employment multiplier of 1.48 means that for every 100 jobs that are created in the construction sector as a result of the project, 48 extra vacancies will be created in related intermediary delivery sectors and the supplying subsectors. These multipliers are fairly stable in the Netherlands because it would take considerable time before structural changes in economic relationships would emerge. However, the multipliers can be affected by technical progress or changes in business management which increase labor productivity. Rising labor productivity would mean that less labor is needed per unit of output.

Permanent, Direct, and Internal Effects

The share of gross value added at factor cost in the total turnover is extracted from the I-O tables. On the basis of total number of passenger kilometers (pkm) traveled per year and manpower needed, the number of man-years required for the production of 1 pkm is derived separately for the railways, urban transport, and regional transport. These figures were almost constant in 1988 to 1991. For the railways, a decrease in man-years per passenger-kilometer represented an increase in productivity that was attributed largely to the introduction of the Public Transport Pass for Students (*6*) in January 1991, and adjustments had to be made accordingly.

Permanent, Indirect, and Internal Effects

These effects relate to changes in value added and in employment by the car dealers and garages (repairs and maintenance) subsector. Increases in public transport ridership can be made at the expense of car ownership and car use. Changes in the number of car trips and distance traveled affect the volume of sales by car dealers or the profit of rental companies. Garages and shops responsible for repairs and maintenance also are affected. An interesting point concerns whether the car left behind is being used by other members of the family or scrapped. In the first situation, the effects on the economy are smaller compared with disinvestment in cars. There are similar repercussions on the bicycle and moped industries as well as effects on dealers and spare-parts suppliers, but they are known to be small and so are excluded.

Permanent, Additional Effects

Changes in accessibility can induce companies to change location, particularly in situations in which companies need extra space to expand or firms seek new opportunities. The magnitude of such an effect depends on the importance of transport costs, journey time, and/or reliability to the activities of the affected concerns. Factories that practice the just-in-time production technique and enterprises that thrive on logistic cost savings are particularly sensitive to changes in the transport environment. Analyses of the I-O tables between 1988 and 1992 and data from company records held by the Chamber of Commerce suggested some differences in the rate of job creation among three types of companies: new branch by a Dutch company, new branch by a foreign company, and expansion of an existing company.

User Approach

The User Approach is based largely on the CBA methodology. The approach is centered on a what-if scenario compared with the situation in a base year. The basic philosophy is that of eliminating the complete public transport system in a stroke. As a result, all public transport journeys have to be made by other forms of transport. The community costs of the drastic change must be estimated (Figure 2). The parameters are journey time, costs of travel, air pollution, noise, traffic safety, and efficiency for business trips. Monetary valuations of these effects give the social costs of losing the public transport system, and this is compared with the amount of public finance to give the economic value.

This thinking model has been transformed into a pragmatic method and has provided a set of useful indicators. Public transport statistics for train services, urban services, and regional services are derived from CBS publications and supplemented by annual reports of operating companies. Displaced public transport trips are assigned to five other modes: car, motorcycle, moped, bicycle, and taxi. The diversion tables are compiled by using research findings from situations in which there was no public transport due, for example, to general strikes. Diversion is estimated for four journey purposes: work, business, education, and others and for three dis-

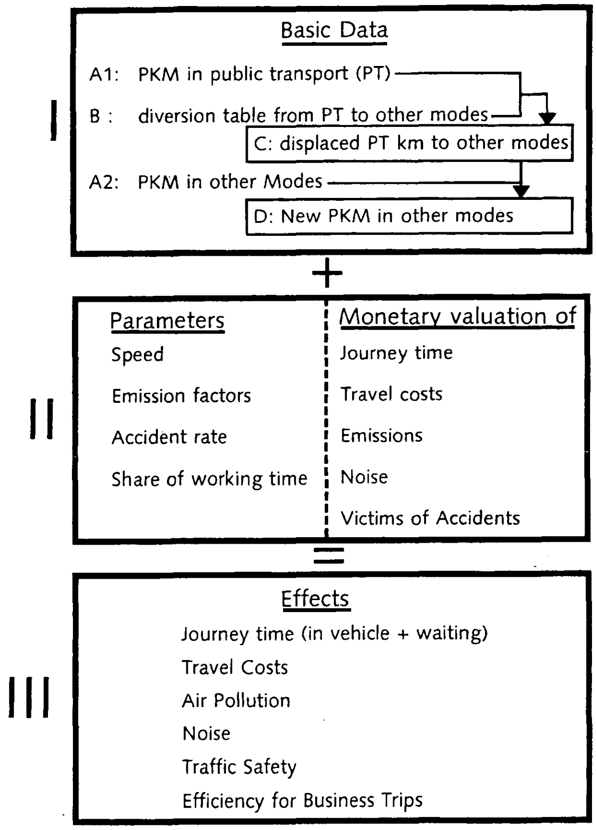

FIGURE 2 Conceptual framework.

tance classes: up to 5 km, 5 to 10 km, and more than 10 km. Average speed per mode is expressed in kilometers per hour.

Journey Time

The doing away of public transport leads to an increase in congestion on the road networks both local and regional. Changes in journey time depend on the level of congestion at any one time. It is assumed that without congestion, the average speed of a car and taxi would be higher than that of public transport modes. Changes in journey time are measured in hours and are identified separately for the passengers in the base situation per public transport mode and per journey purpose. These changes are then valued by standard values of time in Dutch guilders recommended by the Ministry of Transport. The values of travel time savings are derived from the results of extensive empirical research (*7*) in 1988 using revealed-preference and stated-preference techniques. These official values subsequently have been updated to give appropriate values for 1991. The next step is to estimate and monetize the effects of diversions on journey time for existing car users and taxi passengers. Some allowances are made for changes in passenger kilometers and the speed in the new and old situations.

Costs of Travel

Changes in the costs of travel per passenger kilometer in the with and without situations are estimated for each public transport mode, allowing for slight changes in passenger kilometer as a result of a change in route choice. Short-distance trips will be replaced by walking, cycling, or moped travel, for which the cost per kilometer is lower. For people who switch to car or taxi travel, the increase in costs is greater. Only variable costs such as petrol prices, parking, and toll charges are used in the first approximation, and they are derived from empirical studies into the costs of travel in the Netherlands for different trip purposes.

Air Pollution

The elimination of public transport is likely to increase air pollution. Each transport mode has a set of emission factors for each of the six pollutants: CO_2, CO, C_XH_Y, NO_X, SO_2, and aerosol. Bicycles generate no pollution, whereas cars and taxis are responsible for the emissions of NO_X, CO_2, and CO. The calculations deal with emissions at the source and are based on the assumption that the composition of traffic will change, but traffic density will remain constant. Monetary valuation is expressed in Dutch guilders per kilogram, and the equivalent table is based on the results of a 1993 NEI study (*8*) on effects of the opening of the Amsterdam orbital motorway on environmental quality. Emission estimation is based on existing technology and know-how.

Noise

This parameter is measured per transport mode per passenger kilometer traveled. Research study results indicated that noise level per bus or train is higher than that generated by car. The argument is based on observations that steady constant noise generated by routine traffic flows is less intrusive than the sound of trains flashing by at irregular intervals. Another argument is that to meet agreed frequency in the timetable, buses, trams, and trains have to operate as scheduled even though travel demand is low; for example, in late-evening and early-morning hours; hence, the aggregated noise emission is high. Monetary valuation is done separately per mode. The look-up table is based on research results into external costs (*9*) by another consultant IOO on behalf of the Transport Ministry. The calculations take into consideration the costs incurred by the government to prevent or reduce noise emissions as well as reductions in property values as a consequence of noise.

Traffic Safety

A distinction is made between fatal accidents (including accidents leading to death) and injuries. The calculation is based on the number of accidents per transport mode. This is an important consideration in the Netherlands because safety is an explicit policy goal in SVV-2. On the basis of statistical analysis, the safety record for public transport is significantly better than that for cars. The valuation table is based on the IOO study which estimated gross production losses as a result of death, sick leave, or invalidity as well as costs of indemnity payments for invalidity in accordance with Dutch laws and the costs of medical care.

Efficiency Consideration for Business Journeys

Efficiency of business journeys concerns the effective use of in-vehicle travel time, especially by business travelers doing produc-

tive work during train journeys. The argument for its inclusion comes from empirical research using stated-preference techniques to determine the value of travel time savings in the Netherlands as well as from the Paris-Brussels-Amsterdam high-speed rails evaluation study carried out by the European Commission.

Radiant Effect

In the User Approach, this aspect is associated with the relocation of household address. The absence of public transport is likely to induce people in the long term to live nearer to their work address and to reduce the number of trips and passenger kilometers traveled. This effect will have an impact particularly on those people who do not own a car and those who do not wish to use their car when public transport is a good alternative.

Conclusions from Phase 2

The search for greater efficiency in the Netherlands leads to increased urgency to know the economic worth of the public transport system or, as a corollary, the effect that eliminating public transport will have on the national economy. This is an important question that has been raised, and the benefits are often presumed rather than quantified. Instead of a general description of the effects using qualitative analysis or relying on tables with scores (using rating-points or plus and minus signs), the NEI study has put forward a coherent method for integrated estimations of the economic effects based on the Sector and the User Approaches.

In terms of practicality, the consultant concluded that radiant effects are difficult to isolate. Firm theoretical understanding of the dynamics of interactions between transport and land use is lacking. Another prerequisite is ready availability of comprehensive and quality data on traffic, transport, and land use. To minimize the danger of including spurious claims and to avoid possible double counting, it was agreed that the radiant effects would not be included in the calculations. However, as soon as the required knowledge is available, it should be incorporated.

For performance assessment, NEI recommended that gross value added at factor costs based on the Sector Approach and monetized values calculated for each of the economic effects in the User Approach should be added up and the totals compared respectively with the cost of the public transport program. However, the results from the two approaches should not be added together. The steering group endorsed the recommendation and agreed that the methodology should be tested in real-life situations.

PHASE 3: APPLICATION OF EVALUATION METHODOLOGY

First Stage: Total Public Transport Budget

The first stage is to apply the methodology to estimate the contributions of the public transport program to the national economy. According to the Sector Approach, public transport in 1990 contributed over 5.8 million guilders to the national economy (Table 1) in the form of gross value added at factor costs and was responsible for providing some 66,000 jobs. The largest share of these economic achievements had a permanent character, accounting for 86 percent of all gross value added and 80 percent of employment. In the User Approach, with the most recently available sets of data, the economic cost of doing away with public transport amounted to 6.6 million guilders in 1991 (Table 2). In another words, the society had to pay for substantial increases in travel costs and for deteriorations in traffic safety in the without-public-transport situation in order to sustain the same level of mobility in pursuit of their regular economic and social activities.

TABLE 1 Economic Significance of Public Transport Based on Sector Approach, 1990

The sectors	Gross Value Added (at factor costs) (in million guilders)	Employment (in man years)
Temporary Effects		
- Construction sector	322	4,885
- Transport supply industries	148	2,475
- Intermediary delivery to construction	263	3,320
- Intermediary delivery to suppliers	102	1,410
Subtotal	835	12,090
Permanent Effects		
- railways sector	4,010	43,700
- intermediary delivery to PT	960	10,125
Subtotal	4,970	53,825
Total Effects	5,805	65,915

The monetized values calculated by either of the two approaches were significantly higher than what the government had spent in public transport financing. This provides a first approximation of the economic worth of public transport in general.

Second Stage: Rail 21 Project

In the second stage, the methodology is applied to the Rail 21 project. In the calculations, it is assumed that the SVV-2 policy measures would be enacted and the Rail 21 proposals would be financed by the central government. Required infrastructures and planned service improvements (as foreseen by NS in its strategic marketing plan) would be implemented. Capacity of the network would increase and quality of services would improve significantly leading to increases in railway patronage. The Economic significance of the Rail 21 package is estimated using the Sector and the User Approaches.

In the Sector Approach, based on the value added multipliers and employment multipliers, the likely contributions of Rail 21 for 2010 are estimated. Allowances have been made for changes in the level of fares envisaged by NS and for known changes in labor and capital productivity between 1993 and 2010. The temporary and permanent effects resulted from the realization of Rail 21 are estimated to contribute 2.35 million guilders in gross values added at factor cost and almost 22,000 jobs per year throughout the study period.

The User Approach is based on the scenario of what would have happened if the Rail 21 project had been fully implemented and then assumed to disappear subsequently overnight. Calculations are made on the basis of a direct comparison in the composition of traffic and the intensity of use for different transport modes in the situations with and without Rail 21. Extra traffic generated by both existing and new rail passengers would have to be assigned to alternative transport modes. The contribution of Rail 21 is the difference in the overall economic effects. The economic value is estimated to

TABLE 2 Economic Significance of Public Transport Based on User Approach, 1991

Effects	Monetary values (in million guilders)
Journey Time	- 700
Travel Costs	5,509
Air Pollution	99
Noise	- 61
Traffic Safety	1,510
Efficiency of Business Trips	241
Total	6,598

be about 2.6 million guilders per year, associated largely with increases in journey time, travel costs, and accidents.

Conclusions from Phase 3

The results suggest that use of this methodology allows the estimation of the economic significance of the total public transport program as well as major subprograms as exemplified by the Rail 21 project. However, because of its exploratory nature, the results from Phase 3 should be interpreted with caution. The emphasis is on the efficacy of the evaluation methodology and less on exact precision of the calculations. This is because the outcomes are dependent on validity of the simplifications and accuracy of the assumptions. The steering group is of the opinion that the conceptual framework is functional and that the methodology gives a reasonably good indication of the direction of change. Without excessive demands on data, the NEI model is able to give the rough order of magnitude of various economic effects. Admittedly, the methodology still leaves much ground for improvement and refinements; what matters is that a systematic method in its embryo form has been developed.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

1. The conceptual framework developed in Phase 2 provides a thinking model to evaluate the economic significance of public transport finance. The evaluation methodology offers a practical means to quantify and monetize the different economic effects such that a formalized procedure can be adopted for an integrated estimation of the economic effects. Total effects can then be compared with incurred costs to give a general indication of the economic contribution. It has been applied successfully to two real-life situations: the total public transport program and the Rail 21 subprogram. The experience suggest that the evaluation results should not be taken as the final word on the absolute value of public transport finance. But, when the methodology is used with intelligence and understanding of its strengths and weaknesses, it can serve as a suitable tool to assist decision making.

2. The outcomes of the two approaches should not be added together because the theoretical foundation and the philosophical perspectives are quite different. They represent two ways of viewing the same problem. However, when the results are laid side by side, the similarities in the rough order of magnitude reinforce one another. It is reasonable to conclude that the methodology provides a rough guide to the economic worth of expenditure on a public transport program even though the estimates are tentative and the order of magnitude indicative.

3. The results should not be used uncritically. For an intelligent use of the instrument, it is particularly important to make explicit the underlying assumptions used and to make transparent the structural equations deployed in the model. These can be scrutinized and, if necessary, changed in the light of better information or new insights from future research.

4. Existing valuation and transformation tables have been constructed on the basis of empirical findings, research results, conventional wisdom, accepted practices, and educated guesses. They are deemed plausible working assumptions; however, there are also reservations on several sensitive policy areas. A list of observations follows.

–A crucial assumption is the gross simplification that the elimination of public transport will not lead to a reduction in the total number of trips but only a switch to other forms of transport. It is not realistic, but it provides the first stage of developing a thinking model.

–Future technical progress is hard to predict, but new technology can and will have significant impacts on noise, pollution, speed, and traffic safety; for example, electronic road guidance systems will affect road safety, save energy, and reduce air pollution.

–The government is not the only provider of funds for the provision of public transport. To assume that all of the effects are related to government spending is an overestimation. Moreover, a viable public transport network might be able to survive with services provided on commercial grounds in areas where there is a high density of population and where movements are concentrated in particular corridors. The practical difficulty is to define such a commercial network in the absence of knowledge about the business inclinations of the entrepreneurs.

5. Several important areas are suspected to be sources of underestimation, and a few examples follow.

–For congestion, it is assumed that the displaced passengers will be evenly distributed spatially, hence the effect will not concentrate on particular corridors or/and during particular times of the day. Because the average speed of the car is faster than that of public transport, the traveling public as a whole actually benefits from reductions in journey time as a consequence of eliminating public transport. This is a gross simplification that has been made for reasons of expediency (lack of detailed knowledge at the link level). In practice, it is commonly recognized that on particular sections of the motorway (e.g. along the Utrecht–The Hague axis), there is already substantial congestion and further increase will only lead to a complete standstill.

–Only changes in variable car costs are included. Fixed costs such as the cost of buying a car and paying for the road license fee are not included. The model assumes that passengers will switch to cars that are already there. Realistic estimation of the costs of car ownership or the imputed cost of leasing a car for private use will provide a better comparison.

–Although the radiant effects have been expounded to be important, such items have been excluded because of lack of knowledge. This is an important omission if the aim of the exercise is to evaluate the long-term impacts of major policy changes or to assess the economic significance of large-scale transport programs. Advances in dynamic transportation/land use modeling would contribute valuable insights into the process of structural changes, and efforts should be made to further the capability of the methodology.

–At present, the transport program is considered in isolation. It is possible that the public transport program has been conceived as part of an overall strategy to regenerate the economy. The combined forces of a mix of policy measures reinforced by carefully chosen projects can generate more effects than separate projects undertaken on their own.

–The public transport program may be designed to have a supporting role to ensure the success of the regional policy or to fight unemployment in a local district with redistribution as a stated policy goal. The existing methodology makes no allowance for such considerations.

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Modifying Transit Mode Share in Household Survey Expansion

IAN HARRINGTON AND CHEN-YUAN WANG

A procedure to modify the proportion of expanded trips by different travel modes from the 1991 Boston Regional Household-Based Travel Survey is presented; it is based on two data sources: the Census journey-to-work data and local transit ridership estimates. The procedure is a two-step adjustment applied to the existing survey trip expansion factors, which yielded a much higher volume of transit trips than the regional ridership estimates. The first adjustment step adjusts the expansion factors of commuters (persons who reported work trips in Survey) by matching the distribution of commuters in the Survey to the Census journey-to-work data by travel modes and residence-workplace locations. The second adjustment step is an iterative process that revises the expansion factors of other individuals (noncommuters) in the Survey by matching the expanded transit trips to the regional transit ridership estimates by transit submodes. It is assumed that the adopted procedure improves the randomness of the survey sample for modeling purposes. The adjusted trip expansion factors produced from the procedure are used to weigh the survey sample for mode choice model estimation, trip distribution model calibration, or other model evaluation purposes.

This paper presents a procedure to modify the proportion of expanded trips by different travel modes from the 1991 Boston Regional Household–Based Travel Survey. The Survey used an activity-based diary as a survey instrument and was designed following the small-sample technique (*1,2*). Despite taking precautions to avoid biases, analysis of the sample indicated a significant nonresponse bias leading to an overestimation of transit use. This procedure was thus developed to alleviate the nonresponse bias for applying the survey findings to regional mode choice model estimation, trip distribution model calibration, and other descriptive purposes.

The procedure is a two-step adjustment applied to the existing household survey trip expansion factors. The first adjustment step adjusts the expansion factors of commuters by matching the distribution of Household Survey commuters (persons who made work trips) by travel modes and residence-workplace locations to the Census journey-to-work data. The second adjustment step is an iterative process that revises the expansion factors of other individuals (noncommuters) in the Survey by matching the expanded transit trips by submodes to the regional transit ridership estimates.

The existing trip expansion factors from the 1991 Boston Regional Household–based Travel Survey were developed through a series of data processing. The primary expansion was performed by matching the Survey expanded households to the 1990 Census Transportation Planning Package by ring (geographical subregion), household size, and vehicle availability. The expansion was further modified by matching the expanded household totals to the Census household totals at a land use zone level and by synthesizing unreported trips for the missing-one-diary households. The expansion yielded a comparable number of total households in the region but did not produce a favorable total regional transit ridership estimate.

Through expansion of a sample of nearly 4,000 survey households, the number of intraregional linked transit trips was estimated to be about 974,000, which is about 30 percent higher than the regional transit ridership estimate. As considered from available sources of local transit ridership estimates (*3–5*), the regional total linked transit ridership was estimated as 747,000 trips in this study. Moreover, when disaggregated by transit submodes, the magnitude of overestimations is significantly different. Commuter rail trips were highly overestimated, and the overestimation of bus only trips was as serious as rapid transit trips.

These estimations divulge the complexity of bias problems involved in the survey. The survey response data were reviewed for possible information on sample bias, but the information available on the selected households that did not respond to the survey was inadequate for analysis. In addition, analysis of changes in survey responses with respect to lateness of diary return, another possible source of bias information (*6*), proved inconclusive.

The overestimation of transit trips might be caused by oversampling or undersampling of certain categories of households (nonresponse bias) or by inaccurate reporting of transit trips by individuals (inaccurate response bias). In this study, it was assumed that the former is the major cause of the problem, and the adjustment was therefore primarily developed at household and person levels, not at the trip level. By making the sample more representative of the population, based on the Census journey-to-work data and the local transit ridership estimates, the proposed procedure was expected to improve the randomness of the survey sample for various modeling purposes.

ADJUSTMENT STEP 1: MATCHING TO CENSUS JOURNEY-TO-WORK DATA

This adjustment step was conducted by using the Census journey-to-work data, which are deemed more reliable than the Household Survey because of the Census' larger sample size (about 17 percent compared with about 0.25 percent). The journey-to-work data from the 1990 Census Transportation Planning Package for the Boston metropolitan region provide estimates of residence-workplace flows by a longest-distance travel mode for all working people (16 years or older) living or working in the region. The Household Survey, on the other hand, provides information of origin-destination flows by multiple (if not single) travel modes for all work purpose trips (including home-based and nonhome-based) produced by survey households in the region.

To be analogous to the Census data, the Survey data were processed by tracing the work trip maker's residence and workplace locations and linking the multiple-mode trips into single-mode

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ones. The two data sets were then compared by travel modes and residence-workplace locations at the ring level. The comparison yielded a set of adjustment factors. Each survey work trip maker (simply referred to as commuter hereafter) was associated with an adjustment factor by mode and residence-workplace locations. In application, the adjustment factor was then applied to all the trips (not just work trips) made by the commuter.

Identification of Commuters and Their Residence-Workplace Locations

The Household Survey data are organized in three components: household, person, and trip files. The identification of commuters and their residence-workplace locations was done by using the household and trip files because the trip origin and destination information was not available from the person file.

The survey trips file includes information on each trip's origin purpose and destination purpose. A trip was regarded as a work trip if the origin or destination purpose is to work. Once the work trips in the trips file were identified, the associated commuters and their workplace locations were acquired from the trips file directly as well. However, their residence locations were obtained by tracing the commuters' household locations from the survey households file.

The intra-regional trips (both residence and workplace in the region) were included for this study. School bus and taxi trips reported in the Survey and the Census were left out of this study because separate models are used for estimating the generation rates of those trips. In some cases, one commuter produced several work trips with different workplace locations. The first work trip of the day with an identifiable mode, residence, and workplace by each commuter was thus chosen for identification because the Census journey-to-work questions focus on the travel from home to work.

Categorizing Single Travel Mode for Survey Journey-to-Work Trips

As mentioned, the Survey trips were recorded in a multiple-mode fashion (up to six modes), and the Census journey-to-work data manifest the single longest-distance mode by a worker. The identified Survey journey-to-work trips using more than one mode were thus required to be categorized in a single-mode format.

The categorizing is complicated by the fact that the Census uses trip and mode definitions that differ from those used by the household survey. As presented in Table 1, the definitions of the various travel modes in the Survey and the Census are different, especially the transit submodes. Also, the definition of trip (or journey) is different. The Census asks its respondents to describe how they travel from their residence to their workplace. In the case that more than one mode is used in the journey, the respondent is asked to state which mode is used over the greatest distance.

The Household Survey asked respondents to describe trips between activities. If the respondent traveled from activity "At Home" to activity "Work," this trip would be a Home-Based-Work trip and is directly comparable to the journey-to-work inquiry made by the Census. If, however, the commuter goes to an intermediate activity between home and work (convenience store, health club, and such), then the journey was viewed as two distinct trips: a home-based-other trip (HBO) and a nonhome-based-work trip (NHBW). To compare the Survey and Census data sets, it is necessary to concatenate the multiple-trip work journey in the Survey, especially that involved with any transit mode.

The Survey journey-to-work mode was categorized at two levels: (*a*) automobile, transit, and nonvehicular and (*b*) transit subdivided as bus, subway, and commuter rail. First a trip was regarded as transit if any one of the modes it used was bus, rapid transit, or commuter rail. It was regarded as a nonvehicular trip if all of the modes it used were not involved with private or public vehicles. Other trips not included in the above two groups were categorized as auto trips.

Second a transit trip was further categorized into commuter rail, rapid transit (including subway and trolley, for simplification just referred to as subway hereafter), or bus-only trip by a simple rule that commuter rail overrides subway, and subway overrides bus. This assumes that the commuter rail usually is the longest part in a journey and that the subway ride is longer than the bus. The assumption was made because the travel time or distance of a separate mode in a trip was not available in the Survey and neither was the location where transfer between modes was made.

However, manual path building for all Survey transit work trips involving multiple modes was performed to accurately compare the journeys-to-work as reported in the Survey with those reported in the Census. By examining the origin, destination, parking, and other activities of each identified transit work trip, it was possible to specify a mode for each trip presumably the same as the Survey respondent would have reported to the Census.

Once the residence-workplace locations and the single travel mode of the Survey commuters were identified, the Survey journey-to-work flows then could be synthesized. Before matching the Survey journey-to-work flows to the Census, the transit share of the two data sets was analyzed.

TABLE 1 Definitions of Survey and Census Travel Modes for Analysis

Mode of Travel		Household-Based	Census
Major Mode	Sub-Mode	Survey	Journey-To-Work
Auto		Car, Van, or Truck	Drive Alone or 2+ Carpool
Transit	Bus Only	MBTA Bus, Private Bus, and the RIDE	Bus or Trolley Bus
	Subway	Red, Green, Blue or Orange Line Rapid Transit Service	Subway or Elevated, and Streetcar or Trolley car
	Railroad	Commuter Railroad	Railroad
Non-Vehicular		Bike, Walk, and Others	Bicycle, Walk, Motorcycle, Ferry, and Others

Analysis of Transit Share by Travel Modes

The Survey transit share was first examined by separating the total flows by travel modes. The identified commuters with their identified single travel modes to work were expanded to be compared with the Census. Table 2 presents the synthesized Survey journey-to-work and the Census journey-to-work flows by travel modes.

As shown in Table 2, the Survey yielded somewhat comparable shares of total travel in the region by major mode (i.e., automobile, transit, or nonvehicular). However, at the transit submode level (i.e., bus only, subway, and railroad), the Survey yielded a much different proportion of transit trips from the Census.

It was also noted that the Survey expansion yielded less commuters (by about 12.6 percent) than the Census. There are several reasons for this disparity. First the Census requested the most frequently used means of journey during the week before receiving the Census survey form, whereas the Survey requested the journey information for a certain date, which excluded people who did not work on that exact date. Second, the Census included working persons living in group quarters, whereas the Survey did not. Also, the commuters with unknown modes (about 2,000 commuters) were simply left out of the Survey totals, whereas in the Census this portion presumably has been taken into account.

Analysis of Transit Share by Residence-Workplace Locations

The Survey transit share was further analyzed by grouping the flows by the residence-workplace locations. As shown in Table 3, the synthesized Survey journey-to-work flows were grouped into 25 residence-workplace exchanges (at ring level) and were displayed by transit share to the total flows of each group. The Census journey-to-work flows are also displayed in Table 2 for comparison. The definition of geographical rings in the study area is shown in Figure 1.

In general, the Survey yielded a transit share distribution that is incompatible with the Census. Among the 25 residence-workplace exchanges, only nine pairs had the Survey and Census transit share estimates within 20 percent of each other (i.e., transit share ratio ranging from 0.8 to 1.2). When compared with the Census, the Survey produced higher transit shares for the flows from the outer rings to the inner rings (Rings 0 and 1) especially central area (Ring 0); about the same shares for intra-ring or neighboring ring pairs; and lower transit shares for the flows from the inner rings to the outer rings (Rings 2, 3, and 4).

The overestimation portion (the first group, i.e., flows with workplace in Ring 0 or 1) required major attention because the Census indicated that 85 percent of the regional transit journey-to-work flows was in travel to the inner rings. It was postulated that this excessive transit flow was one potential source of bias that caused the overestimation of Survey transit trips. Therefore, the synthesized Survey journey-to-work flows were matched to the Census by not only travel modes but also residence-workplace locations.

Correspondence Between Survey and Census by Modes and Locations

The correspondence is a cell-to-cell adjustment between the two tabulated data sets. The synthesized Survey journey-to-work flows were tabulated by the 25 residence-workplace exchanges and five travel modes (Table 4). The Census journey-to-work data were processed in the same manner (Table 5).

To produce the adjustment factors, the cell values of the two tabulations were transformed from numbers of commuters to shares of subregion (ring) total by residence location. The cell adjustment factor was then obtained by simply comparing the share from the Survey with, that from the Census. In formulation, the adjustment factor for the commuters traveling from r to w by mode m can be expressed as

$$A_{rwm} = \frac{C_{rwm} / \sum_{w} \sum_{m} C_{rwm}}{S_{rwm} / \sum_{w} \sum_{m} S_{rwm}} \qquad (1)$$

where

- r = residence location, Ring 0 to Ring 4;
- w = workplace location, Ring 0 to Ring 4;
- m = travel mode in which 1 is auto, 2 is bus, 3 is rapid transit (subway and trolley), 4 is commuter rail, and, 5 is nonvehicular;
- A_{rwm} = adjustment factor for identified Survey commuters residing in ring r, working in ring w, and traveling via mode m;
- C_{rwm} = Census estimates of number of commuters residing in ring r, working in ring w, and traveling via mode m; and
- S_{rwm} = expanded Survey estimates of number of commuters residing in ring r, working in ring w, and traveling via mode m.

The resulting adjustment factors for the Survey commuters vary from 0.12 to 5.41, with half of them ranging from 0.50 to 1.50.

TABLE 2 Summary of Commuters by Travel Modes in Region

Journey To Work Within the Region		Mode of Travel: Auto	Bus Only	Subway	Railroad	Non-Veh.	All-Mode Total
Survey	Total	1,366,741	49,854	129,121	37,936	118,956	1,702,608
	Percent	80.3%	2.9%	7.6%	2.2%	7.0%	100.0%
Census	Total	1,586,413	86,057	106,694	27,774	133,993	1,940,931
	Percent	81.8%	4.4%	5.5%	1.4%	6.9%	100.0%

Note: about 2,000 commuters with unknown modes were not included in the Survey totals.

TABLE 3 Comparison of Survey and Census Journey-to-Work Transit Share by Residence-Workplace Locations Before Adjustment

		"Survey" Journey-To-Work			Census Journey-To-Work			Ratio of
Residence Ring	Workplace Ring	Total Workers	Transit Users	Transit Share	Total Workers	Transit Users	Transit Share	Transit Share =Sur./Cen.
0	0	54,827	23,163	42.2%	54,503	15913	29.2%	1.45
1	0	108,785	60,018	55.2%	119,087	58802	49.4%	1.12
2	0	82,282	35,639	43.3%	82,301	29998	36.4%	1.19
3	0	72,876	26,761	36.7%	72,609	20050	27.6%	1.33
4	0	26,722	7,627	28.5%	25,549	6767	26.5%	1.08
0	1	14,369	5,723	39.8%	21,743	8394	38.6%	1.03
1	1	130,404	24,759	19.0%	155,061	32968	21.3%	0.89
2	1	52,070	9,516	18.3%	65,532	10516	16.0%	1.14
3	1	40,168	7,136	17.8%	43,379	3782	8.7%	2.04
4	1	10,044	750	7.5%	14,581	1337	9.2%	0.81
0	2	6,757	1,676	24.8%	9,408	2499	26.6%	0.93
1	2	42,521	2,828	6.7%	49,142	7728	15.7%	0.42
2	2	127,882	2,632	2.1%	156,319	5869	3.8%	0.55
3	2	74,570	1,917	2.6%	85,694	1545	1.8%	1.43
4	2	25,276	0	0.0%	31,765	335	1.1%	0.00
0	3	4,294	777	18.1%	6,139	613	10.0%	1.81
1	3	23,223	2,263	9.7%	28,636	3106	10.8%	0.90
2	3	64,363	0	0.0%	69,841	1953	2.8%	0.00
3	3	288,573	1,779	0.6%	336,898	3190	0.9%	0.65
4	3	126,204	447	0.4%	149,897	683	0.5%	0.78
0	4	543	0	0.0%	1,509	124	8.2%	0.00
1	4	3,993	173	4.3%	5,668	530	9.4%	0.46
2	4	10,928	0	0.0%	9,971	241	2.4%	0.00
3	4	47,391	0	0.0%	47,471	212	0.4%	0.00
4	4	263,543	1,327	0.5%	298,228	3370	1.1%	0.45
Regional Total		1,702,608	216,911	12.7%	1,940,931	220,525	11.4%	1.12

There were 36 cells with missing adjustment factors because those cells had zero identified Survey commuters. They were then assigned an adjustment factor of 1.00 in applications.

Application of Adjustment Factor

The identified commuters from the Survey then were assigned an adjustment factor based on each commuter's identified modes and residence-workplace locations. For each commuter, the adjustment was applied to all the trips, not just work trips, he or she made on the survey day. This was based on the assumption that oversampling and undersampling of individuals, not of trips, is the major source of bias. It was also assumed that all of the trips made by a working person on an average work day are basically related to his or her journey-to-work life style.

Effects on Expansion after First Adjustment Step

As indicated in Table 6, the procedure did reduce the total number of transit trips by about 9.3 percent. It also produced more comparable estimates of subway and commuter railroad trips.

This adjustment to the expansion yielded 490,200 subway trips (which is about 15.3 percent different from the ridership estimate of 425,200 trips) and yielded 71,300 commuter rail trips (which is 13.5 percent higher than the estimate of 62,800 trips). These two transit submode ridership estimates were deemed to be composed mostly of work trips, especially the commuter rail.

The reduction of transit trips was attributed mainly to the modification of mode share and residence-workplace distribution for the working population in the Survey. However, the number of expanded transit trips was still much larger than the transit ridership estimates, especially in the bus only trips. This leads to the next step of adjustment, which was aimed to modify the mode share of the nonworking population in the Survey.

ADJUSTMENT STEP 2: MATCHING TO REGIONAL TRANSIT SUBMODE RIDERSHIP ESTIMATES

Although the previous step adjusted work trips by mode according to the estimates in the 1990 Census Transportation Planning Package, the volume of expanded survey trips using transit still far ex-

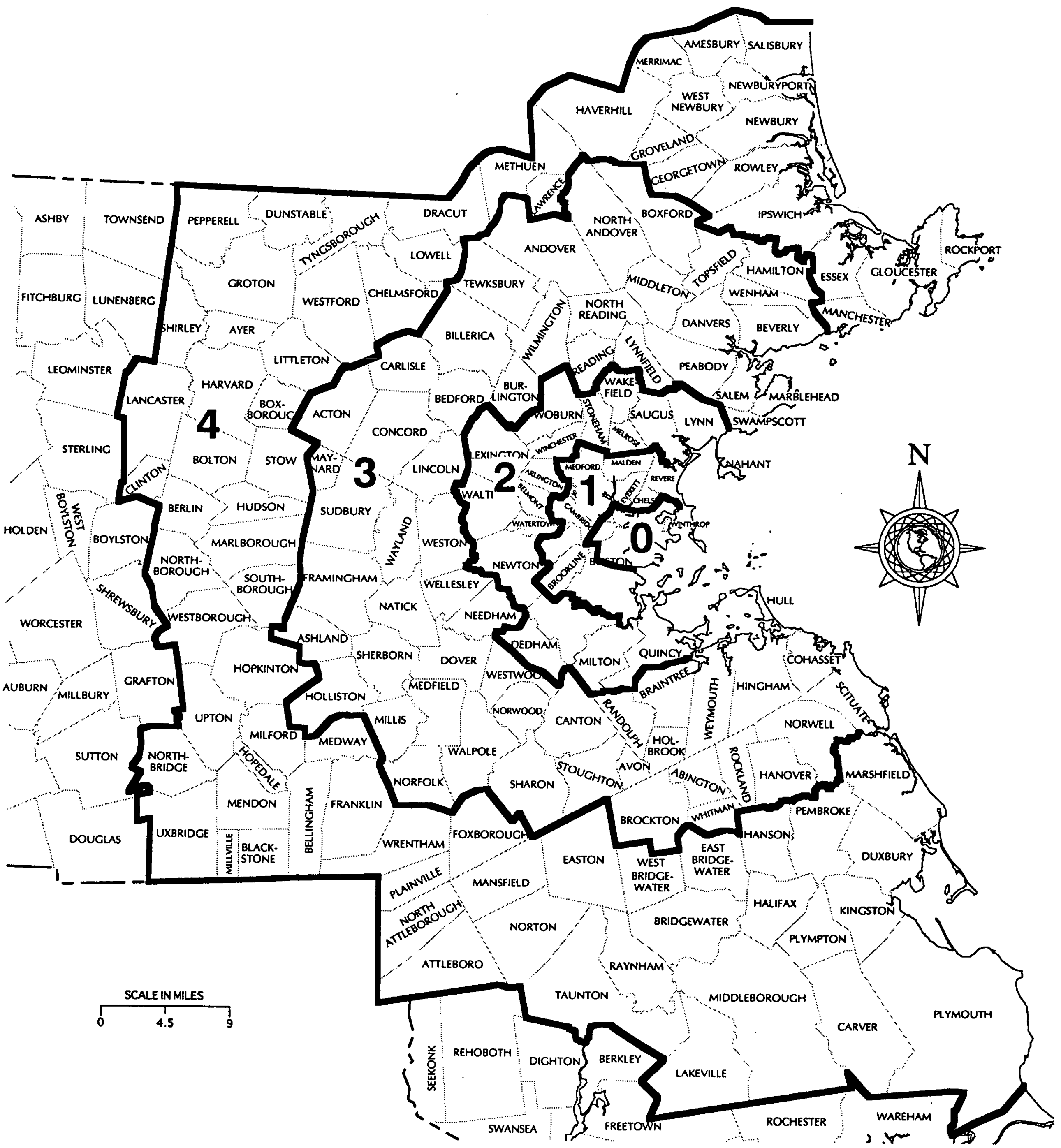

FIGURE 1 Geographical rings in eastern Massachusetts region.

ceeds the regional estimates. The only remaining measure available for adjustment of the survey is the regional transit ridership estimates by submode, so the final adjustment step is weighting the trips taken by nonworkers to match the transit submode ridership totals.

Altering the expansion factors according to mode of travel could dramatically alter the expanded number of trips within a household, so this adjustment was performed in an iterative fashion. At each iteration, after adjusting the weights applied to each nonworker according to the transit submode ridership totals, the expansion factors were revised to keep the expanded total number of trips taken by the households within each ring constant. The process continued until the submode adjustment factors were close to 1.

TABLE 4 Synthesized Survey Journey-to-Work Flows by Residence-Workplace Locations and Travel Modes

Residence	Workplace	Mode of Travel						Ring
Ring	Ring	Auto	Bus Only	Subway	Railroad	Non-Veh.	Total	Total
0	0	12,709	7,041	16,004	118	18,955	54,827	
0	1	6,370	1,431	4,292	0	2,276	14,369	
0	2	4,989	155	1,521	0	92	6,757	
0	3	3,517	251	526	0	0	4,294	
0	4	543	0	0	0	0	543	80,790
1	0	35,270	8,556	51,462	0	13,497	108,785	
1	1	77,573	7,479	17,280	0	28,072	130,404	
1	2	38,267	0	1,535	1,293	1,426	42,521	
1	3	20,960	773	1,302	188	0	23,223	
1	4	3,820	0	0	173	0	3,993	308,926
2	0	43,116	4,036	22,252	9,351	3,527	82,282	
2	1	39,554	5,927	2,494	1,095	3,000	52,070	
2	2	117,208	2,267	365	0	8,042	127,882	
2	3	62,529	0	0	0	1,834	64,363	
2	4	10,684	0	0	0	244	10,928	337,525
3	0	41,879	3,538	6,469	16,754	4,236	72,876	
3	1	32,203	3,408	2,310	1,418	829	40,168	
3	2	71,456	1,376	541	0	1,197	74,570	
3	3	271,886	1,436	0	343	14,908	288,573	
3	4	46,690	0	0	0	701	47,391	523,578
4	0	18,385	1,036	412	6,179	710	26,722	
4	1	9,294	0	0	750	0	10,044	
4	2	25,276	0	0	0	0	25,276	
4	3	125,401	447	0	0	356	126,204	
4	4	247,162	697	356	274	15,054	263,543	451,789
Total by Modes		1,366,741	49,854	129,121	37,936	118,956	1,702,608	1,702,608
Percent of Total		80.3%	2.9%	7.6%	2.2%	7.0%	100.0%	100.0%

Estimation of Regional Transit Submode Ridership Totals

An extensive effort was undertaken to obtain an estimate of the regional total linked transit ridership by submode on an average 1991 weekday. The estimation was derived by incorporating estimates of (Massachusetts Bay Transportation Authority (MBTA), commuter rail, rapid transit, and bus ridership (*3*), Logan Airport bus ridership (*4*), ridership on services by other regional transit agencies within the Eastern Massachusetts region (based on unpublished estimates from the Massachusetts Executive Office of Transportation and Construction, regional planning agencies, and regional transit authorities), and private bus schedules (*5*), together with estimated transfers between submodes (based on unpublished reports of the 1993 systemwide commuter rail and 1994 systemwide rapid transit surveys conducted by the Central Transportation Planning Staff) for the period of household survey (March, April, and May 1991).

The rule of linking multiple-mode trips is the same as that used to identify single travel mode for the Household Survey work trips (see previous adjustment step). As a result, the total intraregional linked transit trips made by the regional residents on an average weekday for the three transit submodes was estimated as

- Commuter rail: 62,800 trips,
- Bus: 259,100 trips, and
- Rapid transit: 425,200 trips.

Starting Point of Iterative Process

Assuming the journey-to-work adjustments reflect the undersampling or oversampling of the sampled households as well as the workers, the starting point of the iterative process was to adjust the expansion factor applied to each nonworker by the average journey-to-work adjustment factor for the workers in his or her household. This is computed using the following formula:

$$B_h = \sum_{\substack{p=1 \\ p=\text{worker}}}^{n} \frac{A_{hp}}{n} \quad (2)$$

where

h = household series number,
p = person series number,
n = number of workers in household h,

TABLE 5 Census Journey-to-Work Flows by Residence-Workplace Locations and Travel Modes

Residence Ring	Workplace Ring	Mode of Travel: Auto	Bus Only	Subway	Railroad	Non-Veh.	Total	Ring Total
0	0	13,697	5,851	9,947	115	24,893	54,503	
0	1	11,233	3,363	4,998	33	2,116	21,743	
0	2	6,372	975	1,440	84	537	9,408	
0	3	5,225	266	284	63	301	6,139	
0	4	1,247	38	59	27	138	1,509	93,302
1	0	55,265	18,946	39,274	582	5,020	119,087	
1	1	84,713	17,853	14,885	230	37,380	155,061	
1	2	39,874	4,108	3,426	194	1,540	49,142	
1	3	24,945	1,420	1,527	159	585	28,636	
1	4	5,047	153	337	40	91	5,668	357,594
2	0	51,515	9,298	16,276	4,424	788	82,301	
2	1	53,803	5,462	4,411	643	1,213	65,532	
2	2	134,187	4,161	1,443	265	16,263	156,319	
2	3	67,279	1,173	583	197	609	69,841	
2	4	9,602	100	85	56	128	9,971	383,964
3	0	51,111	3,126	5,275	11,649	1,448	72,609	
3	1	39,113	728	1,076	1,978	484	43,379	
3	2	83,642	788	342	415	507	85,694	
3	3	315,139	2,486	250	454	18,569	336,898	
3	4	46,861	138	12	62	398	47,471	586,051
4	0	18,568	1,483	471	4,813	214	25,549	
4	1	13,119	320	179	838	125	14,581	
4	2	31,173	105	33	197	257	31,765	
4	3	148,070	478	33	172	1,144	149,897	
4	4	275,613	3,238	48	84	19,245	298,228	520,020
Total by Modes		1,586,413	86,057	106,694	27,774	133,993	1,940,931	1,940,931
Percent of Total		81.7%	4.4%	5.5%	1.4%	6.9%	100.0%	100.0%

B_h = adjustment factor for nonworkers in household h, and
A_{hp} = journey-to-work adjustment factor for worker p in household h.

The regional total expanded trips by mode were obtained from the previous steps and were divided into total submodal trips by workers (Wm) and nonworkers (Vm). They can be shown as

$$W_m = \sum_{hpm}^{p \neq \text{worker}} (T_{hpm} \cdot E_{hp} \cdot A_{hp}) \tag{3}$$

$$V_m = \sum_{hpm}^{p \neq \text{worker}} (T_{hpm} \cdot E_{hp} \cdot B_h) \tag{4}$$

TABLE 6 Summary of Expanded Trips by Mode and Purpose after Journey-to-Work Adjustment

Trip Purpose	Mode of Travel: Auto	Bus Only	Subway	Railroad	Non-Veh	Unknown	All-Mode Total
HB Work	2,370,200	83,800	178,300	40,700	192,000	5,900	2,870,900
HB School	469,400	47,300	72,300	4,900	310,700	800	905,400
HB Other	5,228,800	122,200	102,200	18,400	716,700	5,800	6,194,100
NHB Work	1,529,500	30,400	70,200	3,700	458,900	900	2,093,600
NHB Other	1,448,600	38,800	62,400	3,100	343,800	400	1,897,100
Total	11,046,500	322,500	485,400	70,800	2,022,100	13,800	13,961,100
Percent	79.1%	2.3%	3.5%	0.5%	14.5%	0.1%	100.0%
Before Adj.	10,975,400	291,400	578,900	104,100	2,063,200	13,500	14,026,500
	78.5%	2.1%	4.1%	0.7%	14.7%	0.1%	100.0%

where

m = 1,2,3,4 in which 1 is bus, 2 is rapid transit, 3 is commuter rail, and 4 is others;
W_m = regional total number of trips using mode m by workers;
V_m = regional total number of trips using mode m by nonworkers;
T_{hpm} = number of trips using mode m by individual p in household h;
E_{hp} = existing expansion factor for individual p in household h;
B_h = adjustment factor for nonworkers in household h; and
A_{hp} = journey-to-work adjustment factor for worker p in household h.

Submodal Ridership Adjustment

In the iteration procedure, the trips by workers were kept constant because their expansion factors were unadjusted, whereas, the trips by nonworkers were revised from iteration to iteration. The first step of the procedure was to produce estimated adjustment factors for each transit submode by comparing expanded trips totals with the regional transit ridership estimates by transit submode. Suppose the targeted regional transit ridership estimates are $K1$, $K2$, and $K3$ for the bus, subway, and commuter rail, respectively; the mode share adjustment for each transit submode (m = 1, 2, or 3) at the first iteration (i = 1) is computed as

$$A_m^i = \frac{(K_m - W_m)}{V_m^{i-1}} \qquad (5)$$

where

A_m^i = mode share adjustment factor for transit mode m at iteration i,
K_m = targeted transit ridership estimates for transit mode m,
W_m = regional total number of trips using mode m by workers,
V_m = regional total number of trips using mode m by nonworkers, and
V_m^{i-1} = expanded volume of trips by all nonworkers using transit mode m from previous iteration where at first iteration $V_m^0 = V_m$.

The adjustment factor for the nontransit trips is then determined as a function of the ridership estimates and various expanded trip volumes. In formulation, it is computed as

$$A_m^i = \frac{\left[\sum_{m=\text{all}} V_m^{i-1} - \sum_{m=\text{transit}} (K_m - W_m) - N^{i-1}\right]}{V_m^{i-1}} \qquad (6)$$

where

A_m^i = mode share adjustment factor for all nontransit modes m at iteration i,
K_m = targeted transit ridership estimates for transit mode m,
W_m = regional total number of trips using mode m by workers,
N^{i-1} = total expanded trips of unknown mode by all nonworkers at iteration i − 1, and
V_m^{i-1} = expanded volume of trips by all nonworkers using nontransit mode m from the previous iteration.

Individual Weighting Adjustment

It is assumed that the individuals (not their trips) have been oversampled or undersampled so the nonworker adjustment factor is estimated as a weighted average of the submodal adjustment factors, with the weighting done by the modal distribution of the individual non-worker's trips. This is reflected in the following equation:

$$A_{hp}^i = \frac{\sum_m (T_{hpm} \cdot E_{hp} \cdot B_h \cdot A_m^i)}{\sum_m (T_{hpm} \cdot E_{hp} \cdot B_h)} \qquad (7)$$

where

A_{hp}^i = individual weighting adjustment factor at iteration i for nonworker p in household h,
T_{hpm} = number of trips using mode m by individual p in household h,
E_{hp} = existing expansion factor for individual p in household h,
B_h = adjustment factor for nonworkers in household h, and
A_m^i = mode share adjustment factor for transit mode m at iteration i.

Adjustment of Trip Production Totals at Ring Level

To prevent this adjustment from altering the volume of trips produced in the region, the expanded volumes of trips by nonworkers by ring of residence after the nonworker individual weighting adjustment are matched to the preadjustment expanded totals by ring of residence. This is illustrated in the following equation:

$$A_r^i = \frac{\sum_{hpm}^{\text{all}} (T_{hpmr} \cdot E_{hp} \cdot B_h)}{\sum_{hpm}^{\text{all}} (T_{hpmr} \cdot E_{hp} \cdot B_h \cdot A_{hp}^i)} \qquad (8)$$

where

A_r^i = ring adjustment factor at iteration i for ring r,
T_{hpmr} = number of trips using mode m by nonworker p from household h residing in ring r,
E_{hp} = existing expansion factor for individual p in household h,
B_h = adjustment factor for nonworkers in household h, and
A_{hp}^i = individual weighting adjustment factor at iteration i.

Final Adjustment Factor

The iteration procedure is repeated until the submodal adjustment factors are close to 1. The final modal adjustment factor for nonworker p in household h within ring r can then be shown as:

$$A_{hpr} = B_h \cdot \prod_i (A_{hp}^i \cdot A_r^i) \qquad (9)$$

Results of Second Adjustment Step

Before the first iteration, commuter rail trips by nonworkers were 63 percent of their estimated total, rapid transit trips were 68 per-

TABLE 7 Summary of Expanded Trips by Mode and Purpose after Transit Ridership Adjustment

Trip Purpose	Mode of Travel: Auto	Bus Only	Subway	Railroad	Non-Veh	Unknown	All-Mode Total
HB Work	2,372,000	83,000	175,900	40,400	191,800	5,900	2,869,000
HB School	478,100	30,700	50,800	3,400	328,500	600	892,100
HB Other	5,311,800	87,700	79,700	12,700	717,800	5,900	6,215,600
NHB Work	1,531,200	29,900	69,700	3,700	459,000	900	2,094,400
NHB Other	1,477,600	30,300	50,300	2,300	331,400	400	1,892,300
Total	11,170,700	261,600	426,400	62,500	2,028,500	13,700	13,963,400
Percent	80.0%	1.9%	3.1%	0.4%	14.5%	0.1%	100.0%
Before Adj.	11,046,500	322,500	485,400	70,800	2,022,100	13,800	13,961,100
	79.1%	2.3%	3.5%	0.5%	14.5%	0.1%	100.0%

cent of their estimated total, and bus trips were 62 percent of their estimated total. At the initial iteration, about 90 percent of the individual weighting adjustment factors were between 0.95 and 1.05, less than 2 percent of them are less than 0.65, and none of them are over 1.05. The ring adjustment factors for the first iteration ranged from 0.98 to 1.04.

The ridership estimate-survey estimate ratios (i.e., the mode share adjustment factors) after five iterations were 0.98 for commuter rail, 0.99 for rapid transit, and 0.98 for bus, and all of the fifth iteration personal adjustment factors were between 0.95 and 1.05. Also, at the fifth iteration, the ring adjustment factors ranged from 0.999 to 1.002. These ratios appeared acceptable, so the combination of factors from the first five iterations were applied to the appropriate records in the survey trips file.

As indicated in Table 7, while making this adjustment, the transit trips were reduced by 14.9 percent (by about 131,000 trips) from the previous adjustment step. The largest reduction is in the bus only trips (reduced by 18.3 percent). As a result, the three transit submode trips are all within 1 percent of the regional transit ridership estimates.

CONCLUSIONS

The household survey information generally is organized into three components: household, person, and trip files. Ideally, the expansion factors computed for the household file are adequate for the person and trip files, and additional weights need not be computed (*7*). In some cases, however, the additional adjustments are necessary in application of the survey data because of the poor matching of regional totals of persons or trips.

It is desirable that the adjusted expansion factors are distributed similar to that of the original expansion (developed at household level). Table 8 summarizes the ranges of expansion factors from

TABLE 8 Comparative Distributions of Households by Expansion Factor Ranges

Range of Expansion Factors	Step 0: Original Expansion		Step 1: Journey-To-Work Adjustment		Step 2: Transit Ridership Adjustment	
0 - 50	12	0.3%	16	0.4%	17	0.4%
50 - 150	309	8.0%	367	9.5%	391	10.2%
150 - 250	735	19.1%	719	18.7%	715	18.6%
250 - 350	847	22.0%	865	22.5%	838	21.8%
350 - 450	884	23.0%	837	21.8%	832	21.6%
450 - 550	484	12.6%	457	11.9%	447	11.6%
550 - 650	242	6.3%	232	6.0%	256	6.7%
650 - 750	123	3.2%	137	3.6%	142	3.7%
750 - 850	78	2.0%	70	1.8%	64	1.7%
850 - 950	29	0.8%	34	0.9%	32	0.8%
950 - 1,050	17	0.4%	18	0.5%	19	0.5%
1,050 - 1,550	45	1.2%	53	1.4%	52	1.4%
1,550 - 2,050	17	0.4%	15	0.4%	18	0.5%
2,050 - 2,550	8	0.2%	12	0.3%	13	0.3%
2,550 - 3,050	14	0.4%	12	0.3%	7	0.2%
> 3,050	0	0.0%	0	0.0%	1	0.0%
Total	3,844	100.0%	3,844	100.0%	3,844	100.0%

Note: In Adjustment Steps 1 and 2, the expansion factors for a survey household is a weighted average of all the persons in the household.

TABLE 9 Comparison of Expanded Trips by Trip Purpose

Trip Purpose	Unexpanded Data	Before Adjustment	Adjustment Step 1	Adjustment Step 2
HB Work	20.9%	20.6%	20.6%	20.5%
HB School	6.3%	6.5%	6.5%	6.4%
HB Other	43.2%	44.1%	44.4%	44.5%
NHB Work	16.3%	15.2%	15.0%	15.0%
NHB Other	13.3%	13.6%	13.5%	13.6%
Total	35,318	14,026,500	13,960,100	13,963,400

TABLE 10 Comparison of Expanded Trips by Transit Submode

Transit	Regional Transit Ridership Estimates		Original Expansion		Journey-To-Work Adjustment		Transit Ridership Adjustment	
Sub-Mode	Trips	Share	Trips	Share	Trips	Share	Trips	Share
Bus Only	259,100	34.7%	291,400	29.9%	322,500	36.7%	261,600	34.9%
Subway	425,200	56.9%	578,900	59.4%	485,400	55.2%	426,400	56.8%
Railroad	62,800	8.4%	104,100	10.7%	70,800	8.1%	62,500	8.3%
Total	747,100	100.0%	974,400	100.0%	878,700	100.0%	750,500	100.0%

the original expansion to the transit ridership adjustment step. The factors in the two adjustment steps were developed at the person level, so they are average factors of the persons within a household. As shown, the distributions of factors that form the two steps are not very different from that of the original expansion, and over 80 percent of the expansion factors are concentrated in the range of 150 to 650 (the average expansion factor from the original expansion is 393).

Meanwhile, the distributions of trips by trip purpose from step to step were examined. As indicated in Table 9, there were no significant changes in the distribution of trips by trip purpose while making the two adjustments.

This study proposed a procedure that adjusts the proportion of trips by travel mode in household survey, based on two relatively more reliable data sources: the Census journey-to-work data and local transit ridership estimates. Through the two adjustment steps, the expanded transit trips by submode were matched to transit ridership estimates (Table 10). In application, the adjusted expansion factors from the journey-to-work adjustment can be applied to trip distribution calibration, and that from the transit ridership adjustment can be applied to mode choice model estimation.

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Congestion Management Through Bus Metering at the Lincoln Tunnel

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The Lincoln Tunnel is a three-tube, six-lane tunnel connecting New York to New Jersey and is owned and operated by the Port Authority of New York and New Jersey. The tunnel provides weekday 3-hr p.m. peak service for approximately 22,000 vehicles, of which nearly 10 percent are buses. Bus traffic is concentrated in priority access lanes to avoid the general traffic peak congestion queues. The bus priority access lanes merge with selected lanes of general traffic near the tunnel's entrance portal. The resultant "bus-rich" traffic stream is turbulent, with an average throughput of 1,050 vehicles per hour; this stream consists of 350 buses and 700 cars per lane during p.m. peak hours. In 1993, the Port Authority conducted a test on fixed-rate access metering applied upstream of the bus and general traffic merge point at the New York entrance portal. The access metering investigation results showed a 15 percent increase in throughput, a 20 percent decrease in trip travel time, and a 20 percent reduction in the dispersion of 1-min flow rates (i.e., a more uniform traffic stream) with access metering, compared to unmetered access. The metered bus access lane was found to be a key factor in the experiment, since the bus drivers exhibited a high degree of compliance with the meter control. Their adherence fostered passenger car compliance, resulting in a smooth-flowing traffic stream. Extrapolation of the test results to the entire Lincoln Tunnel facility yields an increase in peak hour tunnel capacity of 1,000 vehicles per hour.

The Lincoln Tunnel is a three-tube, six-lane facility that provides access from New Jersey to midtown Manhattan (New York City). The facility is owned and operated by the Port Authority of New York and New Jersey. The Lincoln Tunnel was constructed in 1937 and consisted of a two-lane tube (now designated the center tube). The north tube was added in 1945, and the south tube was added 10 years later. The resultant complex services more than 110,000 vehicles on an average weekday, over 22,000 vehicles during each of the two daily 3-hr peak periods. The traffic mix at the tunnel is varied, with buses representing approximately 10 percent of the peak period vehicles. To facilitate mass transit, the tunnel management concentrates bus traffic in priority access lanes to allow them to bypass the p.m. peak congestion queues, which average 1,000 vehicles. Traffic in the bus priority access lanes from the Manhattan bus terminal merges with the general traffic flow in the outbound lanes near the tunnel's entrance portal. The resultant traffic stream tends to be turbulent with an average throughput of 1,050 vehicles per hour (vph), in the lanes used by buses. The traffic mix consists of 350 buses and 700 cars during these peak hours.

The congestion management strategy for general traffic utilizes the timely reversal of the center tube's traffic direction to optimally match the tunnel service to the existing demand. This management technique reflects due consideration of the aggregate, unserved demand that develops over the peak period and the availability of appropriate roadway on which the unserved queues may be stored.

Utilization of the Lincoln Tunnel is asymmetric. The a.m. peak period is heavier in the Manhattan-bound (inbound) direction, and the p.m. peak travel period produces an increased outbound flow. As a result, the Port Authority's operating strategy for the facility provides four inbound lanes in the peak a.m. period and four outbound lanes in the peak p.m. period on normal weekdays. This reflects reversal of the center tube to meet the demand.

Congestion management at the Lincoln Tunnel reflects a strategy that includes priority service for mass transit vehicles and prudent choice of the approach roadways selected for storage of unserved demand. Bus access into the tunnel during the peak period is facilitated in the a.m. peak period by a contraflow lane on I-495 that permits bus access directly to the toll plaza, thus bypassing the general traffic queuing normally present during the a.m. peak. During the p.m. peak period, dedicated lanes allow direct egress from the Port Authority's Manhattan bus terminal to a merge point before the entrance portal of the tunnel's center tube. This arrangement permits priority service for buses, avoiding delays.

Aerial surveys of the Lincoln Tunnel indicate that the unserviced demand peaks at approximately 1,000 vehicles in both the a.m. and p.m. peak periods. In the morning, the Manhattan outbound flow is light, and significant queuing does not develop, even though only two outbound lanes are available. The delay due to congestion and queuing in the a.m. peak period is confined to inbound non-bus travelers. In effect, bus travelers are permitted direct access into the tunnel, whereas cargo and passenger vehicles must approach the tunnel through a regional network of roads and access lanes that serve to store the queues built up during the peak periods.

In the p.m. peak period, outbound travel is accommodated by reversal of the center tube at approximately 3:30 p.m. This action matches available capacity to the demand for service and minimizes the need for storage on the Manhattan street network and on the New Jersey road system. In the process, queuing during the p.m. peak period is directed to those roadways where adequate storage exists and reasonable congestion management techniques can be used. This mode of operation is maintained until approximately 7:00 p.m., when the peak demand for outbound service sufficiently subsides so as to permit reallocation of the tunnel complex to a configuration of three lanes in each direction. By that time, the unserved peak queue of approximately 1,000 vehicles begins to dissipate and the congestion subsides within about 30 min.

The capacity of the Lincoln Tunnel, as measured in passenger car equivalents (PCEs), is approximately 9,000 PCEs, with one bus or truck being equivalent to two cars. When this capacity is compared against the peak period maximum queue of about 1,200 PCEs, (1,000 cars and 100 trucks), it is apparent that the peak period queue is approximately equal to 13 percent of total hourly production

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capacity. Unfortunately, storage capacity requirements, congestion abatement principles, and the necessity of providing priority service for transit vehicles produces a situation in which significant queuing occurs in both New York and New Jersey. In effect, motorists seeking access to Manhattan through two lanes in the p.m. peak period experience delays of approximately 24 min under normal conditions. Furthermore, when multiple incidents are experienced during the early part of any peak travel period, the lost productivity contributes between 2 to 4 min of delay per incident per lane. Thus, on some occasions, the peak period congestion (and the associated delay) is twice the norm, and Manhattan-bound travelers may wait 50 min or longer before obtaining access to the tunnel.

In the late 1950s, Eddy and Foote conducted experiments in which access constraints at the Lincoln Tunnel produced throughput improvements of 7 to 10 percent. These early control experiments demonstrated the possibility of improving productivity through access control measures.

In 1993, the Port Authority commissioned Computran Systems Corporation to perform an evaluation study to determine the beneficial impacts that might be achieved from access metering. One phase of this program addressed the application of metering to the tunnel's bus traffic. The principle that motivated the study was that fluctuations in the normal traffic patterns at the Lincoln Tunnel tend to increase the dispersion observed in traffic flow and reduce the sustained average long-term productivity. In effect, metering was being investigated as a possible method of obtaining a more uniform input stream at the tunnel. The expectation was that a decrease in the dispersion (i.e., short-term flow rates) would result in an increase in the average total peak period productivity. The results of the experiment confirmed these expectations on a statistically significant basis for all measured variables.

CONTROL CONCEPTS

Preliminary studies conducted at the Lincoln Tunnel have revealed that the production rates observed in short-term measurements, (i.e., 1-min totals) often approached 1,800 PCEs per hour. However, the tunnel's sustained longer-term productivity (i.e., 15-min totals and greater), generally reflected throughput rates of 1,400 PCEs per hour or less. These data reflect the traffic mix, which consists of roughly one-third buses and two-thirds passenger vehicles at a production level of 1,050 vehicles per hour.

A metering experiment was designed to test the improvements in longer-term tunnel productivity. The site selected for evaluation was the tunnel's center tube, north lane. This roadway is served by two approach lanes: one provides direct access for buses exiting from the Port Authority's Manhattan terminal, and the other lane provides passenger vehicle access from the southern approach roadways that service the Lincoln Tunnel complex.

Metering signals were installed in two lanes with the intent of alternately metering buses and cars. An attempt was made to match the metering process to the underlying traffic mix of two passenger cars per bus. As a result, the metering practice adopted released two passenger vehicles for each bus released. The rate of metering was controlled by a personal computer host and was made adjustable from a baseline of 700 cars and 350 buses per hour (i.e., 1,050 vehicles per hour) to a peak rate of 900 passenger vehicles and 450 buses per hour (i.e., 1,350 vehicles per hour).

A schematic diagram of the control system layout on the approach roads to the center tube is shown in Figure 1. The placement of the traffic metering signals reflects the type of vehicles on which control is imposed and the need for a more homogeneous mixing of the two streams seeking access into the tunnel. For this reason, the metering rate for passenger vehicles was uniformly set at twice the metering rate for buses. The offset between the release time for buses and the release time for passenger vehicles was made field adjustable, so as to permit fine-tuning of the merge process.

OPERATIONAL ADJUSTMENTS

Transit vehicle metering was examined at various meter rate settings. It was observed that several days of familiarity with the signals were required before a reasonable level of bus driver compliance developed. Furthermore, the rate at which metering was set seemed to exhibit a resonance in compliance when the physical characteristics of the bus stream were best matched by the meter rate imposed. In effect, metering at a rate of approximately 400 buses per hour produced a smooth bus stream in which vehicles could coast to the meter signal, and thereafter accelerate smoothly through the merge point. Lower meter rates appeared to impose additional delay, which was objectionable to certain drivers, and higher rates produced a premature green indication. As a result, the metered bus stream seemed to flow most smoothly at approximately 400 buses per hour, even though a small percentage of the bus traffic involved articulating vehicles that took longer to pass the signal.

Compliance of the passenger vehicles to the metering signal was sporadic, compared to the compliance of buses. A substantial percentage of the passenger vehicles seemed unconcerned with the color of the signal when they approached the control point; some of this behavior continued even after the initial "training period" had passed. As a result, the smoothness of flow that developed in the bus stream was not apparent in the stream of passenger vehicles. However, the bus driver's adherence to the metering signal forced the passenger vehicles into a reluctant compliance. When certain passenger vehicles attempted to violate the right-of-way of a metered bus, the bus driver forced compliance by blocking the merge point. The results of the confrontation caused subsequent motorists to observe the metered signal. The smoothness of travel achieved by the bus traffic lane exceeded that of the passenger vehicle lane, but the ratio of buses to cars gaining access to the tunnel matched the metering ratio.

There was an apparent reduction in the size of the unserved queue of passenger vehicles that sought access via the metered lane. At first, this condition was attributed to shortfalls in the demand for service. However, in subsequent evaluation, the dissipation of queued demand was accounted for by the increased productivity that caused a corresponding reduction in the number of unserved motorists awaiting access.

Data collection was conducted over 24 separate p.m. peak periods. Twenty-five percent of these samples were measured without metering in effect. The remaining samples reflect approximately five meter rates in the range between 1,000 and 1,400 vehicles per hour.

The data was collected with a personal computer from vehicle detectors in each of the metered access lanes. Primary data were recorded at the time each vehicle detector was actuated and released. In effect, the time of arrival and departure of each sensed vehicle was recorded and stored on a computer disk for subsequent processing.

Analysis of the data was performed in a sequential fashion. First, the raw data were processed to generate 1-min flow rates in each metered lane. These data were compared to concurrent records of

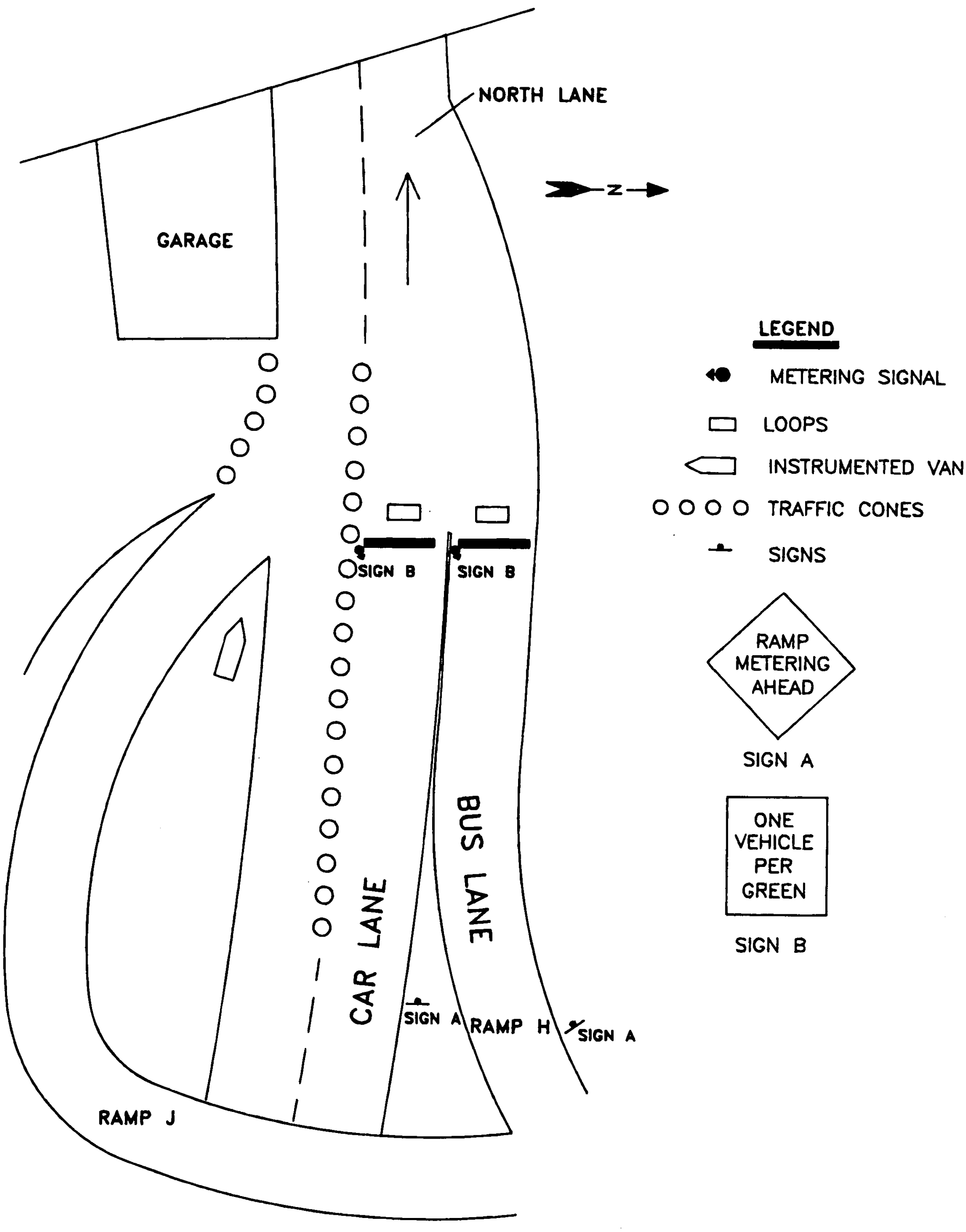

FIGURE 1 Schematic of test set-up at Lincoln Tunnel.

the signal indication to determine the actual per-minute metering rates that were displayed in each lane.

One of the principal variables of comparison was the average production rate achieved during the approximately 2-hr peak period that comprised each daily sample. These average production rates were compared with the average 2-hr peak period production rates achieved in the six unmetered samples.

FINDINGS

The results indicated that without metering, the average peak period production rate was approximately 1,050 vehicles. When metering was imposed, production rates of approximately 1,200 vehicles per hour were achieved. This translates into a production rate of approximately 1,400 PCEs through the tunnel's lane.

A quantitative comparison of the average peak period production rates is shown in Figure 2. On this graph, each test day's throughput is shown along with the respective meter rate in force that day. Additionally, the graph shows the upper and lower three-sigma boundaries of the unmetered throughput average. These data indicate that the average unmetered productivity is statistically different from each of the metered samples using a three-sigma confidence test criteria. In essence, the average productivity of the metered north lane of the center tube is statistically superior to the average productivity obtained without metering. The effect of the meter rate itself upon the observed performance is not discernible, and a linearized curve fitting of the data is relatively flat and approximately constant over the range of the examined meter rates.

As a second indicator of observed impact, the sequence of 1-min flow data was plotted as a function of time for each of the samples. A typical history obtained without metering is shown in Figure 3, and a typical pattern with metering is shown in Figure 4. Comparison of these records indicates two significant improvements. First, the average productivity with metering is greater than the average productivity without metering. Second, the range of variation in 1-min flow rates experienced without metering is significantly greater than the range of 1-min flow rates experienced with metering. In effect, metering increased the average productivity and decreased the dispersion in the throughput data. The result is a more uniform flow into the tunnel and a higher production rate through the tunnel facility.

Volumetric throughput is a key measure of tunnel productivity. It is the mark of the number of vehicles that were serviced through the facility. However, this measure of service quantity is only one of the principal indicators of improved performance. A service quality indicator was developed from measurements of the travel time experienced under both metered and unmetered conditions. A total of 6 sample days were selected for this analysis. Three of the sample days were metered days; the other three sample days reflected unmanaged operation, and were not metered. The study compared the travel time during the sample days to measure the impact of metering on the quality of service. The measurement of travel time was accomplished through the use of video camera recorders. Inflow and outflow at the tunnel was recorded concurrently throughout the 2-hr peak period. These video data were then reduced by the selective tracking of three identifiable vehicles that entered the tunnel in each of the twelve 10-min periods that comprised each 2-hr peak sampling interval. In effect, a total of 36 trip times, uniformly distributed over the 2-hr peak period, were used to measure service quality. The average and dispersion of trip time data were compared for each of the six selected samples. The result indicated a 20 percent decrease in the average travel time through the tunnel, and a decrease of 15 percent in the variation in peak period trip times when metering was imposed.

Analysis of the data clearly indicates that both the quantity and quality of service available with metering in operation were superior. Furthermore, the increase in the peak period throughput obtained with metering in effect reduced the delay experienced by queued motorists by reducing the number of queued vehicles and servicing the ones queued faster. Accordingly, metering produced an even greater beneficial impact on total travel time, since the waiting time to enter the tunnel and the time required to traverse the tunnel were both reduced.

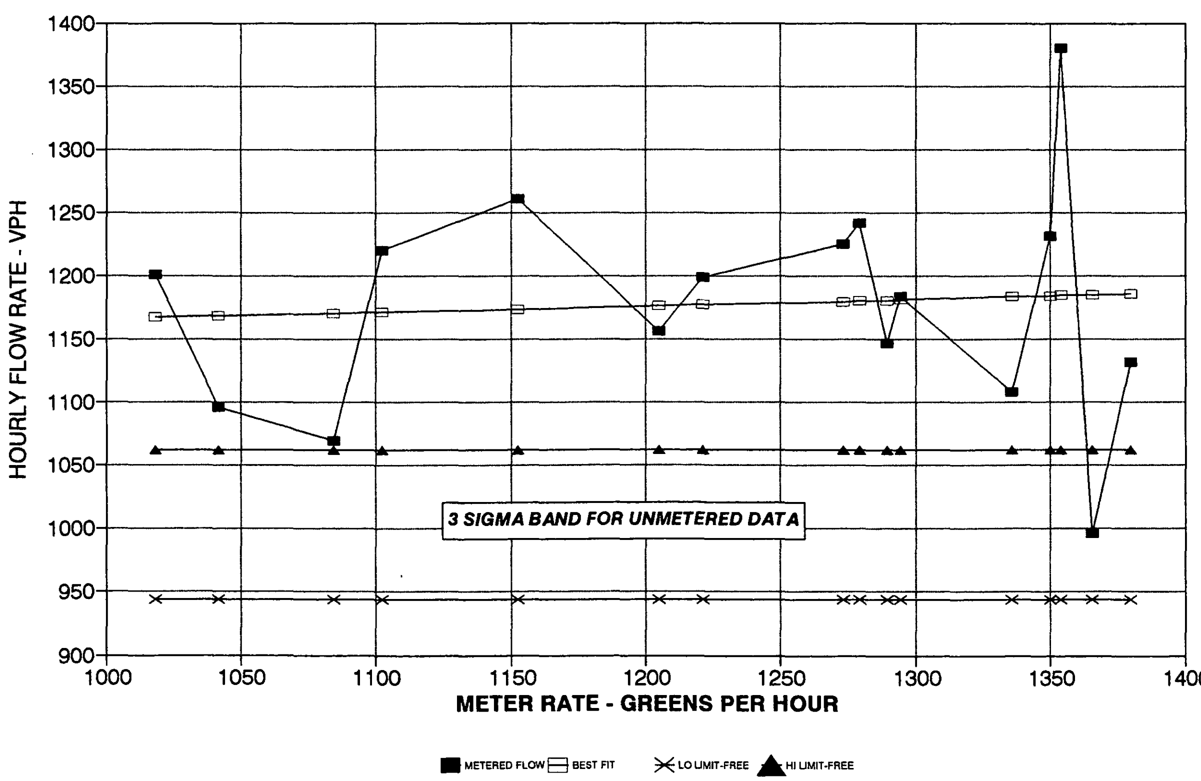

FIGURE 2 Hourly flow versus meter rate at Lincoln Tunnel.

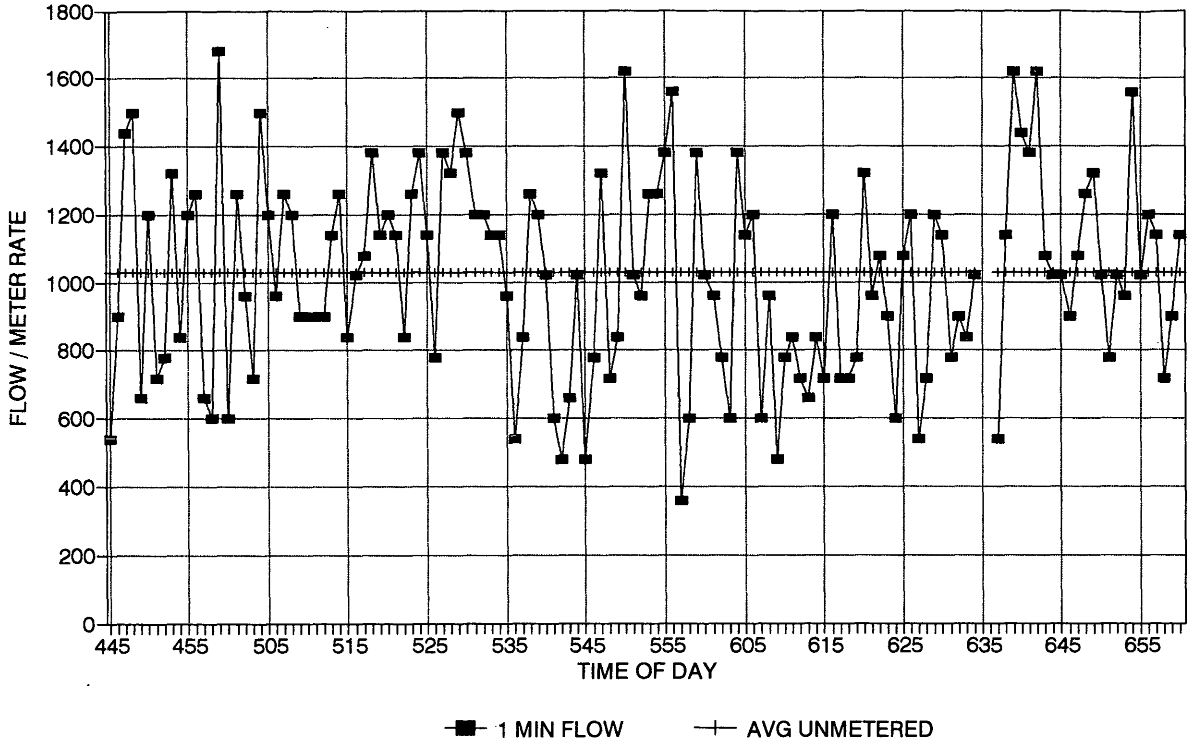

FIGURE 3 **Unmetered 1-min flow rates at Lincoln Tunnel, November 24, 1993.**

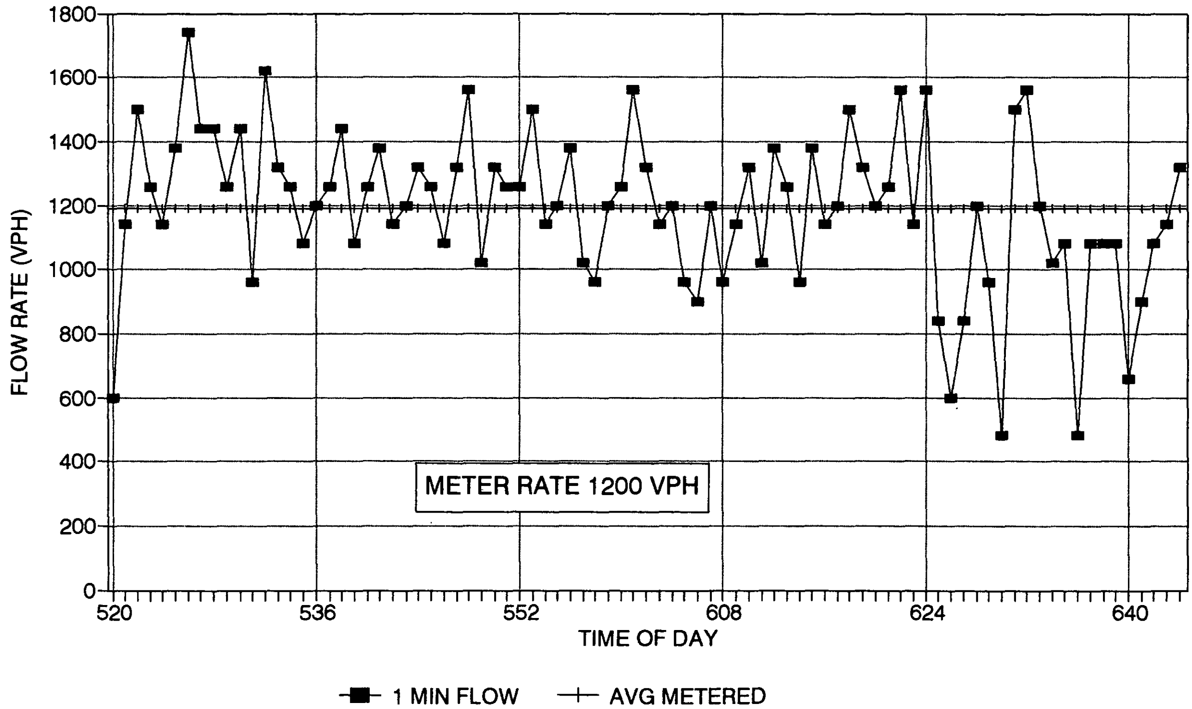

FIGURE 4 **One-minute flow rates (vph) versus time at Lincoln Tunnel, November 29, 1993.**

The total impact of metering at the Lincoln Tunnel is only partially reflected in the improved quantity and quality of service experienced by motorists exiting from Manhattan in the p.m. peak period. The metering of access into the tunnel reduces queuing of excess demand in New Jersey as well as in New York. In effect, increased throughput for New Jersey-bound traffic permits an earlier reversal of the center tube from the four-lane/two-lane mode to a balanced operation of three lanes in each direction. Acceleration of this reversal expedites the increase of the Manhattan-bound capacity by 50 percent (i.e., from two lanes to three) and significantly reduces the extent of congestion and the duration of peak traveler delay. Furthermore, extrapolation of these principles to the entire six-lane facility indicates that the increased productivity will match the present peak period demand. The effect of an improvement of this magnitude is significant relief of the peak period congestion that currently develops at both entrance portals of the Lincoln Tunnel.

CONCLUSION

The experimental program conducted by the Port Authority at the Lincoln Tunnel indicated that metering of mass transit vehicles improved the quality and quantity of service provided to these travelers and all other travelers who shared a common roadway. Thus, the impact of metering of transit vehicles was beneficial to all.

A representative sample of 400 buses that exit the Manhattan bus terminal in the normal weekday p.m. peak period carries between 12,000 and 16,000 passengers. In addition, passenger vehicles in the Lincoln Tunnel average approximately five people per four vehicles (i.e., 1.25 persons per vehicle). Therefore, the capacity of the Lincoln Tunnel was raised by approximately 2,000 travelers per hour through the use of access metering. In addition, peak period travel time was reduced in excess of 1 min for each of the travelers in the metered tube. This improvement corresponds to a savings of 250 person-hr of congestion delay each p.m. peak period. The annualized savings in gas consumption, air pollution, and other socially undesirable penalties complement this improvement in mobility.

The economic impact of improved tunnel productivity on the congestion experienced at the New Jersey side of the tunnel was not quantitatively assessed. However, if peak queuing approximates 1,000 vehicles each weekday p.m. period, and peak delay approximates 30 min, then the size of the peak p.m. period congestion that exists is on the order of 500 vehicle hours per day. With an average vehicle occupancy of 1.25 passengers, it can be projected that the magnitude of congestion experienced by motorists seeking service through the Lincoln Tunnel in both the a.m. and p.m. peak periods totals more than a quarter-million travel hours per year. All measures that reduce this avoidable delay are critical to the economic vitality of the region and warrant added investment in improving system performance. Consequently, the investigative team recommended moving forward on implementation studies of access control on all approaches to the Lincoln Tunnel.

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PART 2

Management

Program Performance Versus Transit Performance: Explanation for Ineffectiveness of Performance-Based Transit Subsidy Programs

BRIAN D. TAYLOR

Concomitant with increasing state support of public transit has been a growing concern in state houses over the operation of "empty" buses and trains and the desirability of tying state transit allocations to transit performance. Despite the popularity of performance-based transit subsidy programs among legislators and voters, performance-based programs have not worked well. In general these programs have either been unpopular and short-lived or politically popular and ineffectual. This occurs because of a conflict in all state transit subsidy programs between the political measures of subsidy program performance and operational measures of transit system performance. State funding of public transportation tends to be structured by programmatic concerns with distributional equity. Legislatures seek to ensure that citizens in all parts of the state benefit from public transportation subsidies. If the rewards and penalties in a performance-based program are large enough to motivate improved transit system performance, they will likely result in an uneven geographical distribution of funds, which is usually politically unpopular and creates pressure to weaken or abandon the performance-based allocation program. A study of the operating subsidy programs in 16 states is summarized and a programs in three states are described to indicate that the programmatic goals of distributional equity supersede efforts to motivate improved transit performance. Reviewed are the rationale for linking transit performance to funding allocations, the political constraints on performance-based allocations, a survey of 16 state transit subsidy programs, and the distributional equity requirements that might be redefined to be more consistent with performance-based programs.

The biggest change in subsidies for public transit during the past decade has been the growth of state support of transit operations in the face of declining federal operating support. In 1980, federal funds accounted for nearly 30 percent of all transit operating subsidies nationwide, compared to less than 25 percent from state programs. By 1992, however, state transit programs accounted for nearly 40 percent of all transit operating subsidies, compared to just 10 percent from federal sources (*1*).

Concomitant with this rise in state support of public transit has been a growing concern in state houses over the operation of "empty" buses and trains and the desirability of tying state transit allocations to transit performance. Despite the visceral popularity of performance-based transit subsidy programs among both legislators and voters, such programs, when implemented, generally fail to influence transit operators to improve performance for one of two reasons:

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1. State operating subsidy programs with strong performance incentives tend to generate strong local opposition from areas with penalized operators. This opposition results in the watering down or abandonment of the performance-based program to restore distributional parity of funding among operators.
2. To maintain distributional equity among operators from the outset, the performance incentive component is only a small component of a much larger state program, so small that the rewards and penalties have little influence on operator performance.

The net effect in either case is a "token" performance-based program; one that appears strong, but does little to influence operator behavior. This occurs because of a conflict in all state transit subsidy programs between subsidy program performance and transit system performance.

Like most resources distributed by state governments, state funding of public transportation tends to be structured by programmatic concerns with distributional equity. In particular, legislatures seek to insure that citizens in all parts of the state benefit from subsidies of public transportation. If the rewards and penalties in a performance-based program are large enough to motivate improved transit system performance, they will likely result in an uneven geographical distribution of funds. This uneven geographical distribution is usually politically unpopular, creating pressure to weaken or abandon the performance-based allocation program.

This paper summarizes a study of the operating subsidy programs in 16 states and describes the programs in three states (California, Pennsylvania, and Michigan) in some detail to indicate that the programmatic goals of distributional equity supersede efforts to motivate improved transit performance. The paper begins by reviewing the rationale for linking transit performance to funding allocations, turns to an examination of the political constraints on performance-based allocations, summarizes a survey of 16 state transit subsidy programs, and concludes with a discussion of how distributional equity requirements might be redefined to be more consistent with performance-based programs.

LINKING TRANSIT PERFORMANCE MEASURES TO FUNDING ALLOCATIONS

Defining and measuring performance in the private sector is fairly straightforward; profitable firms are successful, money-losing firms are not. A variety of measures, such as debt to equity ratios, changes

in market share, and so forth, can be used to analyze different facets of performance, but ultimately all performance is determined by profit or loss.

Performance in the public sector is harder to define. In public transit, operators have multiple, and often competing, goals. A typical transit operator may have defined goals of (*a*) providing bus service to all parts of the service area, (*b*) providing frequent service to schools, malls, the central business district, and low-income areas, (*c*) reducing traffic in congested areas, and (*d*) maximizing cost recovery from the farebox. Evaluating the performance of a transit system with such goals is difficult because achieving some goals can preclude attaining others.

Performance-based funding for public transit, however, is based on the premise that there are "bottom lines" for public transit that can be meaningfully evaluated. Performance measures are regularly used by managers to evaluate their systems and by oversight boards and outside funding agencies to track transit performance and progress (*2*), but their usefulness and accuracy become hotly debated when used as a basis for allocating subsidies between systems.

Whether performance measurement is used as an internal management guide, as a report card to overseeing boards and agencies, or as a basis for funding, multiple and sometimes contradictory measures of performance are often used. Transit performance, in other words, is largely in the eyes of the beholder. Transit users typically want frequent, reliable, and affordable service to their most frequent destinations. Transit managers often favor a smooth operation that stays within budget; for example, high morale and low absenteeism, few accidents and breakdowns, and few complaints from the board of directors or users. Transit boards typically want high-quality service (both coverage and frequency) that attracts riders, particularly in the areas they represent. And outside funding agencies, such as the federal, state, and regional governments, are often interested in reducing operating deficits and insuring an equitable distribution of subsidies among operators.

Determining funding allocation formulas based on performance measures is the most controversial use of performance indicators, particularly among transit managers. Transit operators, especially those slated to lose funding under some performance-based allocation proposal, frequently argue that performance measures are not comparable across properties and that measures should be used to internally manage improvements to transit systems, not to determine funding agency allocations.

Regardless of the particular performance measures used, there are three principal approaches to linking operating subsidies to transit performance:

1. *Threshold standards.* Performance is measured against uniform statewide standards. To be eligible for funding, for example, operators are required to meet or exceed some minimum standard, such as a farebox recovery ratio. California and Wisconsin are two states that currently use threshold standards in their transit subsidy programs.

The advantages of such programs is that they are relatively simple to administer and ostensibly fair, because they hold all systems to a uniform standard. Such programs do not, however, allow for differences in operating environments; they do not reward systems for exceeding standards, and the "death penalty" (withholding all subsidies) for failure to meet standards is difficult to enforce.

2. *Individual comparisons.* Each system is judged individually, either against past performance or current goals. Here systems can be judged (*a*) on annual changes in performance indicators, or (*b*) relative to a set of performance goals set in consultation with the state. The rationale for such an approach is that the service goals and operating environments (terrain, street network, population demographics, prevailing wages, etc.) make each transit system unique and incomparable and, therefore, only longitudinal evaluations of individual system performance changes are meaningful. Michigan and Pennsylvania are two states that use individual comparisons in making allocations.

Individual comparisons are popular with transit operators; they push systems to improve performance every year and hold them directly accountable for goals and performance. On the other hand, such programs can benefit poorly performing systems with room for improvement over already high-performing systems. Further, they do not control for changes (such as increased fuel prices) beyond operators' control, they encourage systems to make small incremental performance improvements instead of large, single-year jumps, and they may encourage operators to set low, easily attainable goals.

3. *Group comparisons.* Systems are judged relative to one another on an annual basis. The two common approaches here are to (*a*) judge each system against the statewide average for one or a number of performance indicators, or (*b*) judge each system against the performance of a "peer group" of similar transit operators nationwide. Indiana and North Carolina are two states that use group comparisons in making transit subsidy allocations.

The advantage of group comparisons is that they hold systems accountable to statewide or peer group performance, which makes it harder to explain away poor performance. And, in contrast to the longitudinal comparisons just described, they control for changes (such as increased fuel prices) beyond individual operators' control and they reward substantial performance improvements in a single year. Group comparisons may not, however, adequately control differences in operating environments between operators; service effectiveness measures (such as passengers per hour) favor operators in densely developed areas while cost-efficiency measures (such as cost per hour) favor operators in areas with low labor costs.

In addition to encouraging improved transit system performance, state transit finance programs are structured by internal program performance goals as well. For example, several state programs are explicitly intended to leverage local financial support of public transit. In Wisconsin and Michigan, systems are required to meet local match threshold requirements to receive funding. And in Indiana, the level of state funding is indexed to the level of local funding.

POLITICAL CONSTRAINTS ON PERFORMANCE-BASED ALLOCATIONS

Whichever performance-based allocation approach is used, state transit finance programs are judged politically by internal standards of programmatic effectiveness, particularly distributional equity. Table 1, drawn from a survey of transit operating subsidy programs in 16 states (*3*), notes several ways that distributional equity can be defined and how these concerns might be accommodated in a performance-based allocation program. The various approaches states have adopted to encourage improved program performance are also summarized.

Program Equity

An important consideration of any new state program is distributional equity. To garner legislative support, funds must be distrib-

TABLE 1 State Approaches to Improved Program Performance

Objective	General Methodology	States Employed
Program Equity		
Operator Equity	Program Expenditures/Transit Operators	Numerous
Geographic Equity	Program Expenditures/ Service Area Population	Florida, Indiana, South Carolina, Tennessee, Texas
Fiscal Equity	Program Expenditures/ Service Area Tax Revenues	California
Passenger Equity	Program Expenditures/ Passengers	Florida, South Carolina
Program Effectiveness		
Statewide Benefits	Program Expenditures/ State Benefits from Transit	Connecticut, Michigan, Wisconsin
Leveraging Local Commitment	Program Expenditures/ Local Expenditures	Indiana, Wisconsin, Connecticut, North Carolina
Program Equity and Effectiveness		
Passenger Equity and Effectiveness	Program Expenditures/ Fare Revenues	Indiana

uted in some equitable manner around the state. Although geography has been the most common measure of equity, a number of other definitions of distributional equity can more effectively link funding allocations to transit system performance.

• *Operator equity* (program expenditures based on number of eligible operators: numerous states)

Frequently favored by transit operators, this rationale allocates funds equally to all operators. Such programs are directly contrary to the logic of performance-based allocations. In practice, programs are rarely based solely on such a rationale because transit operators vary so significantly in size. But variants of the operator equity approach are common (such as with guaranteed minimum allocations); such programs are completely divorced from most performance-based allocation rationales such as revenue needs, service production, and so forth. Despite these shortcomings, however, the logic of transit operator-based equity is frequently found in state transit programs in the form of allocation "floors," or minimums distributed to each operator regardless of size, need, or performance.

• *Geographic equity* (program expenditures based on service area population: Florida, Indiana, South Carolina, Tennessee, and Texas)

Here funds are distributed based on each operator's share of the total state population, which indirectly allocates funds uniformly to all state citizens. Unfortunately, such programs reward poor performance: they benefit operators with low levels of per capita ridership (low service effectiveness) and penalize operators with high levels of per capita ridership (high service effectiveness) (*4*).

• *Fiscal equity* (program expenditures based on service area tax revenues: California)

Based on "return-to-source" principles of tax equity, funds are allocated to operators based on the proportion of revenues estimated to have been collected. Such programs, however, tend to benefit growing areas and penalize economically depressed areas.

• *Passenger equity* (program expenditures based on passenger: Florida and South Carolina)

Here funds are allocated based on each operator's share of total state transit ridership, which directly rewards systems for attracting patrons. This method has the advantage of (indirectly) subsidizing all transit patrons statewide equally. Such a program, however, can encourage operators to lower fares to attract additional riders, which lowers the farebox recovery ratio and can increase dependence on transit subsidies.

Program Effectiveness

In contrast with distributional equity, program effectiveness criteria aim to achieve some statewide policy goals apart from improved transit performance.

• *Statewide benefits* (program expenditures based on state benefits from transit: Connecticut, Michigan, and Wisconsin)

In a study of local, regional, and state policy makers, Cervero (*5*) finds that about half of the perceived societal benefits of public transit accrue to transit users, about 25 percent to local governments, and about 12.5 percent each to states and the federal government. Following this rationale, transit users should be expected to pay about half of the costs at the farebox, with the remaining deficit paid by local governments (25 percent), the state (12.5 percent), and the federal government (12.5 percent).

The motivation for states to allocate transit funds based on this rationale, however, stems more from a desire to cover funding shortfalls than from policy decisions about the relative state bene-

fits of public transportation. While equitable from a programmatic standpoint, such programs, because they usually are structured to cover operating deficits, do little to encourage systems to improve performance.

- *Leverage local commitment* (program expenditures based on local expenditures: Connecticut, Indiana, North Carolina, and Wisconsin)

A common objective of outside (state and federal) funding agencies is to discourage exclusive or primary dependence on their funding and to encourage local revenue generation. This is usually accomplished through matching programs, in which state or federal funds are contingent on local funding matches. The federal highway program, for example, has structured funding programs in this manner for 80 years.

In such a program, funds are used to "leverage" additional local transit expenditures. This method rewards areas with strong local financial commitments to public transit and penalizes areas that do not contribute to public transit. The local funds that qualify as "matching" can take many forms. They can be limited local government and institutional (universities, large employers, etc.) contributions or can include all local revenues (fares, advertising, local contributions, etc.).

Although such programs encourage greater local commitment to public transit, they tend to favor wealthier cities with the financial wherewithal to support local transit service. In general, such areas tend to have low per capita use of transit; thus, such programs can penalize poorer areas with higher levels of transit use.

Program Effectiveness and Equity

None of the surveyed state programs linked allocations directly to fare revenues, though several incorporate farebox recovery rates in some manner. Transit fare research has consistently indicated that transit users, even poor users, prefer high-quality service over low fares (*6*). Yet transit operators find it politically very difficult to raise fares, even if it is to increase service frequencies or add routes.

One way to encourage operators to improve service and attract more paying customers is to allocate funds based on the amount of fare revenue collected. Under such a passenger effectiveness and equity program, funds can be distributed to operators based on that operator's share of statewide fare revenues. This is similar to the passenger-based equity program described earlier, but here operators are specifically rewarded for attracting paying customers.

In effect, states could adopt an equity rationale of indirectly funding a "matching" program for transit users. For every dollar that transit riders paid in fares, the state could provide some fixed match. In addition to encouraging operators to attract fare-paying passengers, such programs are inherently equitable because they would subsidize all transit users equally statewide; every transit patron in the state receives an indirect subsidy from the state in proportion to that patron's contribution (fare).

Of all of the programmatic equity programs described here, linking program expenditures to fare revenues would come closest to balancing the goals of transit performance with program equity. One problem with linking subsidies to fare revenues, however, is that such a matching program would only indirectly contain costs. One way to link subsidies more directly to costs is to allocate funds based on each operator's deficit (or subsidy) per passenger; in other words, the lower the deficit per passenger, the greater the allocation per passenger. But, although such a program is directly linked to both costs and revenues, it may be counter intuitive to elected officials. That is, the less subsidy an operator needs (because of a low deficit per passenger), the more subsidy it receives. Although directly rewarding systems for high performance, such an allocation schema is likely to be viewed by both elected officials and transit managers as programmatically ineffectual and inequitable, given that funding will tend to flow to systems least in "need" of subsidy. However, no such directly performance-based allocation rationale was currently used by any of the 16 states surveyed for this study.

Given this inherent contradiction between programmatic equity and transit performance, any successful performance-based allocation program must satisfactorily accommodate the two. One strategy of accommodation may be to redefine equity. If equity is defined in terms of service consumption, such as either transit patrons or fare revenues, programmatic distributional equity goals do not directly conflict with transit performance goals. More often, however, distributional equity is defined in terms unrelated to transit service, such as number of transit operators, population, or tax revenues collected. In such cases, performance-based transit subsidy programs are handicapped from the outset.

SURVEY OF STATE TRANSIT SUBSIDY PROGRAMS

A survey of state transit subsidy programs was conducted for North Carolina as part of the development of a performance-based transit operating subsidy program for that state. This survey found that the role of performance monitoring in state transit finance programs varies significantly from state to state. In 6 of the 16 states surveyed, we found that performance measurement and monitoring plays a primary or secondary role in the allocation of state funding for transit operations. In four additional surveyed states, performance monitoring plays only a minor role, or no role at all, in the allocation of transit operating funds. And four surveyed states provide no state funding for transit operations.

Time and budget limitations, unfortunately, prevented a census of the practices in all 50 states, so the sample of sixteen states was selected using two criteria.

1. States with large metropolitan areas and many public transit systems (such as Pennsylvania) were emphasized over more rural states (such as Idaho); and
2. As this research was to assist North Carolina in developing a new operating subsidy program, states in the southeast (such as South Carolina) were emphasized over states in other parts of the country (such as Arizona).

Each survey consisted of a 30- to 90-min telephone interview with the state official (usually a manager in the public transportation section of the department of transportation) directly responsible for the administration or funding, or both, of public transit. The respondents were queried on (*a*) whether their state subsidizes public transit operations, (*b*) the history and structure of the operating subsidy program, (*c*) whether and how subsidy allocations were linked to transit performance, and (*d*) the nature of political support for or opposition to performance-based operating subsidies.

The results of this survey are summarized in Table 2. Note that, with the exceptions of the less urbanized, southern states of Alabama and Louisiana, all of the remaining states subsidize public transit. Among the states actively monitoring transit system performance, three general approaches to motivating improved performance have been adopted.

1. Five states directly link some measure(s) of transit performance to allocations: Indiana, Florida, South Carolina, California (Los Angeles area only), and Michigan.

The proportion of the total state program allocated on the basis of performance varies significantly, from nearly 40 percent in Indiana to about 1 percent in Michigan.

2. Three states use performance audits to push systems toward improved performance: South Carolina, California, and Wisconsin.

Though the audits are not directly linked to allocations, states can reserve the right to withhold funding if audit recommendations are not followed. Further, these states have found that the publicity generated by the audits powerfully motivates systems to improve performance.

3. Four states use performance thresholds to qualify systems for state assistance: Indiana, California, Wisconsin, and Michigan.

To be eligible for funding, operators are required to meet or exceed farebox ratio, operating ratio, and/or local match.

Three Case Studies

Given this overview of the transit operating subsidy programs in the 16 surveyed states, the programs of 3 states are outlined below in more detail to indicate how the imperative of distributional equity takes precedence over and shapes performance-based allocation programs.

California

State support of public transit in California began in 1971 with the passage of the state Transportation Development Act (TDA). The TDA program, which is the largest state transit finance program in the United States, allocates about $750 million per year and is funded by 0.25 percent of the state sales tax. Funds can be used for capital or operating expenditures, but with few exceptions cannot cross county lines; in other words, funds must be expended in the

TABLE 2 Comparison of State Allocation Methodologies

State	Cap Funds	Oper Funds	Allocation Method	Track Performance?
Alabama	No	No	N/A	No
Arkansas	Yes	No	N/A	No
California	Yes	Yes	Population + Performance	Yes
Connecticut	Yes	Yes	67% of Operating Deficit	Yes
Florida	Yes	Yes	Population + Performance	Yes
Georgia	Yes	No	N/A	No
Indiana	Yes	Yes	Base Allocation + Performance	Yes
Louisiana	No	No	N/A	No
Michigan	Yes	Yes	Operating Deficit Based	Minor
North Carolina	Yes	Yes	Base Allocation + Performance	Yes
Pennsylvania	Yes	Yes	Operating Deficit Based	No
South Carolina	Yes	Yes	Population + Performance	Yes
Tennessee	Yes	Yes	Population	No
Texas	Yes	Yes	Population + Density	Yes
Virginia	Yes	Yes	Operating Deficit Based	Yes
Wisconsin	Yes	Yes	42% of Operating Deficit	Yes

same county in which they are collected. In rural counties (less than 200,000 population), program funds can be used for streets and roads if the county can demonstrate that there are "no unmet transit needs that are reasonable to meet" in that county (*4*).

In 1978, two performance criteria were attached to allocations: (*a*) systems were required to meet a minimum farebox recovery requirement to qualify for funding and (*b*) all recipients were required to have triennial performance reviews by outside auditors. Beyond these two eligibility requirements, however, all TDA funds are allocated based on geographic criteria without regard to either financial need or transit performance.

1. *Geographic equity.* In most cases, funds must be collected and expended in the same county.
2. *Cost-effectiveness.* All program funding is withheld if an operator fails to achieve a minimum specified farebox recovery ratio.
3. *Geographic equity.* Outside of Los Angeles County, the funds collected in each county are distributed to transit operators in that county based on the relative share of service area population:

(county revenues) * (system service area population)/(countywide service area population)

In Los Angeles County only, funds are distributed to operators as follows:

–*Operator-Based Equity.* One-half of countywide funds are distributed based on each operator's share of countywide transit route mileage:

(county revenues) * (system regular route miles)/(countywide regular route miles)

–*Cost-Effectiveness.* One-half of countywide funds are distributed based on each operator's relative farebox recovery ratio:

(county revenues) * (system fare revs/sys oper cost)/(cnty fare revs/cnty oper cost)

The farebox recovery requirement in the statewide (outside of Los Angeles County) cost-effectiveness criterion listed above is a threshold; if the threshold is barely met or exceeded by 100 percent, funding does not vary. If an operator falls below the standard, funding is cut off. In practice, however, this penalty is so severe that no operator has ever been fully penalized. In addition, the farebox recovery threshold has been repeatedly lowered over the years and numerous exceptions to the requirement have been added. For example, liability insurance premiums and all costs and revenues from new or realigned routes are excluded from the calculations for 3 years (*7*).

In contrast to this farebox "death penalty," the performance audit part of the program has proven to be quite successful. As in South Carolina, the triennial performance audits are conducted by private consulting firms procured by the state or local metropolitan planning organization through competitive bids. Transit system managers have some control in defining the scope and focus of the performance audit, though all audits must report on the annual trends of a uniform set of performance indicators. If any deterioration in performance is noted, the auditors are to identify the causes and, in consultation with the transit manager, make recommendations for improvement. The transit system then has 3 years to act on the recommendations in the audit. In addition, the audited operators are required to discuss the report, along with any proposed remedial actions, with a performance committee composed of peer operators, regional planners, and state representatives.

While transit managers sometimes complain of outside interference, the performance audits are often welcomed as a useful management tool. In this way, the audits reflect a broad range of uses of performance measurement, such as internal management evaluation, system report card, and guidelines for funding allocations. In addition, a recent study of transit performance programs by Fielding (*8*) concludes that performance audits are the most successful examples of funding agencies effectively motivating improved transit system performance.

Overall, the TDA program in California strongly favors lightly patronized suburban transit systems over heavily patronized central city systems. The return-to-source and service area population allocation criteria in particular undermine the performance-based eligibility requirements by favoring service-ineffective systems with low per capita levels of ridership (*4*).

Pennsylvania

Pennsylvania was one of the first states to adopt a performance-based allocation program for public transit. The program, which began in 1980, distributed 90 percent of state transit funding on the basis of need and 10 percent on the basis of performance. This program, which was scrapped for fiscal year 1987, was organized as follows.

The need component consisted of a percentage (60 percent in 1980) of an "allowable deficit" less federal aid. The allowable deficit was determined by estimating "allowable costs" (previous year's deficit times an inflation factor) less "required revenues" (defined in 1980 as a farebox recovery of 40 percent):

Allowable costs = previous deficit * inflation index

Required revenues = minimum revenue/cost ratio of 40%

Allowable deficit = allowable costs − required revenues

90% of state subsidy = allowable deficit * 60%

The performance-based component provided an additional 10 percent incentive, based on four performance indicators: (*a*) cost per hour, (*b*) revenue per hour, (*c*) ridership per hour, and (*d*) revenue-to-expense ratio. For the first three indicators, transit systems were not compared to a peer group or to transit operators statewide; each operator was instead required to maintain or improve performance from the previous fiscal year. For the fourth measure (revenue-to-expense ratio), operators were required to meet or exceed an annually established statewide standard (40 percent in 1980). Initially all four measures were weighted equally at 2.5 percent apiece.

The performance measures had been explicitly structured to avoid peer group or statewide operator comparisons in an effort to forestall objections over the invalidity of comparisons between systems. Only the recovery ratio was applied as a single statewide measure, which was proposed as both a measure of local support and of cost-effectiveness. This did not, however, prevent strong local opposition from areas with systems penalized by these performance measures. Penalized operators complained that the structure rewarded previously inefficient systems that had a lot of waste to cut, while well-run systems had less room for improvement. Fur-

ther, systems that realized large performance improvements got no more than systems with no change in performance; this encouraged systems to focus on small incremental improvements each year, instead of major improvements in any one year.

The Pennsylvania program was complex and cumbersome to administer. Frequent disagreements arose over the accuracy and uniformity of the data used to calculate both need and performance. Pittsburgh and Philadelphia opposed the program because it was easier for small agencies to qualify. The state legislature was uncomfortable with the creation of "winning" and "losing" systems. The program never stabilized; the performance standards were weakened several times before the program was eliminated in 1987 (*8*).

Currently, Pennsylvania allocates funds based on each system's historical share of state funding. For fiscal year 1994, $237 million was distributed over 21 systems, though the large systems in Pittsburgh and Philadelphia receive approximately 95 percent of all allocations.

In transit operator-based equity, allocations to operators are based on each operator's share of statewide appropriations during the 1991 fiscal year. This formula is fixed and does not vary by performance, ridership, service, or financial need. Each system's share is locked in for the indefinite future. This formula reflects both the strong local opposition to performance-based allocations and the desire of operators and their political allies to make funding as predictable as possible. This formula, however, does not account for changes between systems over time, nor is any funding available for systems created after 1990.

Altough the performance-based allocation program of 1980 to 1987 was popular with state transit officials, it was bitterly opposed by transit operators, who objected to the variability of funding from year to year. State transit officials would like to return to a program in which 10 to 20 percent of allocations are based on cost and revenue performance measures, but no current plans are in the works (J. Dockendorf, Bureau of Public Transportation, Pennsylvania Department of Transportation, personal communication 1993).

Michigan

In the early 1980s, Michigan developed a very complex operating subsidy program using 47 indicators. So many countervailing indicators were used that significant changes in overall performance were rarely reflected in allocations. The system was extremely complex and disagreements over the accuracy and comparability of the data and measures were common, causing the program eventually to be abandoned.

Michigan currently uses a deficit-based methodology to allocate state operating funds. Operating assistance comprises about 70 percent of the state program; for fiscal year 1993, this 70-percent share amounted to $103 million (less administrative costs and debt service). Rural (FTA Section 18) systems can receive state subsidies of up to 50 percent of eligible operating costs, while urban (FTA Section 9) systems are eligible for state funding of up to 40 percent of operating costs. This state assistance, which applies to both fixed route and demand-responsive transit, is subject to a growth rate equal to the estimated percentage increase in revenue for the state transit operations fund. In other words, no individual system can receive a proportional allocation increase greater than the proportional growth of the entire state program. Because of the economic recession, however, state transit assistance has not increased for the past 3 years, and allocations have been relatively constant.

All systems are guaranteed a minimum allocation equal to the fiscal year 1989 funding levels. Beyond this, there are two performance components to Michigan's program.

1. *Program effectiveness.* To be eligible for funding, each system must have a local assistance-to-state assistance ratio equal to or higher than it did in the 1989 fiscal year.
2. *Program effectiveness.* Approximately 1 percent of the program ($1 million) is allocated based on each operator's local commitment:

$1 million * (system local funds/system state funds) * system oper costs)/(statewide local funds/total state funds) * (state oper costs)

3. *Service effectiveness.* Approximately 1 percent of the program ($1 million) is allocated based on each operator's share of statewide fare revenues (which function as a proxy for attraction of paying passengers):

$1 million * (system fare revenues/statewide fare revenues)

In addition, transit performance measures are collected by the state and reported to the legislature. State officials report no plans to change the current program, though a proposal sponsored by Michigan transit operators and opposed by state transit officials is under consideration by the legislature to transform the current program into a simple "block grant"-type allocation program for transit and to eliminate the program and service effectiveness criteria entirely (B. Beachler, Michigan Department of Transportation, personal communication 1993).

Summary

A clear lesson from these case studies is that programmatic stability cannot be achieved without a satisfactory accommodation of distributional equity in a performance-based allocation program. In states that link transit performance with state funding, the state transit officials we spoke with emphasized the importance of balancing the goals of improved transit performance with the imperative of distributional equity; successful programs, they say, must effectively strike such a balance. Further, and perhaps not surprisingly, they stressed the importance of building a consensus among transit operators in developing even a small performance-based component to a state operating subsidy program. Most transit managers plan on 3- to 5-year budget projections, and to them any state funding program must be predictable in the short run.

"PROBLEM" OF DISTRIBUTIONAL EQUITY

Transit operators receive operating subsidies from a variety of sources: local, state, and federal. Most of these funds are distributed by formula to insure distributional equity. Accordingly, the influence of any performance-based allocation program on transit operator behavior will depend on the size of the performance-based program relative to all of the other subsidies received.

Consider a transit system receiving $1 million in combined local, state, and federal operating subsidies distributed on the following basis: (*a*) service area population 45 percent ($450,000); (*b*) service area population density 25 percent ($250,000); (*c*) annual vehicle

miles of service 25 percent ($250,000); and (*d*) operating ratio (performance-based allocation) 5 percent ($ 50,000).

In this example, the majority of subsidies (70 percent) are population based and are not directly related to the transit system or its performance; if costs, ridership, or fare revenues go up or down, the subsidies do not change. The next largest share of subsidies (25 percent) encourages systems to offer as much service as possible, regardless of whether this service attracts riders. In contrast, the performance-based allocation encourages systems to attract both passengers and income, and to contain costs; this allocation accounts for only 5 percent of all revenues.

In this hypothetical example, the transit system has little motivation to attract riders and operate full buses. The operator would benefit from increasing vehicle service miles that captured few additional riders (25 percent of subsidies), even if these service expansions lowered the system's operating ratio. Thus, depending on the combined distribution of all operating subsidies, improved transit performance would be either encouraged or discouraged. This, then, is a key obstacle to effective state performance-based allocation programs: the nonperformance-based allocation formulae (which account for 95 percent of the allocations in example above) undermine and/or contradict the performance-inducing part of the program.

There are three basic philosophical approaches to equitably distributing transit subsidies. These three approaches are differentiated primarily by who is viewed as the principal beneficiary of transit subsidies: voters and/or taxpayers, transit operators, or transit passengers. Distinguishing among these three general approaches is important, because most transit subsidies are allocated on the basis of distributional equity and not performance.

When voters and/or taxpayers are viewed as the principal beneficiaries of transit subsidies, allocations are commonly based on (*a*) each transit system's service area population, or (*b*) the proportion of state tax revenues generated locally. Such approaches are consistent with the district-based structure of legislatures and councils, are congruent with the principles of local home rule, and frequently result (as in California) in stable long-term programs. Allocating funds based on population or tax collections, however, does little to motivate systems to increase ridership and can penalize systems with high levels of ridership, since greater per capita ridership equates to lower subsidies per passenger. Under a return-to-source tax revenue plan, rapidly growing areas can benefit from increased funding at the expense of economically depressed areas.

When transit systems are treated as the principal clients of transit subsidy programs, funds are commonly allocated (*a*) on the basis of service produced (such as vehicle service hours or route miles) or (*b*) on the basis of financial need (such as each system's share of the statewide unfunded deficit). Such programs are popular with transit managers because they can ease budget deficits and they reward service production. And, accordingly, service-based funding encourages operators to increase the level of service provided. Such need-based allocations can, in the short-term, eliminate service cutbacks, but financial need-based allocations can reward high deficits and poor financial management, which discourages both cost-efficiency and cost-effectiveness. And, by favoring service produced over service consumed, service-based allocations can discourage service effectiveness by encouraging service expansions without regard for the additional riders attracted.

Finally, when transit patrons are viewed as the principal beneficiaries of transit subsidies, allocations can be made based on (*a*) each operator's share of statewide transit ridership, or (*b*) each operator's statewide share of fare revenues (which equally matches each rider's fare contribution). Such approaches directly reward systems for attracting riders, and each transit patron statewide benefits equally from the state program. Fare revenue-based allocations encourage systems to attract paying customers, which can both increase total transit ridership and reduce net operating deficits. Unfortunately, distributional equity programs based on transit patrons are the least common and are often only small parts of much larger programs. Such programs tend to favor systems with high levels of transit ridership, and this proves unpopular with elected officials and transit managers in areas with poorly patronized systems.

Each of these three approaches achieves a different type of distributional equity: geographic parity, parity among and between transit operators, and parity among and between transit passengers. And each of these general approaches encourages and/or discourages transit performance differently. Whereas passenger-based equity approaches are clearly most consistent with performance goals, they are the least likely to be adopted. This is because they benefit a less influential constituency (transit patrons) than either the transit operator-based approaches (which most directly benefit transit managers, unions, and boards of directors) or geographic-based approaches (which are favored by legislators and voters). And without a passenger-based approach to distributional equity, a performance-based transit subsidy program, regardless of which performance measures or allocation methods are chosen, is not likely to affect transit performance.

CONCLUSIONS

A number of studies during the 1980s argued that the structure of the federal transit finance program strongly influenced transit operator behavior and discouraged improved performance (*9–11*), but there has been little research on the influence of growing state transit subsidy programs. And while the TRB has recently published a study of the growth performance-based transit subsidy programs (*12*), there has yet to be a systematic study of the effects of these programs on transit system performance. This paper has attempted to bridge this gap in the literature by outlining the political constraints on performance-based transit subsidy programs.

It is clearly possible to define and measure the performance of public transit systems. Further, the national trends in transit performance have not been encouraging for many years. While total ridership has held steady or increased on most systems over the past 20 years, most standard measures of performance (such as cost per passenger or passengers per vehicle hour) on most transit systems have been deteriorating. These sobering declines in productivity, however, are explained mostly by things outside of the control of transit managers: the declining cost of owning and driving automobiles, relative declines in central city population and employment, and the continued growth of sprawling, auto-based suburbs that are increasingly difficult to effectively serve with traditional fixed-route, fixed-schedule public transit.

But, whereas most performance declines are the result of factors exogenous to transit systems, some systems are clearly better managed than others. These systems keep labor costs tightly under control, operate well-maintained buses that have few accidents, and adroitly deploy services to attract the most patrons with the fewest vehicles. Transit-funding agencies, such as states, want to encourage this type of high-performance transit service.

But transit subsidy programs that effectively motivate transit systems to improve performance have proven elusive. This is because there are at least two ways to define successful state transit subsidy programs. Programs that have been most successful at motivating transit systems to improve performance have frequently proven programmatic failures: controversial, unstable, and short-lived. Consensual, stable, long-lived programmatic successes, on the other hand, frequently have little relation to system performance.

This paper has suggested that one strategy to overcome the "program versus performance" contradiction would be to make the transit passenger (instead of the geographic region or the transit system) the equity focus of the subsidy program. To do so, however, would be no simple task; it would require overcoming established political constituencies that have defined the politics of transit finance for decades.

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Measuring Impacts of Transit Financing Policy in Geopolitical Context: Montreal Case

ROBERT CHAPLEAU

Redistributive effects of transportation networks are difficult to appreciate with traditional models. Specifically, in a geopolitical context, such as the Montreal case in which the transit fare deficits are absorbed by local municipalities, there is a substantial disparity between funding allocations based on where riders live versus where they use the transit system. The actual research project suggest a new methodology articulated on processing origin and destination survey data with a totally disaggregate approach. The method calculates, for every transit line and bus route, transit consumption in terms of passenger kilometers traveled by respective municipality residents. A spreadsheet is then developed for allocation of costs and revenues against a suitable measure of direct benefits within a multinetwork, multimodal, and multi-institutional framework. In the Montreal context, economic distortions (typically, suburban riders being subsidized by the core city residents) have been observed with the studied (1987) fare-subsidy structure.

The greater Montreal area (GMA), composed of more than 100 municipalities that collectively make up a population of approximately 3 million, is served by 21 small intermunicipal transport corporations (CIT) in addition to three large transit operators (Figure 1). They are:

- STCUM: Montreal Urban Community Transit Corporation, which serves 28 municipalities on the central Montreal Island;
- STL: Laval Transit Corporation, which serves the city of Laval uniquely; and
- STRSM: Montreal South Shore Transit Corporation, which serves eight suburban municipalities on the South Shore.

Transit is funded according to the following ratio [using 1987 data, (*1*)]; fare revenues provide approximately 40 percent of the operating expenses, government subsidies provide approximately 35 percent, and the local municipality's contribution is 25 percent. This local contribution is obtained from taxes, which are for the most part based on land and property values. A generic problem arises from this context. When residents use transit networks outside their own municipality, there are economic impacts that are not necessarily compensated by reciprocal trips.

The topics addressed in this paper deal with the design of a methodological approach to measure urban travel demand (transit usage) in a multinetwork, multimodal, and multi-institutional environment. Two distinct problems arise from this approach: the measure of benefits, related to an urban transport system according to different categories of beneficiaries [direct (transit riders), indirect (employers, businesses), and nonusers (car drivers and passengers)] and the allocation of costs and revenues (fares, subsidies).

A classic informational setup, typical of the urban transport system planning approach, is built around territorial, network, and travel demand data. In the Montreal case, origin-destination (O-D) surveys undertaken in 1982 and 1987, with an average 5 percent sampling of households, are used to characterize O-D trips by mode (car, transit), purpose (work, study, other), geopolitical linking of trip origin, trip destination and residence, time of day (peak, off-peak), gender, and age (reduced fares). All transit networks and modes (train, subway, surface) are coded into a transit assignment framework. The assignment software used is Model for the Disaggregate Analysis of Urban Transport Itineraries (MADITUC), which has the ability to process disaggregate and observed trip data.

The experiments conducted with these planning tools have demonstrated that the Montreal Urban Community (MUC) suburban riders consume a significant amount of passenger kilometers on the core transit network, without any apparent economic compensation. With the objective of calculating the redistributive effects of the actual fare-subsidy structure, a spreadsheet model has been developed to test different allocation scenarios.

The first section of this paper presents the typical transit financing formula, the different actors involved, and the available urban transportation planning system. The next section describes the conceptual framework relative to measuring the benefits of a multinetwork transport system and the related data bases that are processed using the totally disaggregate analysis procedure. Finally, some simulation results are analyzed and put into perspective to obtain a more global and multimodal urban transportation approach.

TRANSPORTATION PLANNING INFORMATION SYSTEM

As outlined in the previous paragraphs, a transit system analysis focuses on the financing (sharing) formula, the different political actors involved, and the tools available to apply some form of a modeling structure among actors and related benefits and costs.

Transit Financing Formula for Montreal Case

The transit financing formula, as it existed and was applied in the 1980s, was mainly developed to cover the operating expenses, thus excluding capital expenditures such as infrastructure implementation (subway, garages) and vehicle acquisition. Every transit authority's operating revenue is derived from its own ridership and

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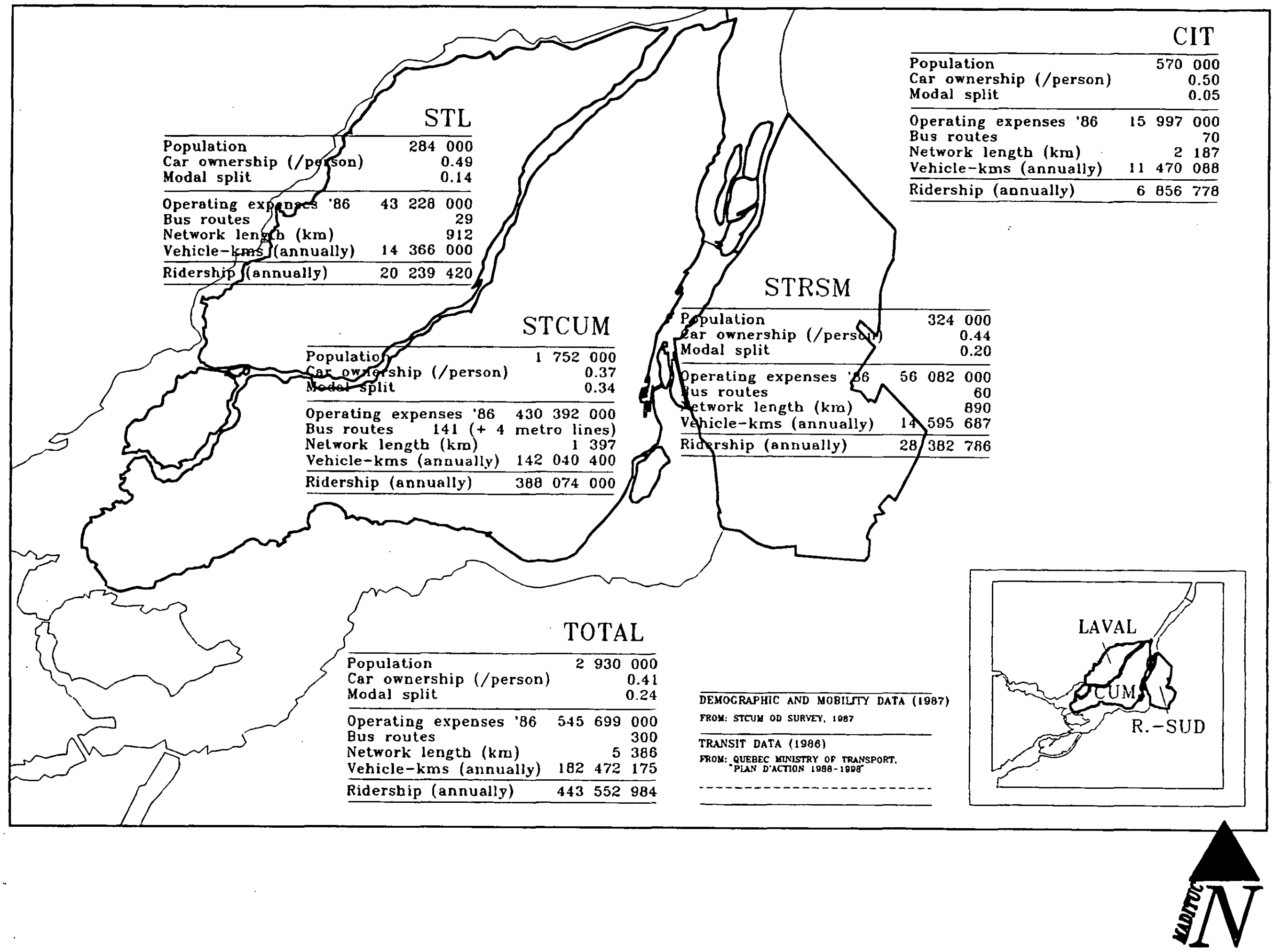

FIGURE 1 GMA transit authorities and related data.

from governmental subsidies, which are roughly proportional to ridership; the difference is compensated by the local government. The simplified model could be seen as:

Municipal share = operating expenses
− ridership · (fare + subsidy)

This equation clearly shows that some conceptual problems may arise when the transit riders are not residents of the authority's governing municipalities or when some transit riders use more than one transit network (trip is twice subsidized by the provincial government).

Actors in Greater Montreal Area

In the GMA, provincial government subsidies are granted to transit operators, or equivalently, to the respective local governments (municipality or urban community) responsible for providing transit services in their territory. Fare integration is considered negligible for our purpose. Every transit authority applies its own fare structure on its network. Typically, in a given network, a single fare permits an unlimited number of transfers from origin to destination.

With this fare structure, typical residents contribute, through taxes paid to their local government, only to the deficit of one transit authority (their own residential authority), even if they are working or studying in another geopolitical territory and, consequently, benefiting from external other transit services.

Depending on the respective consumption of different transit services, some geopolitical areas may suffer from nonsymmetrical situations; this is the case for the central area. Sociodemographic, spatiotemporal trends, as documented by Chapleau, Girard, and Lavigueur (*2,3*) indicate that the more affluent suburban areas are taking advantage of this sociofiscal escape.

Urban Transportation Planning System

The analytical tools available in the GMA are derived from the compilation of 5 percent-sampled O-D surveys undertaken every 4 to 5 years by the STCUM, coupled with the MADITUC system (*4,5*). The related planning information system consists of the rigorous specification of all geopolitical areas in which each transit network is systematically defined in a regional context. O-D trips are validated over the entire regional network, and transit trip

assignment procedures can generate results according to the usual totally disaggregate analytical approach.

The informational setup is composed of the following:

- Precise location data of trip origins and destinations, such as UTM (Mercator) *x-y* coordinates, Canadian postal code (blockface), or small zones (1,500 units for the GMA). These *territorial units*, after being used for precise calculation of walking times and access nodes, are to be aggregated to the most significant level of *geopolitical area*.
- Transit network characterization according to geometry, connectivity, and level-of-service, sufficiently detailed for the estimation of *passenger kilometers and passenger hours* consumed on an average weekday for every transport route and mode (train, subway, bus). About 300 transit lines are coded for the GMA.
- A data file containing all disaggregate O-D transit trip records, according to a data structure enabling the *tracking of every variable* associated with an individual trip. A schematic representation follows (Table 1).

CONCEPTUAL FRAMEWORK

Existing approaches for estimating financial impacts of transit usage are based on classic transit trip assignment procedures. Severe limitations are associated with the use of O-D matrices, particularly because the relationship between trip origin and traveler's residence is fairly weak; CBD origin trips, nonhome-based trips, and a large spectrum of activities are to be discarded in such an analysis. The traditional method lacks feedback mechanism to keep individual relationships among O-D trips, travel modal consumption, and individual personal travel behavior.

Disaggregate Trip-Processing Technique

The totally disaggregate urban transportation modeling approach deals with individual O-D trip records. Each procedure, such as access modeling, path calculation, or network loading, is considered an information additive operator, achieving supplementary interfaces with territorial and network data bases. A schematic of the data and file processing procedures is shown in Figure 2.

The three-step algorithm consists of

1. The calculation of *travel entities* (access and transfer nodes, route links) and *attributes* (walking, waiting, in-vehicle, and total travel times and distances), using the network *access* and trip *validation* (or minimum travel time path computation) procedures for every O-D transit trip.
2. The estimation of *modal usage* (train, subway, and bus) in terms of a transit authority's *ridership, multimodal passenger-hours*, and *passenger-kilometers*, using an *assignment* procedure.
3. *Data aggregation* into a relevant *geopolitical zoning system*, using a retroactive process over the residential zone variable, and the calculation of respective *network* (transit authority) and *mode* consumption by *residents* or any other suitable stratification variable.

Application to Direct and Indirect Transit Users

Instead of simply measuring the benefits from the perspective of the home-based or residential zone variable, the same method could be applied to any other variable or combination of variables. This *process* requires further elaboration on the usual concept of transportation network's benefits and its attribution. For example, *transit riders* benefit *directly* from the transit system; moreover, so does their *employer*, their *school*, or their *shopping center*. In the latter case, the third step, the retroactive process, should be applied to the variable pair *purpose-destination*. Any other study of the redistributive effects of a transit network, considering such variables as age or gender categories, income class, car ownership, and others may be similarly undertaken.

Potential Extensions to Car Users

There is no methodological limitation for considering other dimensions of the urban travel demand. The issues related to transit financing may integrate some measure of *indirect benefits to car drivers*. Two methods of measurement could be applied: (*a*) O-D trip assignment simulation (access, path calculation, network loading) of car users' trips over the regional transit network or (*b*) simulation over the regional road network and the calculation of travel attributes for each geopolitical territory (those corresponding to a transit authority's service area). The choice of method depends on the information system available for the specification of each network's respective interterritorial consumption.

Cost Allocation: Equal Costs and Reciprocity

As already shown, the disaggregate approach has the ability to compute precise travel attributes of individuals who benefit directly or indirectly from the transportation system and to make *relational links among geopolitical areas, transportation networks, and modes* (or routes). At this stage, the method establishes precise measures of travel demand such as volumes, passenger-kilometers, and maximum load, as well as such travel supply characteristics as the

TABLE 1 Schematic Representation of Disaggregate O-D Transit Trip Record

Origin Zone	Destin Zone	Flow	Residential Zone	Travel Purpose	Time Period	Transit Network Path/Time/ Distance
Precise measurement of trip characteristics for every Declared ITINERARY		Weight Expans. factor	Belonging to a Geopolitical Area	Employers Schools Businesses	Maximum Load Peak Off-Peak	Modal consumption Volumes, Pass-kms by Network by mode, by route

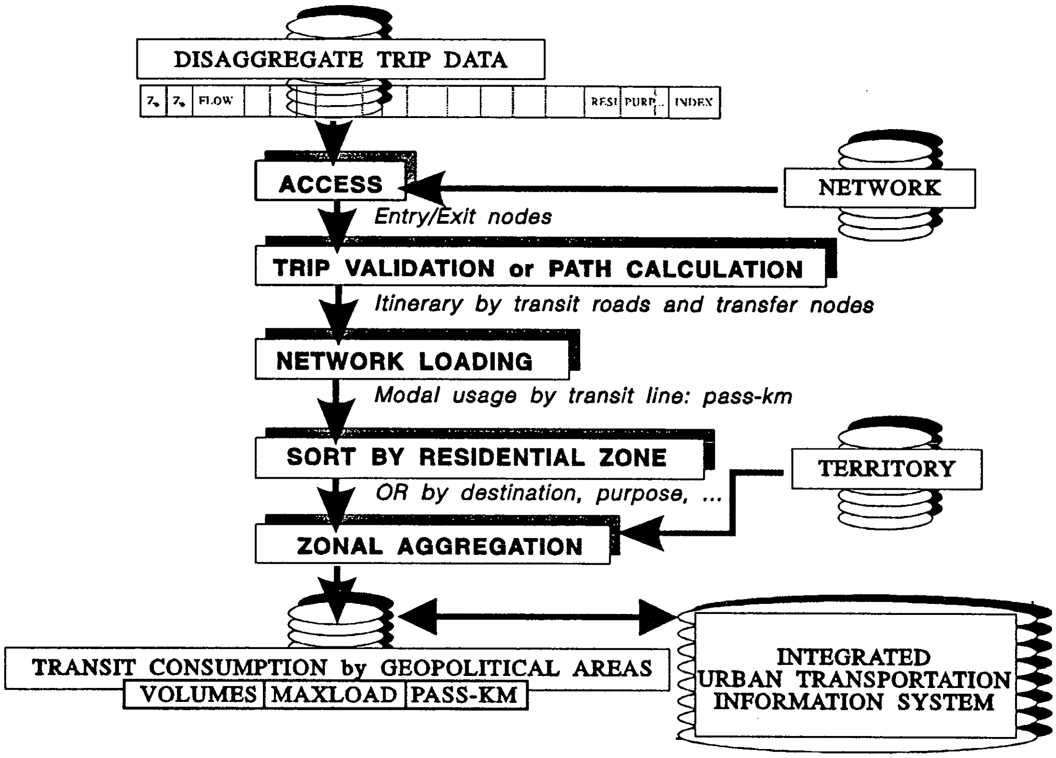

FIGURE 2 Disaggregate processing technique.

number of vehicles required and the number of vehicle-hours and vehicle-kilometers consumed. Classical costing procedures (*6*), often based on UMTA Section 15 data or any other Uniform Information System, are applied to operational data to derive relevant *unit costs*, average fares, and subsidies.

The costing exercise is a critical responsibility for the transportation analyst. Basic assumptions such as the application of the reciprocity principle and cost parity to all geopolitical areas and transportation users are obvious. However, the choice of the cost-fare-subsidy allocation criteria is more difficult. The following model leaves this choice under the control of the analyst. When financial data for each transit authority is available and segmented by operational revenues, total subsidies, and operating expenditures, some choice variables become natural.

INTEGRATED SPREADSHEET

The production of a transit authority is often measured in terms of the amount of vehicle-kilometers offered within a specific territory. A natural performance indicator should, then, focus on the passenger kilometers served. The value of transit usage may be considered proportional to this consumption variable.

Therefore,

Average unit COSTmode = operating expenditures/TOTAL pass-km served

On the other hand, fare revenue and subsidy are typically based on network ridership. For this variable, it is important to distinguish between *person trips* and *network trips* (and even mode or route trip) according to the applicable fare structure. Then:

Average unit FAREnetwork = network revenue/network ridership
Average unit subsidynetwork = network subsidy/network ridership

Application to Montreal Case

The GMA could be seen as being served by four networks. In the situation where only *transit usage* is selected as the basic factor to estimate the monetary value of the benefits generated to the residents of different geopolitical areas, a set of nonofficial data, which reflects the scope of the problem just the same, has been developed for this modeling exercise and is given in Table 2. Figure 3 illustrates the relative importance of transit usage by nonresidents. In the spreadsheet, the data are composed of the following for the 1987 base year.

- Annual financial data, with the distinction between *costs* (annual operating expenditures), operating *revenue*, and annual provincial government's operating *subsidy*. The *deficit*, the difference between costs and revenue + subsidy, is then assumed by the *geopolitical area* responsible for a specific network.
- Weekday transit usage data, derived from 5 percent sampled O-D surveys (STCUM, 1987) processed using the totally disaggregate approach of the MADITUC system over a 24-hr regional network including four subway lines (about 60 stations) and approximately 270 bus routes. Respective mode and network riderships (nonadditive *volumes*) of passenger kilometers traveled by residents of the following four geopolitical areas are calculated:
  - MUC responsible for the STCUM,
  - Montreal's South Shore, a group of eight municipalities managing the STRSM,
  - Laval, a city with the STL as its transit authority,

TABLE 2 Financial and Transit Usage Data (Montreal)

Financial Data ($Millions)*

1987	COSTS	REVENUE	SUBSIDY	MUNIC SHARE
S.T.C.U.M.-Subway(Métro)	296.6			
S.T.C.U.M.-Bus	306.2			
S.T.C.U.M. (All operations)	602.8	206.6	254.9	141.3
S.T.R.S.M.	58.8	20.4	21.7	16.7
S.T.L.	44.1	16.5	14.1	13.5
C.I.T.	21.2	10.9	5.6	4.7
TOTAL	726.9	254.4	296.3	176.2

* non official data

Transit Usage Data

1987	Volumes 24 hrs RESIDENTIAL AREA M.U.C.	S.Sh.	Laval	C.I.T.	Tot.	Pass-km 24 hrs RESIDENTIAL AREA M.U.C.	S.Sh.	Laval	C.I.T.	Tot.
S.T.C.U.M.-Subway	544137	57621	31217	24432	657407	3760747	388612	289612	205055	4644026
S.T.C.U.M.-Bus	825017	16301	15364	8721	865403	3705447	49514	52305	69745	3877011
S.T.C.U.M. (1)	1001776	59341	37397	27027	1125541	7466194	438126	341917	274800	8521037
S.T.R.S.M.	4503	103743	64	1578	109888	28361	889055	213	14183	931812
S.T.L.	4157	143	56255	1731	62286	38712	1556	462167	22229	524664
C.I.T.	965	538	618	19027	21148	24962	9674	7600	354525	396761
All transit authorities	1002487	116164	67454	36760	1222865	7558229	1338411	811897	665737	10374274

Unit Costs ($)

1987	Volumes 24 hrs COSTS	REVENUE	SUBSIDY	MUNIC	per RES RIDERS	Pass-km 24 hrs COSTS	REVENUE	SUBSIDY	MUNIC	per RES RIDERS
S.T.C.U.M.-Subway	451 $					64 $				
S.T.C.U.M.-Bus	354 $					79 $				
S.T.C.U.M. (Sub.+ bus)	536 $	184 $	226 $	126 $	141 $	71 $	24 $	30 $	17 $	19 $
S.T.R.S.M.	535 $	186 $	197 $	152 $	161 $	63 $	22 $	23 $	18 $	19 $
S.T.L.	708 $	265 $	226 $	217 $	240 $	84 $	31 $	27 $	26 $	29 $
C.I.T.	1 002 $	515 $	265 $	222 $	247 $	53 $	27 $	14 $	12 $	13 $
All transit authorities	594 $	208 $	242 $	144 $	144 $	70 $	25 $	29 $	17 $	17 $

- CIT, a group of 21 intermunicipal corporations serving a large number of municipalities on the north and the south shores of the Montreal area.

Accordingly, unit values are calculated for operating costs (average annual unit cost per regular weekday transit rider) and other variables: average annual fare, average annual subsidy, and average local share per rider. A separate column shows a distinct estimate based on the municipal share divided by the number of actual transit riders who are residents of the same geopolitical area. Some interesting facts are derived from the table figures:

- Fare revenues account for only 35 percent;
- Provincial subsidies account for 41 percent of the operating expenditures, and local governments contribute only 24 percent, in comparison to the Toronto case, which has the financing policy of 68 percent-16 percent-16 percent (fares, provincial, local) for operating expenditures. The situation has since drastically changed in Quebec; as of 1992, the provincial government had almost stopped granting its operating subsidies;
- Seventeen percent of the subway ridership and 19 percent of the consumed passenger kilometers are generated by nonresidents of the Montreal Urban Community. Moreover, non-residents contribute to only 11 percent of the total ridership of the STUCM. Consequently, nonresidents are found to travel longer distances at

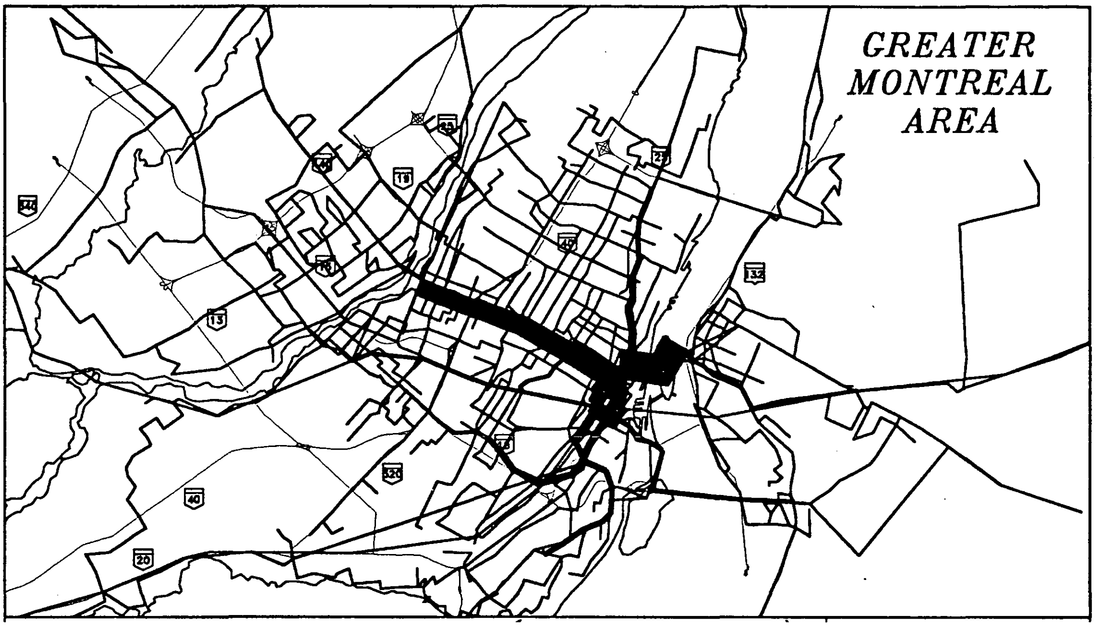

FIGURE 3 Relative importance of transit ridership by nonresidents.

higher speeds, providing proportionally less revenue and thus not contributing to the local municipal share.

Calculation of Geopolitical Financial Distortions

The application of the stated rules provides a means to estimate the relative values of cost, revenue, and subsidy that should be attributed to the residents of every geopolitical area. Table 3 sketches summary results based on the data previously shown:

- *Average annual transit consumption* for a resident of a specific territory. The second row represents the unit cost for a passenger-kilometer per resident. For instance, the MUC residents consume an overall value of $539 million (M) and the STUCM budget accounts for $602M, the difference of approximately $63M equally consumed by the other three areas: the South Shore ($26M), Laval ($18M), and the CIT ($19M).
- *Average annual fare contributed* by each resident. Results show a uniform average fare per passenger-kilometer for all geopolitical areas.
- *Average provincial government subsidy attributed* to a specific resident on the same basis as fare (ridership). Surprisingly, the average subsidy per resident transit rider is minimal for the central area, where the average income is known to be lower by a margin of at least 20 percent. Not surprisingly, the unit subsidy per passenger-kilometer decreases with the travel distance from the CBD.

Finally, the last figures concern the derivation of the fair municipal share, computed from the difference between the costing value of consumed transit by the residents and the sum of fare and subsidy revenues generated by their corresponding transit usage for every geopolitical area. Clearly:

Municipal sharearea = COST − (FARE REVENUE + SUBSIDY)

When consolidating the fair municipal shares for every combination of network and geopolitical area, differences appear between the amount actually attributed to the transit operator and the amount that should be fairly applied to the transit usage. That final amount, called a financial distortion, is negative for the CUM (−$17M) and should be compensated by the other geopolitical authorities at the indicated level.

CONCLUSIONS

This paper has demonstrated a consistent and coherent approach to address transit financing issues in a multigeopolitical urban context using a methodology (totally disaggregate approach applied to home-based O-D survey data) enabling the transportation analyst to take into account a large spectrum of variables and cost allocation scenarios.

When applying a limited-scope cost allocation scenario, that is, considering only transit usage (direct beneficiaries) for the Montreal case, financial distortions were calculated, thus suggesting the creation of a compensation mechanism among the several geopolitical areas of the metropolitan region. In fact, since 1989, there has been a commission called the Conseil Métropolitain du Transport en Commun, grouping the STCUM, the STRSM, and the STL, whose mandate consists of administrating fare integration (regional monthly pass) and some service coordination among the three larger transit operators. The provincial government has contributed a global annual subsidy of $25M for a limited period of 5 years. The proposed analytical methodology, when applied solely to the examination of the transit system of a metropolitan area, takes into consideration about only 25 to 30 percent of the personal motorized trips.

A better knowledge of the multimodal urban transport consumption in a metropolitan area, respective to geopolitical areas and direct-indirect beneficiaries, should lead to a better understanding of the underlying economic issues of transportation networks. How-

TABLE 3 Summary Transit Financial Calculation for Geopolitical Areas

Transit Consumption	M.U.C.	S.Shore	Laval	C.I.T.	Total-GMA
Consolidated TOTAL	539.2	85.5	61.9	40.3	726.9
NET value - network	-63.6	26.7	17.8	19.1	0.0
per resident transit rider					
Unit consumption per rider	538 $	736 $	918 $	1 097 $	594 $
Unit Cons. per Pass-km	71 $	64 $	76 $	61 $	70 $
Unit Fare per rider	186 $	262 $	328 $	422 $	208 $
Unit fare per Pass-km	25 $	23 $	27 $	23 $	25 $
Unit Subsidy per rider	228 $	294 $	317 $	323 $	242 $
Unit Subsidy per Pass-km	30 $	25 $	26 $	18 $	29 $
average F+S per rider	414 $	556 $	645 $	745 $	450 $
average F+S per Pass-km	55 $	48 $	54 $	41 $	53 $

Costs - (Revenue + Subsidy) ($ M)

Fair Municipal Share	RESIDENTIAL AREA M.U.C.	S.Shore	Laval	C.I.T.	Total-GMA
S.T.C.U.M. (Subway +bus)	122.1	4.4	7.3	7.5	141.3
S.T.R.S.M.	0.1	16.4	0.0	0.3	16.7
S.T.L.	1.2	0.1	11.2	1.0	13.5
C.I.T.	0.6	0.1	-0.1	4.1	4.7
Consolidated TOTAL	123.9	20.9	18.4	12.9	176.2
Financial Distortion	-17.4	4.2	4.9	8.2	0.0
Unit local share per rider	124 $	180 $	273 $	352 $	144 $
Unit local share per Pass-km	16 $	16 $	23 $	19 $	17 $

*** unit costs per rider in xx$**
*** annual costs in xxMillions**

ever, from a geopolitical standpoint, it seems that it may take a long time before issues of equity, in a world with sociodemographic and economic disparities spatially exacerbated by continuous urban sprawl and related land use management policy, should suggest to integrate car usage in a multimodal approach to transit system financing.

ACKNOWLEDGMENTS

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Life-Cycle Costing in Support of Strategic Transit Vehicle Technology Decision: Hamilton Street Railway Looks to the Future

SUSAN SHERMAN AND HENRY HIDE

The approach, data, methods, and results of a detailed disaggregate life-cycle costing analysis of transit vehicle operation at the Hamilton Street Railway (HSR) in Hamilton, Ontario, are summarized. The life-cycle costing was performed in 1991 as part of an overall study of future technology, which included particulate-trap-equipped diesel, compressed natural gas, and electric trolleybuses. The study used the HSR's detailed maintenance, fuel, mileage, and other records to obtain base diesel lifetime costs. A combination of internal records and those from manufacturers and other operators were used to forecast lifetime costs of the new technologies. Pollution, noise, transit planning, and other such aspects included in the overall study are not discussed. This analysis indicates that an all-natural-gas fleet would be the least expensive to operate in the long term, with an all-diesel fleet second most economical.

The Hamilton Street Railway (HSR) provides transit services to the Region of Hamilton-Wentworth, Ontario. Located at the western end of Lake Ontario, this city of 440,000 people is approximately midway (by road) between Buffalo and Toronto. This transit company has retained its historical name, despite the discontinuation of streetcar service in the postwar years in favor of electric trolleybuses and, later, gasoline and diesel buses.

In the early 1990s, an aging electric trolleybus fleet and infrastructure forced the Region to decide whether to invest substantially in electric trolleybus service or to move to an all engine-driven fleet.

Coincidentally, HSR was assessing the viability of compressed natural gas (CNG) as a bus fuel by running a fleet of 10 converted diesel buses. This prototype work, begun in 1983, was among the first in North America; it led to HSR, the Toronto Transit Commission, and Mississauga Transit being the first to place a significant order for production for CNG buses (totalling 50 Orion V buses with Cummins engines and roof-mounted CNG tanks) (*1,2*).

The mandate of the Alternative Vehicle Technology Investigation was therefore to study the relative merits of electric trolleybuses, diesel, and CNG buses based on a variety of environmental, economic, and other criteria.

The investigation involved representatives from the HSR, the Ministry of Transportation of Ontario (MTO), and a variety of specialist consultants. A citizen representative was also selected to participate in the study process. MTO participation was both as technical advisors and as providers of subsidy. The MTO's policy of providing 75 percent funding for capital purchases and 19.5 percent funding for operating expenses was considered in the economic evaluation. A special 90 percent subsidy rate for electric vehicle purchases was, at that time, under review.

Cole, Sherman, & Associates, Ltd., 75 Commerce Drive East, Thornhill, Ontario L3T 7N9, Canada.

STUDY APPROACH

HSR was interested in making a decision in 1991 that would serve it through the next 20 years. Rather than considering only what vehicles to purchase this year or next, the question was more fundamental: what kind of vehicle technology should HSR invest in over the long term? This type of decision involves many more considerations than simply a determination of what is most convenient or most cost-effective.

The following criteria were addressed in evaluating the transit options:

- Noise pollution;
- Vehicle emissions;
- Air quality impact;
- Vehicle operating costs;
- Infrastructure costs;
- Availability of vehicles, parts, and energy;
- Special staffing needs;
- Safety;
- Energy cost and availability; and
- Public acceptance.

To maintain the highest possible standards throughout the study, HSR engaged specialist consultants in the areas of public involvement, noise, emissions, air quality, energy pricing, transit planning, cost modelling, and engineering design, so that each of these criteria could be investigated by experts in that particular field.

The approach of the study began with the definition of eight viable strategies for providing transit service in the Hamilton area. In each case, the service level was the same as that currently provided. The eight options were

1. Status quo (except that diesel buses would be equipped with particulate traps.) The 1992 (base year) mix was 45 trolleys, 170 diesel buses, and 25 CNG buses.
2. Option 1, plus extend one trolley line to McMaster University.
3. Option 2, plus extend another trolley line up the "Hamilton Mountain" (actually a section of the Niagara Escarpment).
4. Replace all retiring vehicles with CNG.
5. Replace all retiring vehicles with "improved diesel."

6. Option 1, except CNG replaces all retiring diesel buses.
7. Option 2, except CNG replaces all retiring diesel buses.
8. Option 3, except CNG replaces all retiring diesel buses.

This paper concerns only the cost modeling portion of the study.

APPROACH TO VEHICLE LIFE-CYCLE COSTING

The costs of vehicle ownership are complex and are not readily comparable with one another. One vehicle may have a higher purchase price but may be more fuel-efficient than another. Maintenance costs may be quite different and may have a different pattern over the vehicle's lifetime.

Life-cycle costing seeks to reconcile the differences among alternative vehicle types without losing any of the distinctions. A life-cycle costing table lays out all the expenditures relating to each option in the year in which they occur. Discounting is then applied to the table so that costs relating to different years may be compared on an equal footing.

Any end effects are treated as a residual value at the end of the study period. For example, if one option involved the purchase of a number of expensive vehicles in the last year of the study, the ownership value remaining in those vehicles at the horizon year is considered as a credit to that option. The residual value is determined using straight line interpolation, consistent with the fact that the vehicles are valued at their worth as functioning equipment to provide transit service, rather than their resale value.

Costs to be examined in this exercise include only those that may be subject to variation among the alternative vehicles, specifically maintenance, capital, energy, and infrastructure. Other costs, such as drivers and administration, do not affect the outcome of the study and so were not included in the analysis.

This study used cross-sectional analysis to determine the maintenance costs associated with the vehicles under investigation. Cross-sectional analysis uses many vehicles of different ages to determine the cost profile throughout a vehicle's lifetime. This is particularly appropriate to the Hamilton analysis because there is little difference among the vehicles other than their age. Cross-sectional analysis has the added advantage of being unaffected by inflation or changes in maintenance procedures.

An alternate approach may have been to obtain a picture of maintenance expenditures throughout a vehicle's lifetime. However, it is virtually never the case that every dollar spent in maintaining a vehicle is recorded and categorized. Furthermore, such a dataset could not be completed until the vehicle was retired. Such an approach to obtaining vehicle maintenance histories is clearly not appropriate to this type of study.

The study relied on the Vehicle Maintenance System (VMS) data base installed at the HSR, which made it possible to obtain in electronic format a detailed history of expenditures on each individual vehicle in the fleet, including details of the maintenance activity to date. Data relating to the most recent 12 months were used in the study because they were believed to be most reliable.

The maintenance life-cycle cost model used disaggregated maintenance cost models for the standard diesel bus as a basis for the analysis. The 1 year of available maintenance cost information on the entire fleet provided sufficient data to calibrate a separate cross-sectional life-cycle cost model for labor and materials in each of 15 component subgroups. The subgroups used in the study are given in Table 1. Figure 1 illustrates 1 of the 15 such models developed for the base case.

The cost models were then applied to the three technologies that were the subject of the investigation. Whereas other studies have attempted to derive maintenance costs for new technologies by estimating the total cost variation from the base case, this study benefitted from the availability of 15 different submodels, clearly identifiable by the technical differences among the different vehicle types. Ten categories of maintenance did not vary at all among vehicle types, as indicated in Table 1.

The improved diesel differed from the base case (standard diesel) in only two categories: the particulate trap and the electrical system. Particulate trap maintenance and replacement costs were estimated after discussions with trap designers and test fleet operators. Several categories did not apply to electric trolleybuses at all but were easily adapted to CNG from the baseline diesel costs using technical knowledge combined with HSR experience with the prototype CNG buses.

TABLE 1 Component Groups Used in Maintenance Cost Analysis

	Component
Common to all vehicle types:	Preventative Maintenance Tires, Steering, Suspension Air Systems Brakes Farebox / Communications Service / Cleaning Auxiliary Electrical Systems Body Heating / Air Conditioning
Engine-driven vehicles only:	Transmission, Drive Lines Engine and Accessories Cooling System Fuel System
Trolleys only:	Trolley Lines Electric Motive Power System

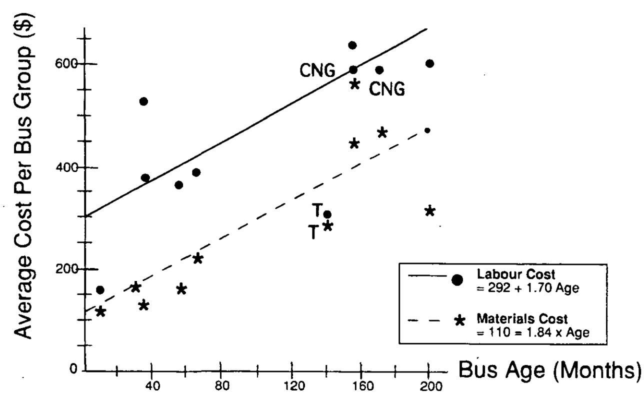

FIGURE 1 Tires and steering maintenance costs (example of derived component group cost relationship).

Unique electric trolleybus component costs were estimated from historical HSR costs for these items, using the experience of other North American trolley operators in determining the maintenance impacts to be expected with more modern equipment. Auxiliary power unit costs were estimated from technical data and limited HSR experience.

Miscellaneous garage costs were determined separately for the three vehicle types, ensuring that engine-related items such as batteries, antifreeze, and engine oil would not be assigned to trolleys. By breaking the costs of maintenance into small subcosts in this way, the total costs were easily assembled and defensible.

CAPITAL COSTS

Capital costs of CNG and diesel buses were obtained from recent HSR bids, which were nearly identical to the study buses in terms of options. The cost of the particulate trap was estimated and added to the diesel bus cost. Adjustments were made to account for inflation and taxes in the base year.

The purchase price of an electric trolleybus meeting the HSR requirements is not easily determined. Few trolleys had been purchased in North America in the previous 10 years, and few bus manufacturers were generally interested in producing them. The cost of an electric trolleybus was estimated using the results of an earlier study (by Cole, Sherman & Associates, Ltd, for the Hamilton Street Railway, unpublished work), as well as published bid prices from all trolley purchases in North America over the past 10 years; the result was verified using component costs.

Trolley purchase price depends heavily on bid quantity because the traction motors are not an "in-stock" item. The price used in this study depended on the assumption that another (larger) trolley user would place an order for new vehicles in the near future, and the HSR purchase could then be "piggy-backed" onto this order to obtain the benefit of a lower price. The estimated purchase prices of the three vehicle types to HSR in 1991 are presented in Table 2. Prices include all applicable taxes and are quoted in Canadian dollars; they all include air conditioning.

ENERGY COSTS

As is the case in many other studies of this nature, the cost of energy is the most significant, as well as the most subject to market fluctuations. For this reason, HSR engaged a specialist consultant in the field of energy pricing who produced high, low, and most likely estimates of energy prices for the three vehicle technologies for the entire study period.

Figure 2 illustrates the forecast energy prices, including all taxes, to the HSR. In reference to Figure 2, it should be noted that

1. All figures arè expressed in Canadian dollars.
2. The cost of compressing CNG is included separately in the analysis, based on known compression energy and the electricity costs included in this paper.
3. The demand charge for electricity was estimated to grow at the same rate as the consumption charge shown included in this paper.

Comparisons among the prices are significantly different in Ontario from what is observed in many parts of the United States, in particular the low cost of natural gas in relation to that of diesel fuel. There are two main reasons for this. Natural gas is abundant in Canada and is supplied through a well established pipeline network. It is not subject to road taxes, because it is not in common use as a vehicle fuel. (This factor may change in the long term but is not expected to do so in the study timeframe.) Diesel fuel is, like gasoline, subjected to substantial taxation from both provincial and federal governments. Energy costs for trolleys included both consumption and demand charges for electricity. Demand charges were forecast to increase at the same rate as consumption charges during the study period.

The fuel (energy) efficiencies of the three vehicle technologies (summarized in Table 3) were determined from a combination of sources:

• Diesel bus fuel economy was derived from HSR fuel usage records, using detailed data to isolate the energy penalties associated with air conditioning (included on 1989 buses) and with the larger 6V92 engines (included since 1987). An additional 1 percent penalty was added to account for the particulate trap. The

TABLE 2 Summary of Vehicle Costs and Life Expectancies

Type	Cost	Life Expectancy
CNG:	$246,000	18 years
Diesel:	$243,000	18 years
Trolley:	$478,000	36 years, with a major refurbishment at about 18 years

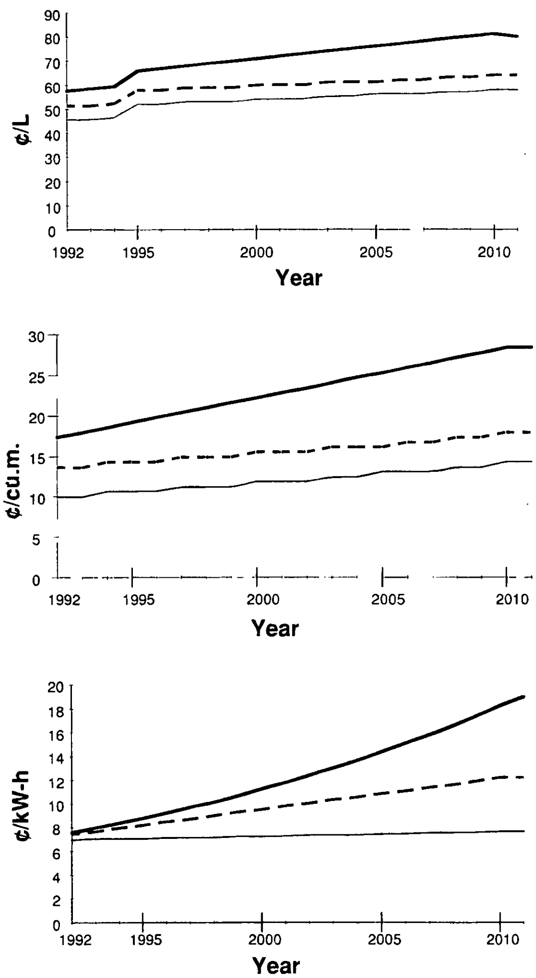

FIGURE 2 Diesel fuel cost projections (¢/L) (*top*); CNG cost projections (¢/m³) (*middle*); electricity cost projections (¢/kW-hr) (*bottom*).

resulting fuel economy was verified by comparison with published figures.

• CNG bus fuel economy was determined primarily from published figures, applying the deviations from "average" calculated for diesel buses to adjust the published figures to the HSR situation. The electricity required to compress the natural gas was taken from HSR records for its existing (prototype) CNG fleet. A premium for air conditioning was applied. Under Options 4, 6, 7, and 8, HSR's significantly increased CNG fleet would warrant the installation of a larger compression facility (see Infrastructure Costs). For these scenarios the compression energy was reduced because of the higher supply line pressure that would then be available.

• Trolley energy efficiency was estimated using HSR electricity charges for 1987 (the last year with uninterrupted trolley service on all routes). Both consumption and demand charges were divided by the number of fleet km to obtain an average. Adjustments were made to account for air conditioning and chopper controls (expected to be a feature of any new trolleys purchased after 1991). Energy efficiency determined in this way included distribution losses under actual HSR conditions and is not obscured by the existence of other power users, such as streetcars or subway trains, using the same distribution network.

INFRASTRUCTURE COSTS

Infrastructure costs were determined following a preliminary assessment of the infrastructure needs for each option and a preliminary design in each case. For the options that included electric trolleybuses, the existing infrastructure would need to be upgraded to allow the newer electric trolleybuses to operate because the older overhead does not provide clean enough power to operate the more sensitive new vehicles. In addition, some of the power supply lines would need to be buried to meet new city standards. Under Options 2, 3, 7, and 8, trolley extensions would be required, including an additional substation. Options 4, 6, 7, and 8 would require new natural gas compression facilities. Options 4 and 5 include the cost of demolishing old trolley lines.

The costs of these requirements were determined in some detail through a preliminary design that estimated numbers of poles, lengths of wire, and the degree to which other utilities would be affected. Construction/demolition costs were estimated, along with a suitable timetable for their implementation, as shown in Table 4. Preliminary design was also carried out on the natural gas compression facility, which is reflected in Scenario 4 Costs in Table 4.

UNDISCOUNTED COSTS (CASH FLOW)

To combine the costs of the different operating cost sources, overheads were determined that would bring the costs to a common denominator. Labor overhead included benefits, as well as direct supervision and clerical staff. Materials and capital costs were adjusted to include the cost of purchasing and stocking.

Figures 3 through 10 illustrate the costs in current dollars involved with operation of the fleet over the study period. Options

TABLE 3 Summary of Energy Usage for HSR Alternative Vehicles

Bus Type	Fuel Economy
Diesel Bus (with Particulate Trap)	71.3 L/100 km
CNG Bus	83.5 m^3/100 km plus compression energy @ • 35.6 kW-h/100 km. (Scenarios 1, 2, 3 and 5) • 22.4 kW-h/100 km. (Scenarios 4, 6, 7 and 8)
Electric trolleybus	308.5 kW-h/100 km plus 317 kW/trolley/year peak demand

TABLE 4 Infrastructure Capital Costs ($ millions)

Scenario	1	2	3	4	5
MAJOR COST GROUP					
1. Bus Maintenance Infrastructure					
1.1. Maintenance Facilities	0.050	0.100	0.100	5.400	0.050
2. Bus Route Infrastructure					
2.1 Sub-station Work	3.072	5.483	7.101	-	-
2.2 New Trolley Overhead	0.295	6.969	12.643	-	-
2.3 Existing Trolley O/H Upgrade(*)	9.552	9.848	9.848	-	-
2.4 Roadworks	0.266	1.148	2.305	-	-
2.5 Removal of O/H	-	-	-	1.909	1.909
Contingency/Engineering	2.647	4.710	6.399	1.461	0.391
TOTAL	15.882	28.258	38.396	8.770	2.350

* Scenarios 2 and 3 have a different feeder arrangement from Scenario 1 because of the new downtown sub-station required in Scenarios 2 and 3.

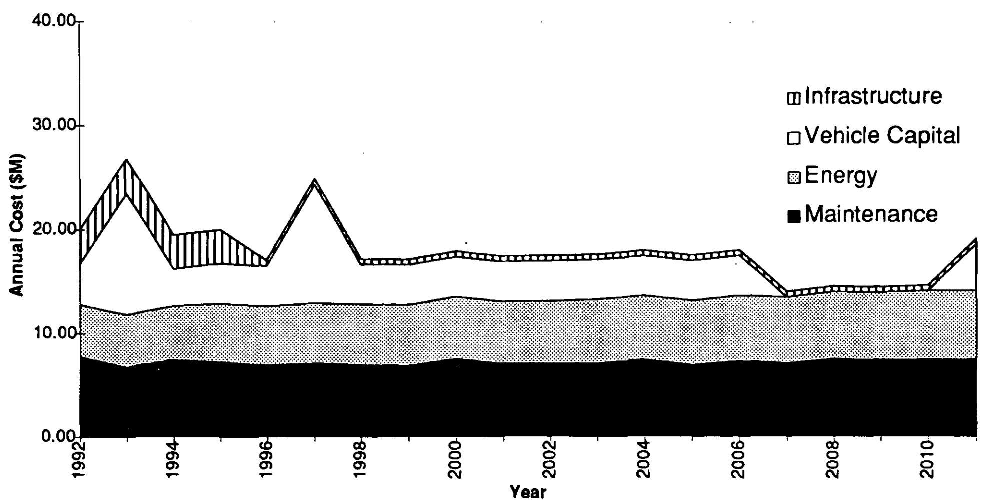

FIGURE 3 Summary of undiscounted costs for status quo scenario.

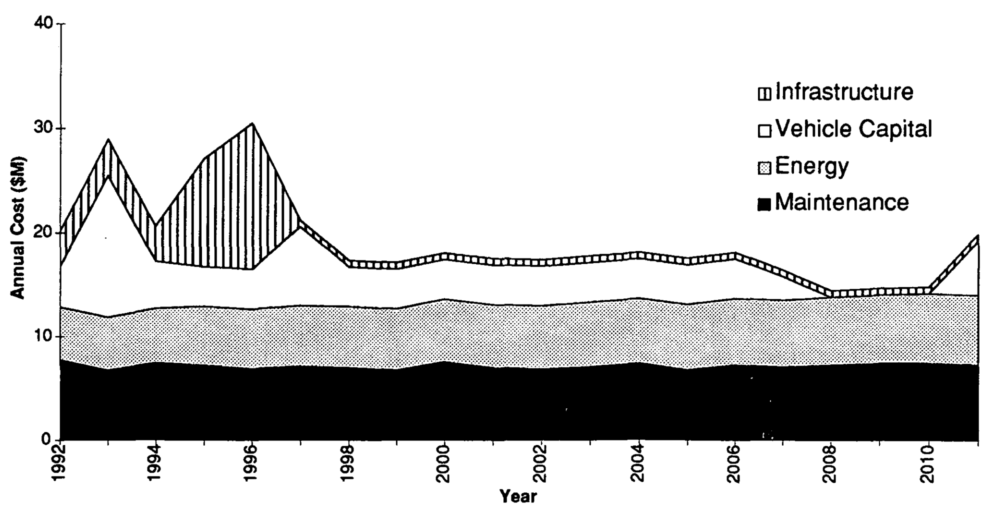

FIGURE 4 Summary of undiscounted costs for King Street Trolley extension scenario.

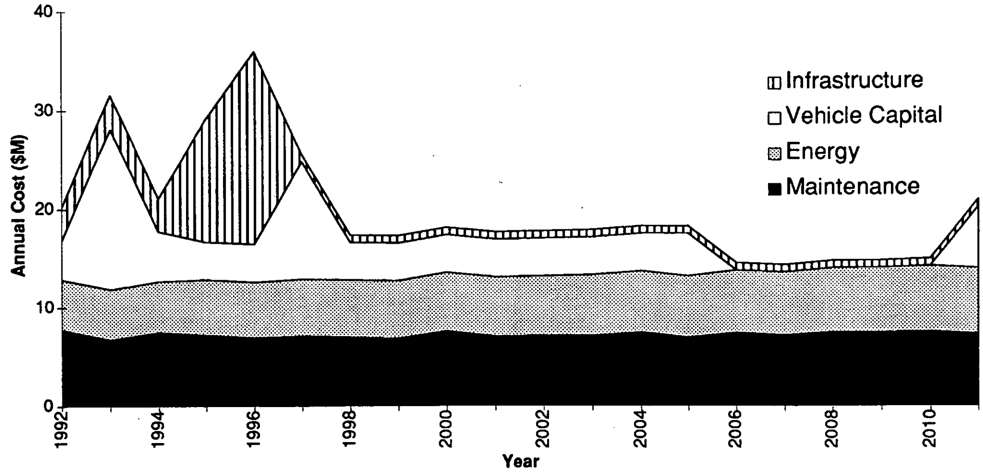

FIGURE 5 Summary of undiscounted costs for King Street and Mountain Trolley extension scenario.

1, 2, and 3 show increasing costs with the introduction of additional trolleys, due to the capital and infrastructure costs. Options 4 and 5 have very low infrastructure expenditures and relatively smooth expenditures on vehicle purchases throughout the study period. Option 4 is also notable for its lower energy costs. Options 6, 7, and 8 are less costly than the corresponding Options 1, 2, and 3 but are more costly than 4 and 5.

The costs were discounted at a rate of 6.8 percent (taken from actual HSR borrowing costs) and then were subjected to a sensitivity analysis that varied the costs in each category according to the uncertainty level associated with it. Figure 11 shows the ranges in total price for the eight options. The dollar amounts in Figure 11 represent the total amount of money HSR would need to put in the bank now to pay for the entire fleet for 20 years.

CONCLUSIONS AND RECOMMENDATIONS

As stated earlier, the life-cycle costing analysis outlined in this paper represents only a part of the study that was carried out for the HSR. For that reason, it would not be appropriate to draw

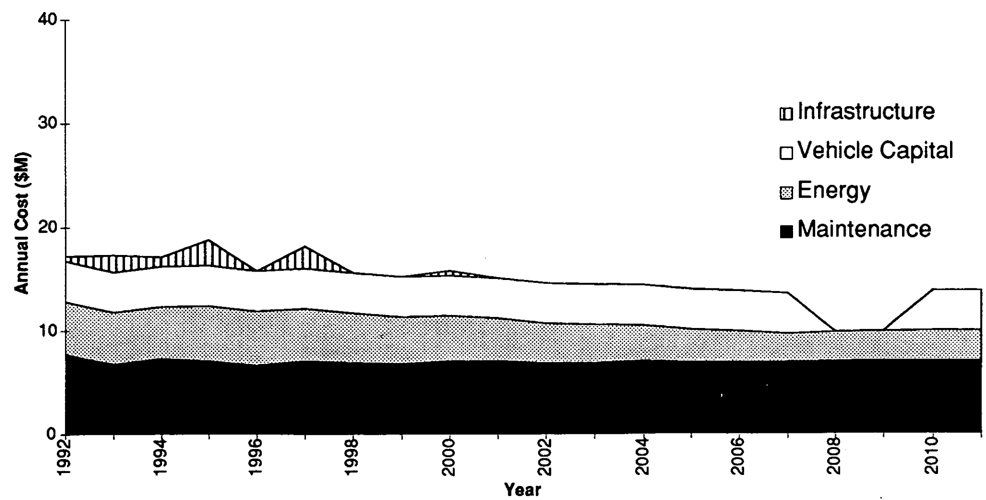

FIGURE 6 Summary of undiscounted costs for CNG bus scenario.

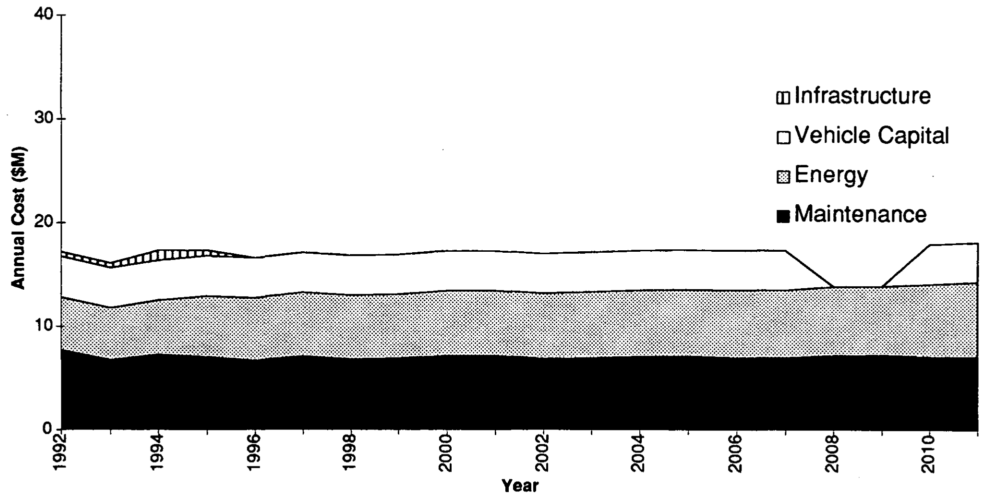

FIGURE 7 Summary of undiscounted costs for "improved diesel bus" scenario.

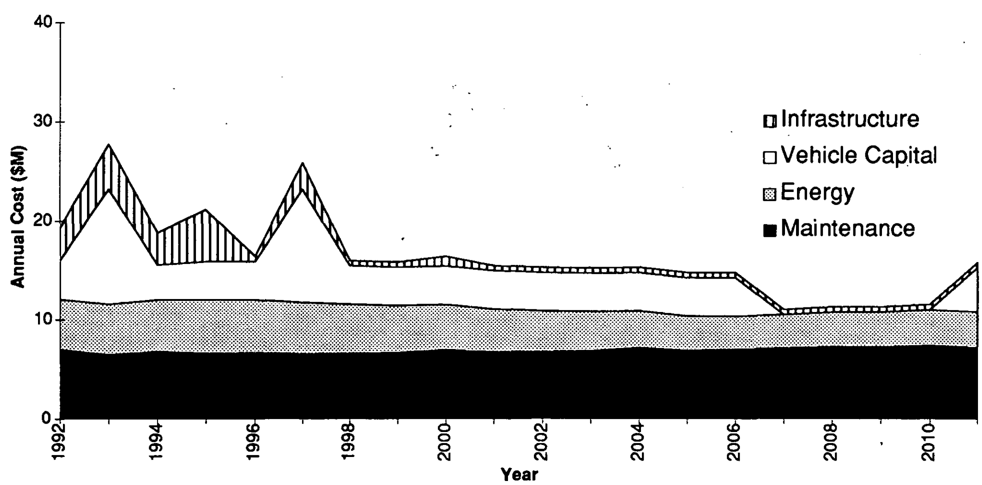

FIGURE 8 Summary of undiscounted costs for existing trolleys plus CNG buses scenario.

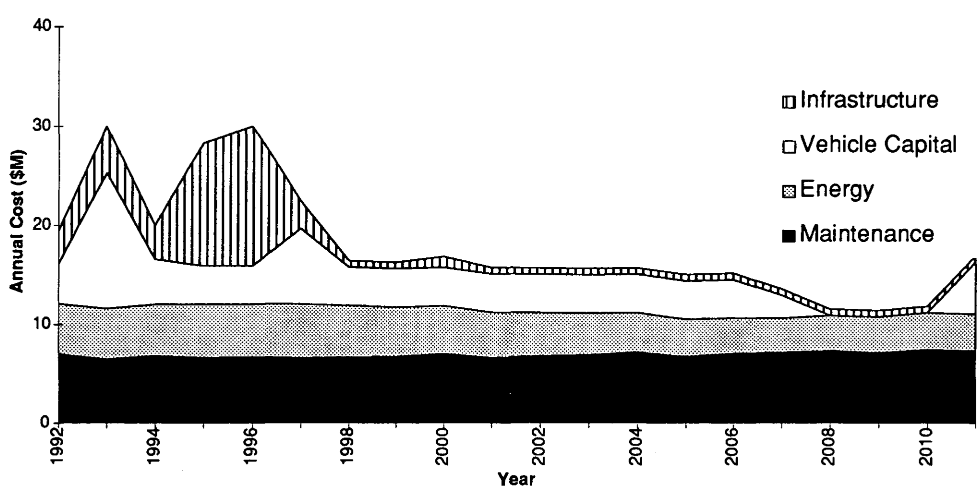

FIGURE 9 Summary of undiscounted costs for King Street Trolley Extension plus CNG buses scenario.

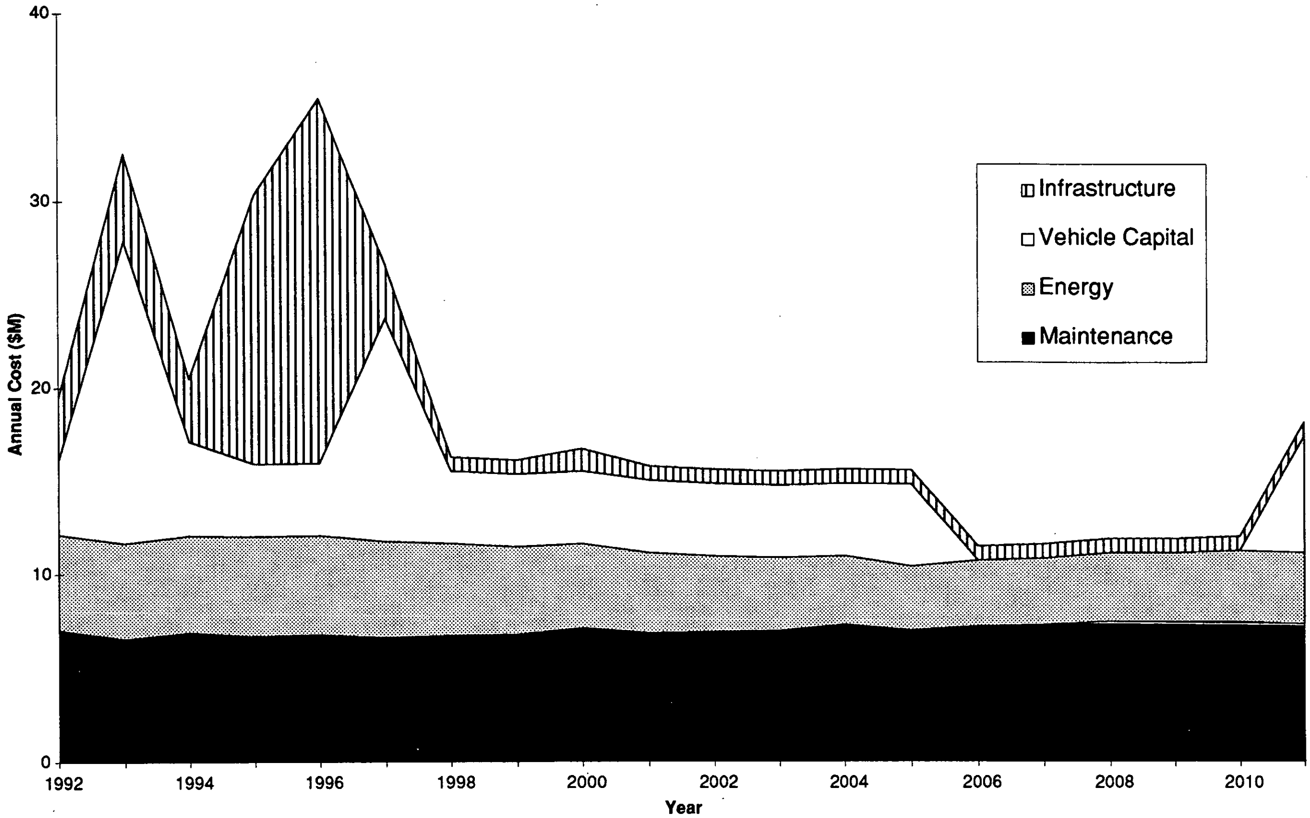

FIGURE 10 Summary of undiscounted costs for King Street and Mountain Trolley extension plus CNG buses scenario.

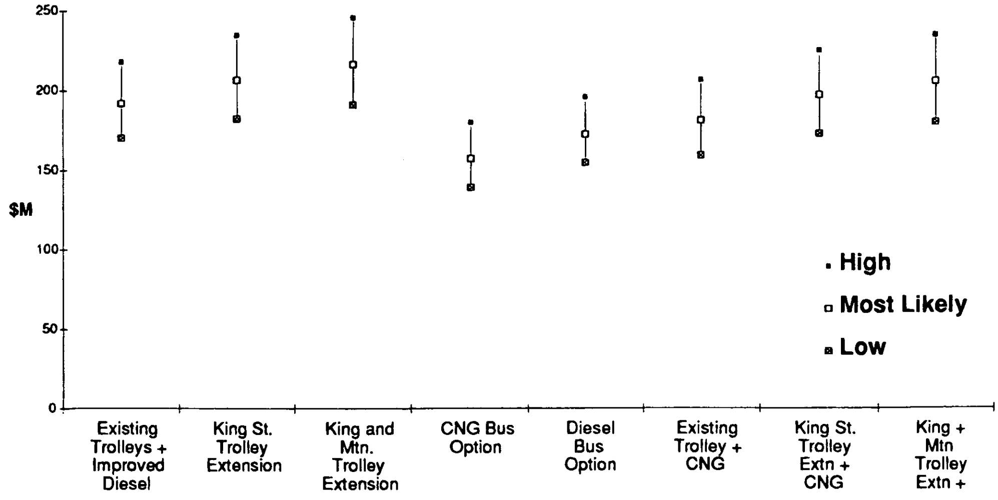

FIGURE 11 Summary of total cost sensitivities (at 6.8 percent discount rate).

a conclusion based solely on the outcome of this portion of the investigation.

If costs were the only consideration Option 4, featuring the CNG bus, would clearly be the choice for the HSR in view of its significantly lower forecast energy costs for the study period. As shown in Figure 6, the real cost of this option decreases with time, as more and more of the fleet is converted to the gaseous fuel. Option 5 is also reasonably priced, primarily because of its lower capital and infrastructure costs in comparison with options that feature the trolleys.

The study was subjected to expert review by a four-member panel. In addition, two series of public involvement sessions sought to acquire Hamiltonians' input into the direction of the study near its beginning and to give the opportunity for them to comment on its findings before a policy decision could be made.

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Incremental Bus Allocation with Competing Mass Transit Services

ISAM KAYSI AND GEBRAN BASSIL

An efficient allocation of fixed equipment among routes in a bus network can be primarily achieved by choosing appropriate headways or frequencies on each route. An interesting exercise arises when the allocation of additional equipment is likely to result in significant ridership attraction from competing services. In this case, models that take into account the operating environment and the nature and extent of competing services on different routes are needed to estimate the demand response to various headways and to allocate additional equipment efficiently. In this paper, a model that allocates buses among various lines based on a realistic correlation between bus headways and demand for bus service is proposed and applied to the case of the bus transit operation in the city of Beirut, Lebanon. The transit authority in Beirut runs a limited bus network with a small fleet that will be expanded on over the course of the coming 2 years. Competing mass transit services in Beirut include private jitneys operating over an extensive network as well as limited private bus fleets. In this paper, the allocation of additional buses in the bus transit operation in Beirut is addressed. A variable demand representation was applied in the bus allocation model and necessitated a data collection effort to identify the potential for ridership attraction from competing services. The model was then applied based on an incremental analysis and with cost-recovery considerations in order to allocate efficiently the additional buses to the existing network.

Given a transit operation with established routes, areas being served, and hours of service, a common exercise for the bus transit planner involves deciding on the levels of service or frequencies that should be provided on each route. This procedure of setting headways or frequencies on bus routes is commonly referred to as the equipment allocation, or fleet allocation, problem. The frequency-setting decision is a complex component in the planning process that involves determination of the distribution of the operating resources over an existing network. In its most general sense, the aim is for an efficient, system-wide allocation of services among routes as well as across time of day (*1*).

An interesting exercise arises when additional equipment is to be allocated and where such allocation is likely to result in significant ridership attraction from competing mass transit services. In this case, models that take into account the operating environment and the nature and extent of competing services on different routes are needed to estimate the demand response to various headways and to allocate additional equipment efficiently. In this paper, a model that allocates buses among various lines based on a realistic correlation between bus headways and demand for bus service is proposed and applied to the case of the bus transit operation in the city of Beirut, Lebanon. The transit authority in Beirut runs a limited bus network with a small fleet that will be expanded over the course of the coming two years. As such, an analysis involving an allocation of additional equipment to the existing network based on potential ridership attraction from competing services and cost-recovery considerations was implemented.

EXISTING APPROACHES TO FLEET ALLOCATION WITH VARIABLE DEMAND

Early approaches to the optimum headway problem assumed demands that did not vary with the headway, although they might vary with time. The objective function commonly related to the minimization of a weighted sum of operators' monetary costs and passengers' waiting time (*2,3*) or the minimization of passengers' waiting time subject to budget or fleet size constraints (*4–6*).

Variable demand formulations of the fleet allocation problem have appeared in a number of studies. For instance, the allocation of buses in networks with overlapping routes based on a minimization of a function of passenger wait time and bus crowding is discussed by Han and Wilson (*7*). The allocation is constrained by the number of available buses and the provision of enough capacity on each route to carry all passengers selecting that route. Although the demand for bus service, expressed by the set of origin-destination flows, is given and assumed fixed in this approach, the number of passengers eventually using each route is variable and depends on the bus allocation, since passenger flows are split between competing routes serving some of the origin-destination pairs. Moreover, Kocur and Hendrickson (*8*) analyze the design of local bus service and determine the optimal route spacing, headway, and fare for three objective functions. The analysis is based on an equilibrium framework whereby transit ridership is sensitive to the level of service provided by the bus system. Finally, Furth and Wilson (*9*) propose a model to allocate available buses between time periods and on fixed routes so as to maximize the net social benefit subject to constraints on total subsidy, fleet size, and levels of vehicle loading. The model formulates the problem of setting frequencies on bus routes as a constrained resource allocation problem with the objective function consisting of maximizing the summation of two distinct components: consumer surplus and transit ridership. Of particular interest here is the fact that in this (nonlinear) formulation, headway is used as the basic decision variable and ridership is expressed explicitly as a function of headway.

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PROPOSED APPROACH TO INCREMENTAL BUS ALLOCATION IN A COMPETITIVE ENVIRONMENT

With fixed bus routes, fares, and speeds, the only operating factor capable of attracting riders from competing services is a change in headways, which can be achieved through fleet allocation. The focus of this paper is on proposing an approach for bus allocation over several routes in a network in the case where the bus service is competing for ridership with other mass transit services. To estimate the demand response to various headways, models that take into account the operating environment and the nature and extent of competing services on different routes are needed. Given the need for a variable demand formulation in the competitive environment being considered, an appropriate form of the demand function that relates ridership on a bus route to that route's headway must be determined.

Problem Context

In the analysis that follows, it is considered that public transit buses will be competing for riders with two other types of mass transit services, namely (a) buses of similar operating characteristics (for instance, private bus operations), and (b) an alternate mass transit service of distinct operating characteristics (for instance, jitney operations). The potential reaction and shift of auto passengers is not considered because the limited improvement in bus level of service is not expected to be sufficient to incur any significant switching from the auto mode.

The analysis will focus on the assignment of additional buses to routes in an existing network to improve on a minimal level of bus service. The assignment will be based on the potential attraction of riders from each of the two competitors.

Possible Models of Ridership Attraction

To estimate the potential attraction of riders from competing services based on the allocation of additional buses, three variable demand models were considered: the trinomial logit model, the nested logit model, and a third model that considers competition with each of the two other modes separately. First, it was concluded that the application of a trinomial logit model (public bus, private bus, or other distinct service) would not have been feasible because the operating characteristics of public and private buses are quite similar, and therefore such a model would violate the independence of irrelevant alternatives (IIA) assumption of the logit model (*10*). Second, it was noted that the application of the nested logit model in the competition context being considered is possible in principle. In such a case, the upper-level choices would include "bus service" and "other distinct service," and the lower-level choices (under bus service) would incorporate both the public and private bus operations. A detailed description of the nested logit model can be found in the work of Ben-Akiva and Lerman (*10*).

A third model, which is being proposed here, considers competition between the public bus operation and each of the two other mass transit services separately. This model stresses the differences in competition mechanisms between public buses and each of the two competing modes, and is useful in cases where including the three modes in the same model is likely to be inappropriate. As such, two different approaches are adopted for computing ridership attracted from each of the two competing services. The proposed model is described in detail next.

Competition with Services of Distinct Operating Characteristics

Logit Model

Demand for bus service is modeled as a choice process in which each individual traveler has the possibility of choosing either bus transit or an alternative, distinct mass transit mode (such as jitneys). The demand function to be used here is the logit model, the most commonly used disaggregate mode choice model and one that allows the analyst to predict the modal choice probabilities for individual trip-makers. The logit model takes the form:

$$P_i(1) = \frac{e^{V_i(1)}}{e^{V_i(1)} + e^{V_i(2)}} \qquad (1)$$

where

$P_i(1)$ = probability of a mass transit rider served by route i choosing bus (mode 1),
$V_i(1)$ = utility of bus transit for population served by route i, and
$V_i(2)$ = utility of alternative mass transit mode for population served by route i (mode 2).

For the population of mass transit riders whose origins and destinations are served by route i, or POP_i, the number of riders who will choose bus transit is given by

$$r_i = POP_i * P_i(1) = POP_i * \frac{e^{V_i(1)}}{e^{V_i(1)} + e^{V_i(2)}}$$

where r_i equals the number of mass transit riders served by route i choosing to use buses and POP_i is the total mass transit-riding population served by route i.

Utility Function

The utility of each of the two competing modes is a function of variables describing that mode (travel time, travel cost, comfort and convenience, etc.) and the individual making the modal choice decision (income, automobile availability, etc.). Assuming random passenger arrivals and constant bus headways, the average passenger wait time at the bus stop is equal to half the headway. As such, the impact of the passenger wait time on demand for transit service can be directly related to bus headway. This suggests the inclusion of a variable relating to bus headway in the utility function. In particular, the utility of bus transit may be represented as:

$$V_i(1) = \theta * h_i + \text{other terms}$$

where h_i is the headway on route i and θ is the headway coefficient in the utility function.

Pivot-Point Form

If the base probability of choosing bus transit is known, and headway on route i is changed by an amount Δh_i from its base value of h_i^0 to h_i, the new probability of choosing transit can be predicted

from the pivot-point form of the binary logit model, which can be derived from Equation 1. This form is (*10*):

$$P'_i = \left[1 + \frac{1 - P_i^0}{P_i^0} * e^{-\theta\Delta h_i}\right]^{-1}$$

In this formulation, P_i^0 is the base probability of choosing bus transit for the population of mass transit riders served by route i; that is, it corresponds to the observed proportion of total mass transit travelers served by route i choosing bus transit. P_i^0 can also be referred to as the base bus transit share. Δh_i is the change in the headway of route i from its base value ($h_i - h_i^0$). *Note that* h_i^0 is the observed, base headway for bus transit on route i whereas h_i is the new headway on route i. P'_i is the probability of choosing bus transit given the new headway h_i. The primary feature of the pivot-point logit model that makes it a suitable demand function is that it reproduces the observed ridership, so that demand variation is considered only from the actual point of observation. This at least ensures that the present steady-state conditions are reproduced in the model.

Attracted Ridership

In the model considered here, the base headway, ridership, and transit share correspond to a minimal level of transit service. The allocation of additional buses will strictly improve the headway on all routes, and as such ridership will always be attracted from the competing, distinct mode. The final equation for attracted ridership on route i from this first class of competing services, or the difference between the ridership because of the improved headway and the base ridership, is:

$$\Delta r_1(h_i) = POP_i * P'_i - r_i^0 = \frac{r_i^0}{P_i^0} * P'_i - r_i^0$$

$$= \frac{r_i^0}{P_i^0} * \left[1 + \frac{1 - P_i^0}{P_i^0} * e^{-\theta\Delta(h_i - h_i^0)}\right]^{-1} - r_i^0 \quad (2)$$

where r_i^0 is the base ridership on route i or the observed number of riders.

Competition with Private Bus Services

Private buses represent the second class of competitors being considered for the public bus system. In this case, "bus riders" have the choice of riding on either private or public buses that serve their intended trip origin and destination. The two services are assumed to have similar service quality and similar operating characteristics with respect to fares, in-vehicle travel times, and comfort on the different routes they serve. Within this context, the frequency of operation is the major, if not only, factor determining the split in ridership between the private and public systems. As in the first case of competition outlined above, the allocation of additional buses to the public bus system will be considered starting from a minimal basic level of service. Therefore, only the attraction of additional riders from the private buses as the frequency of public buses is increased will be considered. The number of additional riders who are attracted from private buses is:

$$\Delta r_2(h_i) = \frac{f_{bi}}{f_{bi} + f_{vi}} * r_{Ti} - r_i^0 \quad (3)$$

where

f_{bi} = frequency of public buses on route i,
f_{vi} = frequency of private buses on route i, and
r_{Ti} = total current bus (public and private) ridership.

Total Attracted Ridership

The total number of riders attracted to an improved public bus system will be computed as the sum of the two terms appearing in Equations 2 and 3. The final public bus ridership will be equal to:

$$r_i(h_i) = r_i^0 + \Delta r_1(h_i) + \Delta r_2(h_i) \quad (4)$$

In other words, the final public bus ridership is the sum of three components, namely: (a) the base ridership, (b) ridership attracted from the competing of distinct operating characteristics (as in Equation 2), and (c) riders attracted from private buses (as in Equation 3).

Data Requirements

The use of the above modeling approach requires data on the ridership served on each route by the different mass transit services for the base case of current public bus service. This data can be used to determine the base public bus ridership (r_i^0), the current modal split between public buses and the first class of competing services (p_i^0), as well as the total current bus ridership (r_{Ti}). Current frequencies of the two types of bus services on each route (f_{bi} and f_{vi}) are also required. Finally, the headway coefficient θ, to be used in Equation 2, is also required.

CASE STUDY: BEIRUT CONTEXT

The proposed methodology for incremental bus allocation in a competitive environment is illustrated in the case of the city of Beirut, Lebanon. The Beirut context is described first by discussing mass transit operations in existence, modal usage trends, and the potential role of the public bus system. The study objectives and scope are also described at the end of the section.

Mass Transit Operations

The public bus system in Beirut has been limited in its operations for a number of years, providing a service that is too infrequent to be reliable and highly subsidized. The public bus authority owned and operated 150 buses in the greater Beirut area in 1965. All the buses were destroyed during the first years of the war. In 1978, the authority ordered 220 buses, which were shipped in stages until the late 1980s. However, many of these buses were eventually destroyed or stolen, and as a result only 60 buses remained in operable condition as of the end of 1992. However, because of a lack of manpower and inefficient management practices, only a fraction of these buses are actually operating on the different routes (42 in 1991 and 22 since the latter part of 1992).

In contrast, mass transport in Beirut is characterized by a significant supply of privately operated transit services, which are mostly unstructured and unregulated. Jitneys, locally known as "service"

and which rely on sedan cars, form the backbone of these services. Moreover, limited private bus fleets have begun to grow in recent years to fill the void created by the weakness of the public bus system, and now carry significantly more passengers than public buses. However, the private buses are operating without authorization, and the rather old equipment being used is not properly maintained and lacks certain safety requirements. The private bus operations within Beirut are certain to be scaled down (or phased out altogether) by the government when the public bus system gets revitalized.

Modal Usage Trends

The limited service offered by the public bus system within Beirut, the absence of public bus services outside Beirut, and the expanding ownership and use of the private automobile (about 100,000 cars were imported into the country in 1991) have resulted in the predominance of the auto as the most important transportation mode. Traffic counts conducted in 1984 (*11*) indicated that buses carried less than 5 percent of midday trips in Beirut (peak period ridership levels were unavailable) and jitneys carried about 23 percent, with the remaining 72 percent of trips being made by the private auto. Comparable pre-war figures for 1970 (*12*) were 11, 44, and 44 percent, respectively, indicating a trend toward less reliance on public transit.

Potential Role of Public Bus System

Based on the factors outlined above, and given the probable financial and physical constraints on major new infrastructure investments in Beirut, public transit has the potential to play a significant role in reducing congestion based on its ability to provide higher capacities and vehicle occupancies than the private auto. The last major government planning study for the Beirut Metropolitan Region (BMR), the Schema Directeur (*13*), suggests that a greater reliance on public transit to transport passengers from the suburbs to Beirut and within Beirut itself should be a major component of an overall plan to ease traffic congestion in the BMR.

During the coming 2 years, the transit authority in Beirut is planning to expand its bus fleet to close to 120 buses through the rehabilitation of older buses and the acquisition of a limited number of new ones. Based on this modest public investment, it becomes possible for the public bus system to improve travel conditions in Beirut in at least two respects: (a) by providing a viable, cheap alternative to jitneys, and consequently inducing a shift in ridership away from this less-efficient travel mode; and, (b) by reassuming its role as the prime bus mode in Beirut, and consequently helping to phase out the illegal private bus operations by reducing reliance on them.

Study Objectives and Scope

Since the transit authority in Beirut will, for the near future, be constrained with respect to major equipment acquisition to support bus network expansion, the existing network structure, which has been relatively stable since 1991, is likely to be maintained until further notice. In such a context, the major lever in improving service is in setting the route headways on the existing network. Constrained by a limited number of operating buses and a limited budget, it is primarily in choosing the headways that these limited resources can be allocated more efficiently. It is therefore imperative that the allocation be performed in a way that maximizes the social benefit and ensures efficiency.

In view of the likelihood that the transit authority will be in charge of running a larger fleet within the next 1 to 2 years, the next section describes a proposed approach for allocating buses among lines based on a realistic correlation between bus headways and demand for bus service. This need for a variable demand representation in the bus allocation model necessitated a data collection effort to identify the potential for ridership attraction. The approach was then applied, in an incremental mode, to efficiently allocate the potential additional buses on the existing network.

INCREMENTAL BUS ALLOCATION IN COMPETITIVE ENVIRONMENT

During the latter part of 1992, the bus fleet in Beirut comprised only 22 buses, which were being operated on a network consisting of nine lines. The operating fleet has remained at about that size since then. However, during the coming 2 years, the transit agency is likely to be able to expand the bus fleet to nearly 120 buses, raising the question of how these buses should be distributed among the different lines in the existing network.

The expected fleet expansion will introduce modifications to the current system conditions, including a potential for attracting riders from competing modes of mass transit. Therefore, a need exists for variable demand models for setting headways. In the following, the proposed approach to incremental bus allocation (described above and represented by Equations 2 to 4) is adopted instead of the nested logit model since, in the context of the expansion of the public bus system in Beirut, all demand shifts will be in the direction of this revitalized system. Moreover, and with the likely restrictions on and phasing out of the private bus operations, this mode cannot be considered as a viable, equivalent bus alternative in the lower-level choices, as the nested logit model would imply.

In the analysis that follows, it is considered that public buses will be competing with jitneys and private buses for riders. Because the extent of the public bus service will remain rather limited, the potential reaction and shift of auto passengers is not considered. As such, the binary choice represented by Equation 2 is whether to ride the public bus or to use the jitneys. Equation 2 models demand variation that results from bus headway changes only, and hence wait time changes.

Data Requirements for Model Application

As outlined above, the use of the suggested model requires data on the ridership served on each route by the different mass transit services, frequencies of bus services on each route, and an estimate of the headway coefficient θ. Because the required data were not readily available, a limited data collection effort was undertaken.

Mass Transit Ridership

The data collection procedure consisted of ride checks to determine public bus ridership levels and traffic counts at the maximum load points to determine ridership on competing mass transit modes. Being limited by a small research budget, each of the counts could be conducted only once. This was thought to be sufficient for the

purpose of this study, which was to illustrate a methodology for allocating additional buses and to obtain a rough first allocation instead of to reach an exact and final conclusion.

Ride checks were conducted for both directions on each route and for peak period trips (7:00 to 9:00 a.m.). Once the peak load point on each route was determined, a traffic count was used to count person trips by all mass transit modes in the peak direction. The counts were conducted on weekdays during November 1992 from 7:00 to 10:00 in the peak a.m. period. The data collected at each of the nine counting stations included (*a*) traffic volumes classified according to public buses, private buses, and jitneys; and (*b*) the passenger occupancy of each vehicle.

The model proposed for predicting the potential attraction of riders to public buses from competing services considers a target choice population of mass transit riders whose trips are served by bus routes and who are willing to switch to an improved bus system. However, the number of riders on the competing mass transit services that observed during the traffic counts includes individuals whose origins and destinations may not be served by the public bus system as well as individuals who may be unwilling to switch to the public bus system. To remedy this difficulty, the choice population was obtained from the observed ridership by introducing the following two factors.

O-D Factor The origins and/or destinations of riders on other modes of collective transport may not correspond to bus routes. The boundaries of served origins and destinations are uncertain, and an accurate trip table is not available. The fraction of the observed ridership whose origins and destinations are served by a particular route was estimated for each route based on judgment. For jitney riders, this fraction ranged between 0.45 and 0.75 based on route characteristics such as geometry of road network along the route, type of area served (whether commercial or residential), type of route (whether radial or cross-town), length of the route, and so forth. For private bus riders, the choice fraction was taken as 1.0 (except for Line 9), because private buses follow practically the same routes as public bus lines.

Switching Factor Some riders are unwilling to switch to a bus even if the bus route coincides with their O-Ds. The fraction of jitney riders willing to switch to an improved public bus system was obtained from a survey conducted by students at the American University of Beirut (*14*), in which 92 percent of jitney riders indicated a willingness to switch to an improved public bus service. This fraction was assumed the same for all lines. The fraction for private bus riders is taken to be 100 percent as its service characteristics are quite similar to those of the public bus system.

The choice jitney population associated with each bus route is inferred by multiplying the O-D factor and the switching factor by the observed jitney ridership (obtained from traffic counts) on each of the routes. A similar procedure was followed to obtain the choice private bus population.

Estimation of Base Modal Split Ratio, p_i^0

Based on the determination of the choice jitney population associated with each of the public bus routes, the base modal split ratio to be used in Equation 2 can be computed as follows:

$$p_i^0 = r_i^0/(r_i^0 + \text{choice jitney riders})$$

Determination of Headway Coefficient, θ

The data set that was used to obtain the headway coefficient relates to work trip mode choice in Beirut and is extracted from surveys conducted by students at the American University of Beirut (*14*). Only two travel modes are taken into consideration, namely, public bus and jitney. The data set that was used consisted of answers to detailed questionnaires and provided 108 observations of socioeconomic and mode characteristics associated with a group of trip makers and the mode choices they made (24 used buses and 84 used jitneys). Various utility functions associated with the logit model were specified and their parameters estimated. The model that was chosen based on statistical validity tests revealed a value for the wait time coefficient θ of approximately −0.05.

Demand Elasticities with Respect to Headways

For the logit model, the point elasticity of demand for bus service with respect to headway on route i is

$$e_i = \theta * h_i^0(1 - P_i^0)$$

Elasticity values for the different lines are presented below. As one might expect for a bus system that currently provides very low-frequency service, the demand is quite elastic with respect to headway. Note that the demand on Line 1 is inelastic with respect to headway because the base bus share was relatively high for this line.

Model Application

Having determined all principal factors of the model, its application based on Equations 2 to 4 becomes straightforward. It is worth mentioning that the analysis was performed based on ridership figures for the 3-hr A.M. peak period (7:00 to 10:00 A.M.). The base public bus ridership on the eight lines being analyzed was 1,345 for a service that was provided by 22 buses. The computed choice populations over the 3-hr period for jitneys and private buses were 5,700 and 3,530, respectively, for a total of 10,575 and a base public bus share of 12.7 percent.

Incremental Analysis

Additional buses to be rehabilitated and acquired by the bus transit authority in Beirut during the coming 1 to 2 years will be put in service in stages. Using the proposed model, an incremental assignment of additional buses as they become available is proposed here.

With the adoption of the objective of providing public service to as many travelers as possible, the allocation of each additional bus is made to the route having the highest marginal benefit with respect to passenger attraction. With this technique, a route "priority list" is generated. Starting with a baseline of the existing 22 buses, and terminating at the upper bound of 120 buses, the list serves as a guide each time an additional bus is to be allocated. The starting point in the above analysis was the 22 available buses distributed so as to provide minimum regular service, and according to the service standard of policy headways (*15*). A summary of the results (allocated buses and corresponding headways) is reported in Table 1. One interesting observation is that, with the 120 buses being allo-

TABLE 1 Summary of Incremental Analysis Results

Total No. of Buses	21	40	50	75	100	120
Line #	Bus Allocation					
1	4	5	7	9	10	12
2	2	5	6	9	12	15
3	3	7	9	14	19	22
4	1	2	2	3	4	4
5	2	3	3	4	5	6
6	3	6	8	12	16	19
7	3	7	9	14	20	25
9	3	5	6	10	14	17
Line #	Headway (min.)					
1	30	24	17	13	12	10
2	45	18	15	10	7	6
3	40	17	13	8	6	5
4	90	45	45	30	23	23
5	45	30	30	22	18	15
6	30	15	11	7	5	5
7	40	17	13	8	6	5
9	30	18	15	9	7	5

cated, five of the lines would have headways of 5 to 6 min, representing peak-period frequencies that are necessary to build up a solid ridership base. This indicates that the 120 buses are needed to provide strong basic service on existing routes, and that additional bus routes have to be considered if the fleet is expanded any further.

Figure 1 indicates the increment in ridership with additional buses allocated according to the priority list. The trend indicates a continuously increasing ridership as the number of operating buses increases. On the other hand, the incremental rate of attraction is decreasing: the effect of adding a bus at latter stages is much lower than at initial stages. For instance, during the 3-hr a.m. peak period, the 22nd bus attracts 160 additional trip makers, the 50th attracts 48 more, and the 120th attracts 13 more. This relates to the fact that the model is only interested in the limited mass transit market (10,575 total travelers during the peak 3 hr along routes served by the existing public bus routes). An extension of the analysis presented in Figure 1 indicates that the increment in ridership with each additional bus becomes almost insignificant starting at 200 buses, at which stage the public bus share of choice mass transit riders would have reached 62.6 percent. As public transit service improves beyond a certain level, a shift is likely to occur from the auto-driver and auto-passenger markets.

Bus Allocation With Cost-Recovery Considerations

Based on the incremental analysis results, a number of questions arise: Given the decreasing marginal return of additional buses with respect to ridership attraction, what is the ceiling at which procurement of buses on the existing network should stop? How should a trade-off be made between cost considerations and social benefits (additional ridership)? To answer these questions, cost-recovery ratios, relevant to subsidy levels, are calculated.

To compute cost-recovery figures, the 1991 operating costs per vehicle kilometer were used (after accounting for inflation since that time). For any number of allocated buses on a bus route: (*a*) the vehicle kilometers and the associated costs are calculated, (*b*) the expected ridership and the revenues (based on the flat fare currently in effect) are predicted, and (*c*) the cost-recovery ratio is obtained. This procedure is followed on each route independently. Sample results for Line 9 are reported in Figure 2. This figure indicates that a maximum cost recovery of around 30.5 percent can be achieved for this line based on the allocation of four to six buses to it. The maximum cost recovery that could be achieved for each line and the associated number of buses summarized in Table 2. Figure 3 indicates that cost recovery is optimal (29 percent) for a fleet ranging between 35 and 50 buses. Between 100 and 150, cost recovery is within the range of 17 to 21 percent. However, for a much bigger fleet, the cost-recovery ratio becomes unacceptable. With almost the same cost-recovery ratio, it would be recommended to use 47 buses instead of 35 since social service (ridership) is improved by 23.2 percent.

Fleet Size and Subsidy Considerations

The final question relates to the recommended fleet size needed to operate on the existing network, given no switching from the auto mode. Two main factors will be considered: potential ridership attraction and maximum permissible subsidy. In the latter case, the decision on fleet allocation could be financially dominated. If the transit authority is awarded the same subsidy as in 1991 (inflated), it can operate almost 147 buses with the improved allocation made possible by the proposed approach. If, on the other hand, the authority tries to minimize costs while providing a fairly good service, the 120 buses soon to be available provide a good combination: a 56.2 percent public bus share (4.4 times the 1991 share), a 20 percent cost-recovery ratio, and a subsidy level about 80 percent that of the year 1991 (inflated).

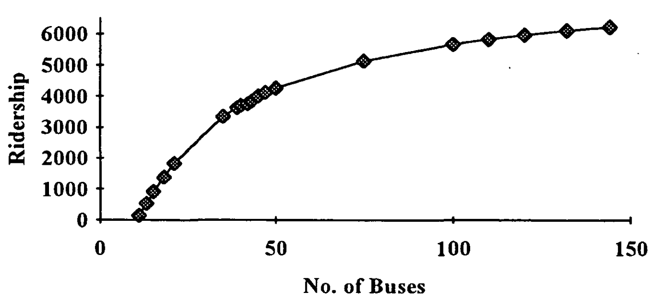

FIGURE 1 Ridership with additional buses.

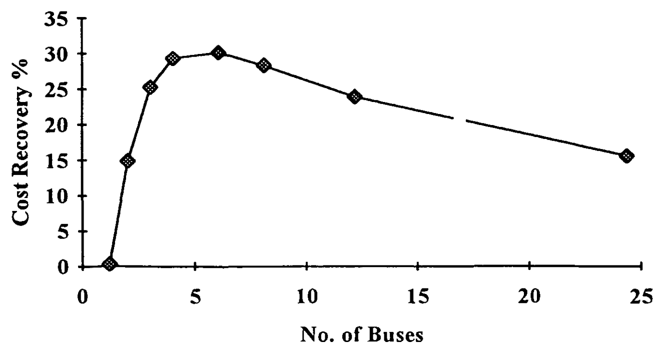

FIGURE 2 Cost recovery for Line 9.

TABLE 2 Bus Allocation with Cost-Recovery Considerations

Line #	Maximum Cost Recovery	Number of Buses	Headway (min.)	Ridership
1	28.1%	6-7	18-19	440- 498
2	69.2%	5-6	14-16	618- 689
3	26.8 %	6-8	17-18	523- 655
4	12.3 %	2-4	60-90	104- 160
5	17.4 %	3-4	23-27	212- 258
6	30.8 %	4-6	17-19	489- 660
7	30.7 %	5-6	20-22	568- 661
9	30.5 %	4-6	17-18	391- 530
Total	29.0%-29.2%	35-47		3345-4121

CONCLUSIONS

In this paper, an approach for assigning additional buses to routes of an existing network in the context of competition with other mass transit services has been presented. The proposed approach allocates additional buses based on maximum potential ridership attraction from competing services. The bus system in Beirut, Lebanon was considered as a case study for incremental bus allocation using the proposed approach. With jitneys and private buses representing competing modes of mass transit in Beirut, a priority list was generated for the assignment of additional buses, which are expected to become available soon. In addition to ridership attraction, cost-recovery implications were considered. The adopted approach clearly provided an improved allocation of buses. For instance, it was found that 147 buses could be assigned to the network and operated at the same effective level of subsidy, as was the case in 1991 when only 42 buses were operational. However, the analysis indicated that with a larger bus fleet, the introduction of new lines to the existing network needs to be considered. Moreover, with a significant improvement in the bus level of service, the potential attraction of riders from the auto mode would become possible, a situation that needs to be addressed. These two items, as well as the consideration of possible response from jitney and private bus operators to public bus fleet expansion, represent interesting avenues for further research.

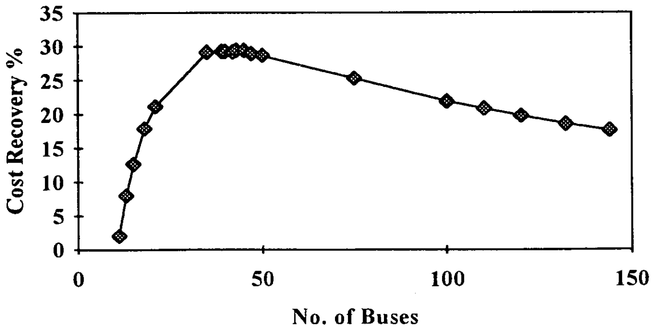

FIGURE 3 Systemwide cost recovery.

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Negative Impacts of Busway and Bus Lane Conversions into High-Occupancy Vehicle Facilities

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The extensive planning and construction of high-occupancy vehicle (HOV) facilities during the past 20 years has resulted in more efficient freeway operations in many cities. There are, however, considerable differences among the effects of different types of HOV facilities, such as those converted from the existing lanes versus the newly constructed ones and HOV lanes versus exclusive busways. Actually, most of the newly constructed HOV facilities and conversions of busways into HOV facilities have resulted in increased vehicular capacity rather than passenger capacity of highways, which is contrary to the Intermodal Surface Transportation Efficiency Act mandate. Planning of HOV facilities, therefore, requires a careful analysis of goals as well as impacts in each particular case. Different types of HOV facilities are analyzed, principles for planning transit preferential facilities are developed, and one major problem—negative impacts of HOV facilities on bus systems—is explored. A hypothetical model based on experiences from different cities is developed and used for comparative evaluation of four cases: busways and HOV facilities obtained by conversion or addition of lanes. The present conflict between traditional urban transportation planning and the current mandated transportation systems approach is also analyzed. Relationships among policies, actions, and goals in planning HOV and busway facilities are discussed. Several revisions in the current policies and practices regarding busways and HOV facilities are recommended.

During the 1970s the importance of providing *separate rights-of-way for transit* to make it competitive with the automobile was recognized in many countries. This separation is needed on all major transit lines regardless of technology used. Although for most rail systems such separation is physically necessary, it was realized that the technological compatibility of buses with street/highway traffic should not prevent their separation for functional reasons.

Excellent busway facilities were built in several cities around the world, including Washington (Shirley Busway), Los Angeles (El Monte), Pittsburgh, Ottawa, Lima, Essen, and Adelaide, during that period. These busways were seen as distinct transit incentives, and many cities introduced these facilities in parallel with various auto use disincentives.

In the United States, however, two new developments occurred subsequently. First, the policy of *promoting high-occupancy vehicles (HOVs)* by giving them separate lanes or roadways was introduced. This has been a correct policy, and it has had a very positive impact on increasing productivity of highway facilities. Second, the fact that exclusive bus facilities are not always physically filled by buses led to the claims that they are "underutilized" (*1*), that is, the idea was accepted that *other vehicles should be permitted to "fill the space between buses."* This "empty lane syndrome," based on the fallacious belief that filling the lanes does not have any negative impacts on buses, has resulted in degradation of bus services. It has also introduced an incentive to use the major competitors of transit: vanpools, carpools, and, where new lanes are constructed, even single occupancy automobiles.

The first of these new developments is very positive; it introduces the principle that more productive modes should be favored over less productive ones. However, the conversion of busways to HOV facilities has had major negative impacts from the transportation systems policy point of view for two reasons. First, the common "transit incentive/auto disincentive package," used successfully in many countries, has been gradually converted into a far more expensive and less efficient "transit incentive/auto incentive package." And second, downgrading of busways into HOV facilities has virtually eliminated exclusive busways as a viable, high-quality transit system.

Looking nationally, excellent busways in several cities that were planned and built in the early 1970s have by now been downgraded to indistinguishable part-time bus operations that primarily serve the peak hour passengers but fail to provide all-day regular bus services.

The purpose of this paper is to analyze the impacts of HOV facilities on bus services and on the role of transit in urban transportation. The rationale for providing priorities and separation of transit is given, and the impacts of various types of HOV facilities on modal split are analyzed.

"FLEXIBILITY" OF BUSES: ADVANTAGE OR LIABILITY?

The fact that buses can operate on most streets mixed with general traffic and require few extra fixed facilities is often considered to be their "flexibility" and a great advantage, particularly in comparison to rail transit. This flexibility of buses, however, is often misunderstood and misused. It is presented as if it were *always* a great advantage of the bus mode. Actually, "flexible routing" means that service is individualized, such as taxi service; but it also means that people who have bus service may soon lose it because routes can be relocated. "Flexible scheduling" may imply that users cannot rely on the convenience of a fixed schedule. "Flexible pricing," often found in taxi services, leads to much more illegal overcharging of passengers than "fixed pricing," which users can easily understand.

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Although flexibility in operation may generally be an advantage for bus services with low and moderate passenger volumes, it also implies lack of permanence, lack of distinction from other traffic, and great difficulty in achieving separation of buses from other vehicles. Wherever a separate bus lane is provided, that strip of pavement is very attractive to all other vehicle drivers as well. In many cities in this country political pressures and court decisions have succeeded in preventing introduction or even in discontinuing operation of excellent busway facilities. Consequently, bus compatibility with other highway traffic has become a major liability of this mode wherever a distinctive high quality transit has to be provided.

BUS TRANSIT AS A SYSTEM

Bus services in most cities consist of buses operating on streets and highways in mixed traffic and stopping frequently at locations marked by bus stop signs and shelters. These services attract mostly captive riders. To attract a substantial portion of automobile drivers to transit, it is necessary to provide attractive buses, special infrastructure, and services that represent a distinct, high-performance *bus transit system (BTS).*

The basic component of a BTS is a mostly separated right-of-way that allows buses to have higher speed, reliability, and safety than vehicles traveling in general purpose lanes. *Priority treatments, separate rights-of-way, stations, and clear information give buses a distinct image and permanence.* These features add considerably to the ability of BTS to attract passengers. Their stations can be integrated with concentrated land use developments.

Another basic characteristic of the BTS is that it should be *regular transit*, that is, it should offer service among many points of the served area (many-to-many) at all times of the day. This should be distinguished from *commuter transit*, which usually operates many-to-one and one-to-many services during peak hours only.

SURVEYS OF CONDITIONS OF BUS TRANSIT

The authors recently conducted a study of the conditions of bus services in the cities of North America and several other countries (*2*). For that study two surveys were made: one of major transit agencies and the other of bus transit experts. The surveys focused on the priorities given to bus transit and, particularly, on the problem of "backsliding," or gradual abandonment, of bus priority measures. Table 1 summarizes the results of the survey in three categories of facilities: bus/HOV lanes on streets, exclusive bus/HOV streets and roadways, and bus/HOV lanes on freeways.

The table shows that most North American cities have *extremely limited lengths of bus or HOV lanes on city streets.* Except for the two largest systems, in Ottawa and Pittsburgh, the remaining 11 cities in the Table 1 have a total of only 68.3 km of exclusive bus lanes. Similarly, there are *few exclusive streets for buses or HOVs.* Excluding Ottawa and Pittsburgh, the surveyed cities have a total of 12.0 km of such facilities.

The length of *bus/HOV lanes on freeways* is considerably greater, amounting to a total of 389.4 km, but the distribution of these lanes is again very uneven: 308.1 of the 389.4 km (over 79 percent) are located in Houston, Seattle, and Los Angeles. Among the other 10 cities, 4 have no busway or HOV facilities on freeways, and the remaining 6 have a total length of 81.3 km. Despite the substantial lengths of the facilities in Houston and Seattle, the apparent advantage for buses is deceptive because buses are given the lowest possible priority; most of them are part-time, one-way HOV 2+ (cars with 2 or more persons) facilities, which have been gradually degraded from bus lanes, 4+ and 3+ facilities.

The best bus system in North America, and the only one that can be defined as a BTS, is in Ottawa, one of two cities that still have exclusive bus facilities (the other is Pittsburgh). The most extensive system of HOV facilities exists in Houston, but it consists, as mentioned earlier, nearly exclusively of reversible freeway lanes for HOV 2+. It is therefore a system that caters primarily to commuter traffic and has the lowest distinction of transit services among all priority systems.

These findings show that bus transit in the U.S. suffers from a serious neglect. In many U.S. cities the focus has been on improvements of commuter bus services, whereas regular, all-day services within urban areas have suffered from gradual "backsliding" or dilution of their priorities from exclusive bus to HOV facilities.

RATIONALE FOR SEPARATING BUSES FROM OTHER TRAFFIC

As in many other areas of human society, there is a dichotomy between the interests of the individual and the interests of the group, aggregation of system users, or, globally, the entire society. Similar dilemmas are found in regulating human behavior with respect to the use of urban streets. For example, there are limitations of locations where pedestrians can cross streets, restriction of vehicle movements on certain streets to one direction only, parking regulations, and so on. For the same reason it is rational to influence in various ways the use of different modes, such as automobiles, vans, and transit.

A general conceptual flow of the goals, objectives, and means in improving transportation in a given city (or area) is shown in Figure 1. In many actions toward improving transportation the main objective is to achieve a shift of travel from the private automobile to transit. Figure 1 shows that there are a number of means for achieving this objective. They consist of two groups: *transit improvements*, which include separation of rights-of-way and various priorities resulting in increased speed, reliability, and enhanced transit system image, and *auto disincentives*, such as introduction of realistic charges for auto travel, limitation of parking, and retention of congested conditions. The apparent need to increase highway capacities and "eliminate bottlenecks" has been proven ineffective in most cases because it generates additional vehicular traffic and works directly against the shift of travel to transit and other HOV categories. The focus in this paper is on the transit incentives, referring specifically to the bus mode, and on auto disincentives with respect to the limiting of freeway capacities.

The rationale for providing priority treatments of transit vehicles over private cars and other vehicles includes the following major points:

1. It is an accepted principle to *favor public over private facilities*; the society pays from its general funds for public schools, parks, and other public facilities; public funds are not used to support private schools, golf courses, and private streets. In the case of transportation, transit is the only mode that provides mobility for all citizens and thus contributes to the basic living standard of the entire population.

TABLE 1 Summary of R/W Improvements for 14 City Participants in Survey (2)

Transit Agency	Bus/HOV lanes on streets					Exclusive bus/HOV streets, roadways, malls				Bus/HOV lanes on freeways				
	No.	Length [km]	Usage	Placement	Direction	No.	Length [km]	Usage	Type of facility	No.	Length [km]	Usage	Placement	Direction
Calgary, CALTRANS	1	0.6	bus only -discon'd	curb	withflow	1	2	bus+LRT	mall	/	/	/	/	/
Chicago, CTA	6	5.5	bus only	curb	withflow reversib.	1	1.8	bus+taxi	mall	/	/	/	/	/
Denver, RTD	2	9.6	bus only discon'd	curb	withflow	1	3.2	bus only	mall	1	6.4	bus only	median	withflow
Hartford CTT	10	0.8	bus only	curb	withflow	/	/	/	/	1	19.2	HOV 3+	median	withflow
Houston METRO	5	8	bus only	curb	withflow	/	/	/	/	6	152.8	HOV 2+	median	reversible
Los Angeles, RTD	1	0.8	bus only	curb	contraflow	/	/	/	/	2	70.4	HOV 3+	median	withflow
Newark, NJT	3	8	bus only	curb	withflow	/	/	/	/	1	6.4	bus only	left	contraflow
Oslo, Norway	12	35	bus only and bus + taxi only	curb, median	withflow	2	6	bus only	busway	2	8	bus + taxi	right	withflow
Ottawa, OC Transpo	1 1 1	3 2.5 3.8	peak, bus only all day, bus only peak direction HOV 3+	curb second lane curb	withflow withflow withflow	1 1 1 1	25 0.4 0.4 0.7	bus only bus+taxi bus only-discon'd bus only	busway mall mall busway	1 1	8 7.5	peak, bus only peak, bus only-discon'd	curb curb	withflow withflow
Pittsburgh, PATransit	4	4.5	bus only	curb	contraflow	2	17.3	bus only	busway	1	6.4	HOV 3+	median	reversible
San Antonio, VIA	6	4.3	bus only	curb	withflow	/	/	/	/	/	/	/	/	/
San Francisco, MUNI	11	19	bus+taxi, all day	curb	withflow	/	/	/	/	/	/	/	/	/
Seattle, METRO	8	11.7	bus only and HOV	curb	withflow contraflow	2	5	bus only	busway	20	84.9	HOV 3+ HOV 2+	curb median	withflow withflow
Washington, WMATA	/	/	/	/	/	/	/	/	/	2	27.4	HOV 3+	median	withflow

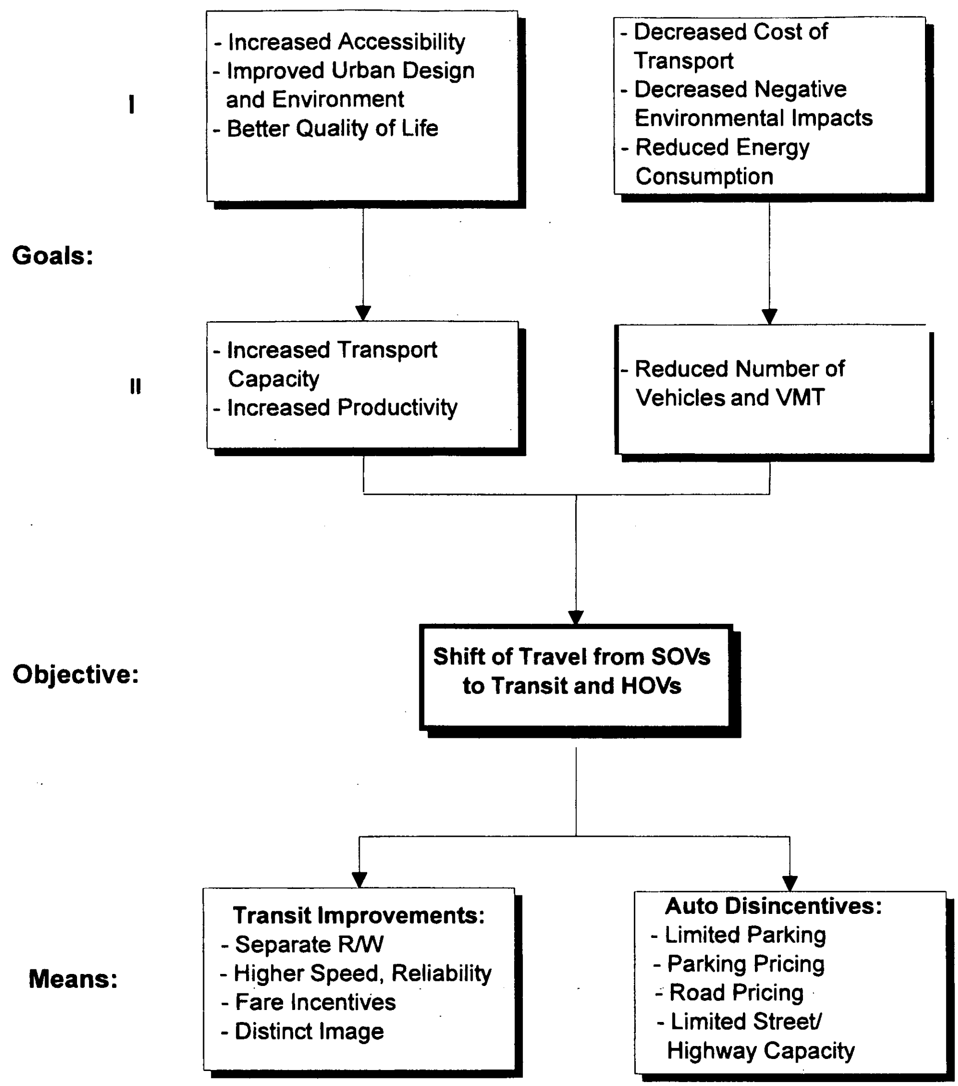

FIGURE 1 Means, objective, and goals in improving transportation by shifting automobile travel to transit.

2. Because of their large capacity and common carrier character (open to the public), *buses inherently have much higher productivity (lower cost and area per passenger-kilometer) on major travel corridors than automobiles.*

3. The conventional management of traffic on highways is based on maximizing the vehicular flow. However, since the main objective in passenger transportation is to *move persons rather than vehicles*, highway flows should be managed considering relative productivity of different modes.

4. Bus priorities are needed to give transit faster and more reliable service and thus *to offset the advantages an individual finds in using the automobile*, such as extremely low out-of-pocket cost, privacy, and personal convenience. The very low out-of-pocket cost results from several factors. First, most of the large cost items of an automobile (purchase, insurance, major repairs, registration) are so indirectly related to the distance traveled that they have no bearing on a driver's decisions for individual trips. Second, subsidized ("free") parking is a widespread practice. And third, auto users are not charged for any congestion or social and environmental impacts that auto travel causes.

5. The greater the use of buses, the greater is their advantage in *lower negative side effects* (such as congestion, air pollution, noise and energy consumption) per person-kilometers transported over the private automobiles.

6. Bus priorities are justified also by the fact that *transit in general is a key element that allows creation of a more human-based city and more livable urban environment* than is the case where all travel is performed by the private automobile.

Among the reasons for providing *exclusive rights-of-way* for buses, the following are the major ones:

1. Bus separation from general traffic is *the most effective way of achieving speed comparable with that of the automobile.* The higher running speed of buses free from congestion allows them to compensate for additional time required for stopping at bus stops compared with automobile travel.

2. Exclusive bus facilities allow *faster, more reliable, and safer operations*, which result in lower operating costs.

3. *Separate rights-of-way, stations, and other infrastructure give the bus service a distinct, positive image*. These characteristics make bus service much more attractive to the public than buses mixed in general traffic. The advantages of distinctive facilities are not only limited to immediate attraction of passengers; they also *give the system a character of permanence* and contribute to the shaping of land uses, urban form, and, finally, higher quality of urban life.

COMPARATIVE ANALYSIS OF BUSWAYS AND HOV FACILITIES

There is presently an enthusiasm for constructing additional HOV lanes in many cities. The alternative to such construction, to convert existing lanes into HOV lanes, is often not even considered. The explanation for this major omission is usually a simplistic statement that such an action would be "politically unacceptable."

The discussion in this paper, however, clearly indicates that alternatives of highway upgradings differ so substantially among themselves in their results and impacts that they should be systematically analyzed. Actually, a methodology for such a comparison has been missing. For that purpose, a procedure that allows systematic comparisons of different types of preferential facilities is presented here.

Classification of Vehicles and Right-of-Way Facilities

Highway facilities with preferential treatments can be defined by the classes of vehicles permitted to use them.

Category I facilities serve transit buses only; there are examples of such facilities in Ottawa, Pittsburgh, Adelaide (with O-Bahn), and Sao Paulo. The category, "*Busway*," is comparable with a light rail transit (LRT) system by its regime of operation. The busways have by far the strongest identity and image of all categories of preferential facilities.

Category II are the facilities that are also open to other buses (long-distance, charter, and private coaches and others), to paratransit, and to semipublic vanpools (belonging to companies, universities, hospitals, and others). Compared with Category I, this "*Public and Paratransit HOV*" facility accommodates more vehicles and carries more passengers than a comparable busway, but transit vehicles are exposed to more friction, they are subjected to competition, and thus their distinct image is weakened.

There is a major change in Category III. Instead of only public and semipublic vehicles with professional drivers, "*HOV facility*" allows entry to a much greater number of vehicles, referred to as "carpools." The definition of carpools, as well as of HOVs, has changed over time from the vehicles with at least four passengers (4+), which are mostly organized commuter carpools, to the cases in which vehicles with 3+, and finally, with 2+ passengers are included. This development and its consequences deserve a careful analysis; they are discussed in the following section.

Category IV is an unrestricted highway carrying all vehicle classes.

Downgrading Bus Transit Services Because of Vehicle Mix

Allowing private automobiles into preferential lanes changes the character of such lanes considerably for two reasons. First, vehicular volume increases greatly. The promoters of lowering the minimum occupancies of vehicles permitted to use the facility claim that thereby "the gaps between buses are utilized." Although that sounds plausible to laypeople, the tendency to "fill the gaps between transit vehicles" is a short-range view. Actually, the price that this "utilization of gaps" carries in the long run is substantial: higher vehicular volume with nonuniform composition decreases speed, reliability, and safety of traffic and thus negatively affects the truly high-occupancy vehicles: buses and vans.

Second, the level of service is further affected by the fact that the facility is used not only by the vehicles driven by professional drivers but by any licensed drivers, so that the regularity and quality of vehicle flow are decreased.

A systematic evaluation of the consequences of converting busways into HOV facilities (*3*) clearly shows that *all of the benefits from the conversion of a busway into an HOV facility are accrued by passengers of other than transit vehicles. Transit passengers, existing and potential, have only losses from such a change*. In other words, nontransit users gain, and transit users lose, in service quality. Competitiveness of transit is decreased, and, consequently, riders are lost, leading to a decrease of service frequency and further passenger losses—the well-known downward spiral of transit use.

The priority of buses is further reduced by the fact that the other lanes of the same highway now have lower traffic volumes, so that even the lower occupancy automobiles, including the single-occupant-vehicles (SOVs), have improved travel conditions. This gives SOVs an additional advantage over transit buses.

Although all of these problems occur as soon as any automobiles (starting with 4+) are permitted into the HOV facility, the situation becomes progressively worse with the transition from 4+ to 3+ and, ultimately, to the 2+ regime. This last type of facility is actually a regular highway with prohibition of only SOVs and trucks. A study of this backsliding of HOV facilities from 3+ to 2+ regimes on Seattle freeways (*4*) has shown that such a change results in substantial increases of traffic volume in the HOV facility, as well as in "refilling" of the general purpose lanes by additional vehicles. This "refilling" partly represents attraction of the latent demand, leading to the reduction of the overall average vehicle occupancy.

It is often claimed that construction of additional HOV lanes will make travel of HOV so superior to the travel in general purpose lanes that many riders will begin to carpool; this will, supposedly, decrease vehicle miles traveled (VMT). The data from Seattle (*4*), among others, indicate that this is not the case. When new HOV lanes are added and HOVs use them, travel conditions in general purpose lanes actually improve, so that SOV travel becomes more attractive. Thus, the observations in Seattle show that there is actually a shift from HOVs to SOVs, resulting in increased VMT. In Dallas (*5*), conversion of the I-30 contraflow HOV lane from 3+ to 2+ increased the HOV volume by 45 percent, and volumes in general purpose lanes also increased by 20 percent.

This Seattle study (*4*) also found that bus travel times increased with the degradation of the HOV facility from 3+ to 2+, causing protests from the bus users.

Model for Comparing Busways and HOV Facilities

To illustrate the discussion presented above in a quantitative manner, a "model freeway" in an urban corridor, sketched in Figure 2,

is created. Alternative schemes of priority facilities are analyzed with respect to different shifts in vehicle classes, levels of service, and changes in modal split and average vehicle occupancies. The assumptions, four different alternative facilities, and the results of the analysis are presented here.

The model used here represents a set of conditions similar to those found in a number of cities: an existing eight-lane freeway is congested, and different possible alternatives for favoring transit and/or HOV are analyzed. The traffic volumes, their assignment, and reassignment are modelled on the basis of typical situations on urban freeways; levels of service are based on the Highway Capacity Manual.

Assumptions and Initial Conditions

The initial conditions of the analysis in terms of lane geometry and demand are typical for an urban radial freeway with saturated peak-hour flows:

- Lane configuration of the existing freeway: four lanes per direction.
- Total number of persons traveling: 12,000 persons per hour per direction.
- Number of vehicles: 1,000 two-person cars per hour, 7,000 one-person cars per hour, and 60 buses per hour with 50 persons per bus.
- Average occupancy of all vehicles: 1.49 persons per vehicle.
- Average number of vehicles per lane: 2,015 vehicles per hour.
- Current traffic flow level of service: E.
- Latent demand (the number of persons who would travel if the freeway condition were improved): 3,000 persons per hour.
- Composition of latent demand: 1,000 car captives, 1,000 transit captives, and 1,000 choice travelers.

With respect to vehicle classes permitted in the upgraded facility, two cases are considered: *exclusive busway*, and *HOV roadway*. Two ways of upgrading the facility are also considered: *converting existing freeway lanes and constructing additional lanes.*

Permutations of these cases make four alternatives, as shown in Figure 2:

- C/B—convert two existing lanes (one per direction) into a busway,
- C/H—convert two existing lanes into an HOV roadway,
- A/B—add (construct new) busway, and
- A/H—add an HOV roadway.

Each one of the four alternatives is analyzed in the sequence shown in Figure 3. From the present condition, which represents a saturated flow (2,015 vehicle/hr/lane) with mixed traffic in all lanes (*Column 1*), each of the four alternatives (*Column 2*) is analyzed in several steps.

First (*Column 3*), the present volumes are assigned to the new set of lanes when the upgraded roadway is opened; then (*Column 4*), traffic conditions on each facility are evaluated, likely shifts of passengers among modes are estimated, and vehicular volumes are reassigned. In the next step (*Column 5*), the new levels of service are evaluated, and, in the cases in which they have been improved for individual modes, the likely attraction of the latent demand is

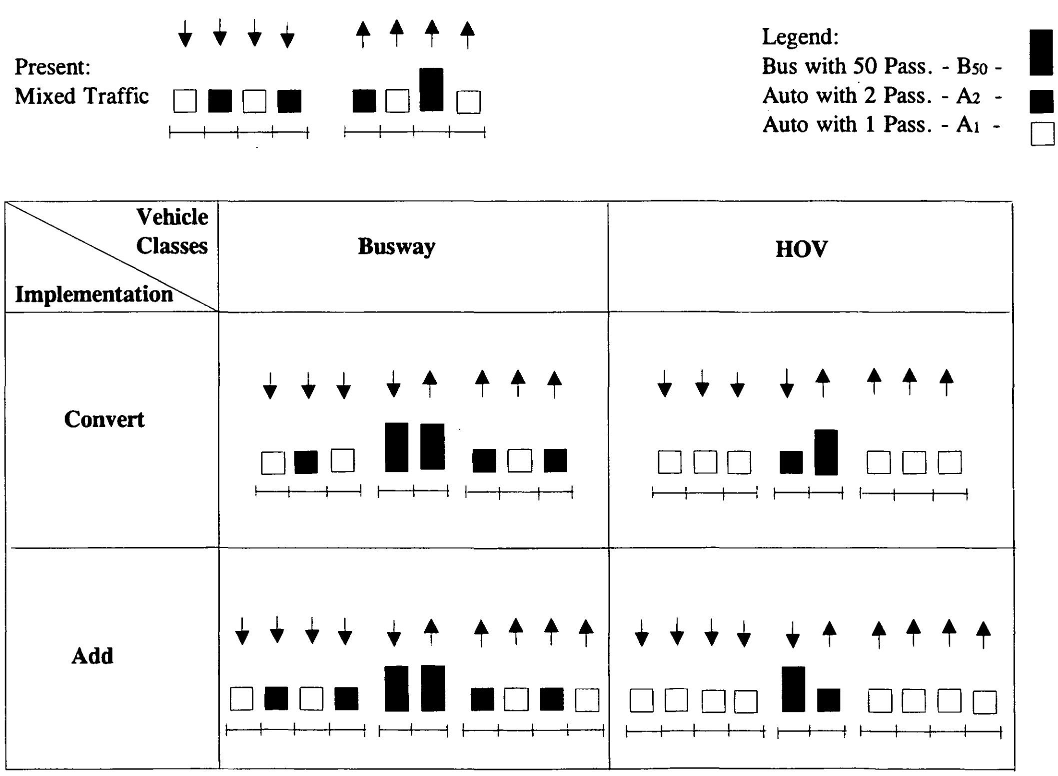

FIGURE 2 Present and alternative cross section of model freeway with priority lanes.

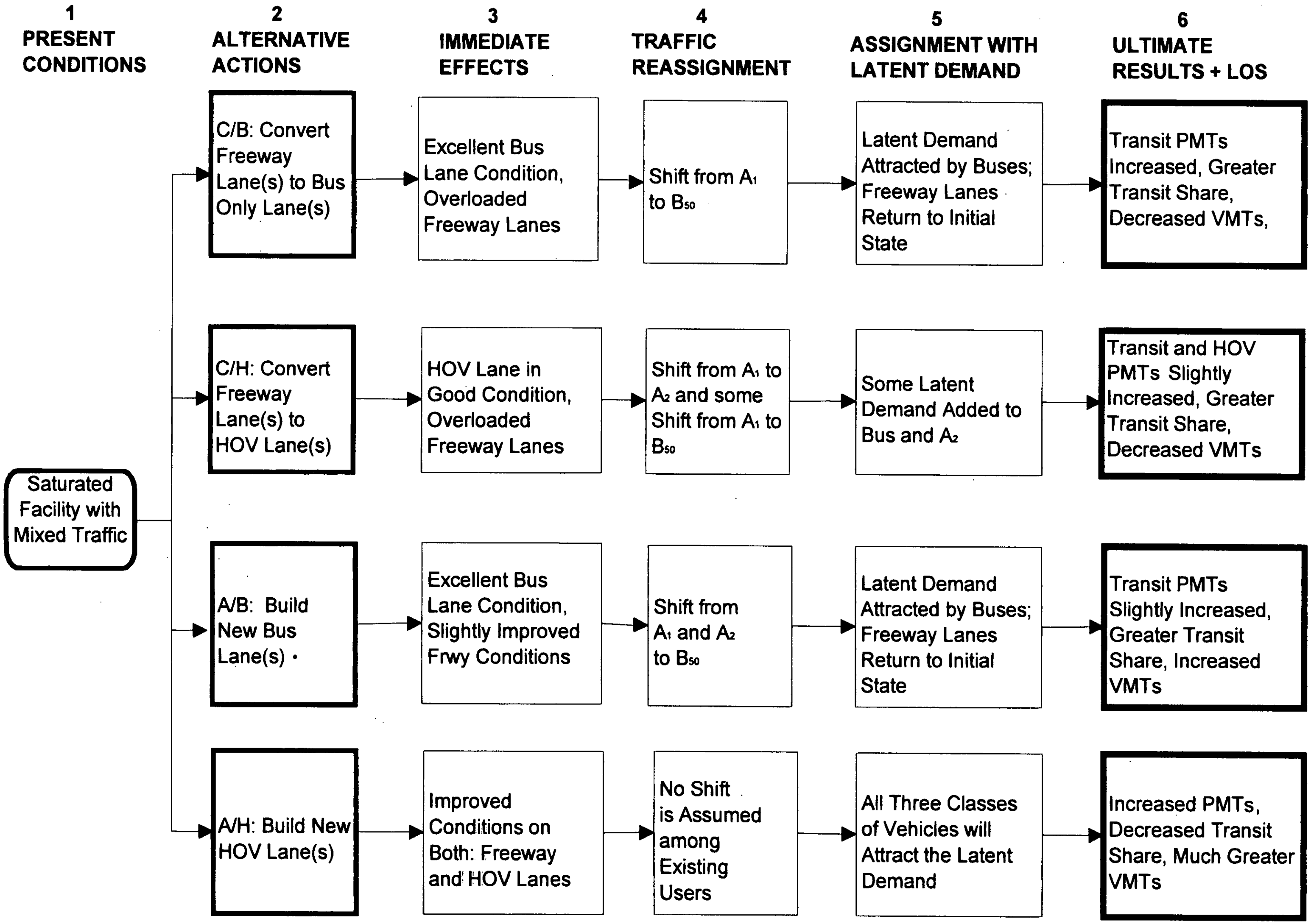

FIGURE 3 Flow chart of travel reassignments in model facility.

estimated and is shown as the "second stage" traffic assignment. The last set of boxes (*Column 6*) gives brief descriptions for the outcome of each of the four alternatives.

Computed traffic volumes and estimates of levels-of-service and of attraction of latent demand for the four alternatives are presented in Table 2. The wide columns with numerical values in this table represent the three assignments described in Columns 3, 4, and 5 of Figure 3. The two narrow columns with arrows in Table 2 give brief descriptions of the conditions and reasons for reassignments.

The last column of Table 2 shows that the C/B case is by far the best one with respect to achieving the goals of shifting the travel from automobiles to transit and reducing the total number of vehicles; this case has the smallest number of vehicles (6,160) carrying 14,800 of the 15,000 present and potential travelers. The average vehicle occupancy of 2.40 persons per vehicle is much higher than in the other three cases, and the modal split (last column) is 35 percent higher than in the A/B case (54 vs. 40 percent of the total) and is nearly 112 percent higher than in the cases with HOV facilities, T/H, and A/H (54 vs. 25 percent).

The least effective case with respect to achieving the goals is A/H: it attracts 2,500 of the 3,000 latent travelers (an increase of 21 percent over the initial 12,000 travelers), but it actually results in a significant (19 percent) *increase* in the number of vehicles by (from 8,060 to 9,570). This results in aggravated congestion and virtually no improvement in modal split and average vehicle occupancy.

The two cases with busways, C/B and A/B, clearly result in situations in which buses have a distinctly higher level of service than private automobiles. Thus, these two cases are far more successful in achieving the goal of shifting ridership from automobiles to transit. The two cases with converting the lanes (C/B and C/H) do not attract as many latent travelers as the cases with adding the lanes, but they result in lower vehicular volumes (24 and 5 percent, respectively), thus decreasing the VMT. Overall, with respect to promotion of transit and achieving modal split changes in its favor, the C/B case is the best, and the A/H case is the worst of the four alternatives.

The purpose of this model is to clarify the basic concepts of alternative preferential lanes and to select prioritized vehicle classes. The volumes and other numerical values were assumed to indicate relative more than absolute values. The findings of the model generally corroborate the real world experiences, as reported in (*4–7*); conversions of busways into HOV facilities increase total vehicular volumes on the freeway but decrease the share of transit riders; converted lanes are much more effective in shifting riders from automobiles to transit (and carpools) than construction of new lanes; opening up HOV facilities from public HOV to 4+, then to 3+ and, ultimately, to 2+ operations progressively diminishes the performance of such facilities as devices to encourage transit use.

GOALS IN HOV AND BUSWAY FACILITIES PLANNING

Present planning and implementation of HOV facilities, treatment of transit, and various related actions are not always based on clearly defined goals and objectives. Actually, the basic problem in urban transportation planning is the fundamental difference between traditional highway planning and the more recent systems approach, which is mandated by the Intermodal Surface Transportation Efficiency Act (ISTEA) and Clean Air Act Amendments (CAAA).

Traditional urban and highway planning has been generally aimed at providing adequate capacity for travel demand. Thus, highway congestion was to be solved by building more highways, as well as by increasing *vehicular capacity* through traffic engineering measures, intelligent transportation systems, and so on.

ISTEA and CAAA call for a broader approach: coordination of different modes for improved accessibility, increased efficiency, and reduction of negative impacts of transportation systems. The emphasis is on the *movement of persons and goods rather than vehicles*. Some solutions require changes in people's travel habits for long-range improvements of accessibility and creation of more livable cities. These policies are based on the experience of recent decades that urban traffic congestion cannot be solved simply by building more freeways and unlimited auto use. The problem of congestion is aggravated by the fact that auto users pay extremely low out-of-pocket costs and that they do not pay for most of the social and environmental costs they incur. An interesting analysis of this problem is discussed in a recent report by E.W. Johnson (*8*).

The differences between the traditional highway planning and multimodal systems approach are reflected in the selection among alternatives in solving highway congestion. As the flow chart in Figure 4 shows, the traditional approach of increasing highway capacity leads to results contrary to the ISTEA and CAAA requirements because it *increases VMT*. Policies leading to *reductions of VMT* consist of such actions as conversions of lanes to HOV, transit improvements, gas taxes, road pricing, and better land use planning.

Adding Versus Converting HOV Lanes

Adding HOV lanes represents the traditional approach of "solving" congestion by increasing vehicular capacity of highways. This action actually represents a "HOV incentive/SOV incentive" policy, and it usually results in decreased average auto occupancy. Although politically popular in the short run, it is extremely costly and counterproductive in the long run.

Conversion of lanes to HOV and *introduction of exclusive busways* represents a policy of "auto disincentive/bus and HOV incentive," which may be less popular in the short run, but it is the rational policy consistent with the long run transportation systems point of view.

Introduction of HOV facilities has been generally accepted as an effective way of encouraging higher vehicle occupancies and thus increasing efficiency of highways. Converting existing lanes into HOV lanes achieves this goal. However, when new HOV lanes are constructed, they decrease congestion in the short run, but they also usually decrease average occupancy because additional capacity encourages SOV travel. Thus, if the decrease of VMT is the goal, conversion should be preferable to new construction under nearly all conditions.

Why are most cities then adding HOV lanes instead of converting lanes into HOV facilities? This is actually a remnant of traditional highway planning hidden behind the explanation that "taking lanes from general traffic is politically unacceptable." The 1977 court-ordered discontinuance of the Santa Monica HOV lanes is frequently quoted as a "proof" for this claim. However, this can be seriously challenged.

First, many regulatory measures must overcome opposition of various affected groups: one-way street patterns, prohibition of street parking, or introduction of pedestrian malls nearly always have initial opponents. Yet, they are introduced for long-term effi-

TABLE 2 Model of Corridor Travel and Likely Modal Redistribution Due to Introduction of Upgraded Lanes

C/B. CONVERT A FREEWAY LANE TO A BUS LANE

	Present volumes + immediate shift					Transitional state					Ultimate state			
Vehicle classes	A_1	A_2	B_{50}	Total	⇨ Overloaded freeway lanes; modal shift A_1 to B_{50} and A_2 to B_{50} ⇨	A_1	A_2	B_{50}	Total	⇨ The bus attracts latent demand of 2000 pass. (1000 bus captives + 1000 of those who have choice). Some latent demand is assigned to A_1 and A_2 (400 + 400). ⇨	A_1	A_2	B_{50}	Total
Persons/hour	7000	2000	3000	12000		4800	1200	6000	12000		5200	1600	8000	14800
Vehicles/hour	7000	1000	60	8060		4800	600	120	5520		5200	800	160	6160
Veh/hour/freeway lane Veh/hour/bus lane*	2000 → 2667 0 → 60 x 1.5 = 90					1800 120 x 1.5 = 180					2000 160 x 1.5 = 240			
LOS for freeway lane LOS for bus lane	E → F E → A					D A					E A			
Avarage vehicle occupancy	Total 1.49		A_1 and A_2 only 1.12			Total 2.17		A_1 and A_2 only 1.13			Total 2.40		A_1 and A_2 only 1.13	
% pass/h by transit	25.0%					50.0%					54.0%			

C/H. CONVERT A FREEWAY LANE TO HOV LANE

	Present volumes + immediate shift					Transitional state					Ultimate state			
Vehicle classes	A_1	A_2	B_{50}	Total	⇨ Overloaded freeway lanes; modal shift A_1 to A_2 and some A_1 to B_{50} ⇨	A_1	A_2	B_{50}	Total	⇨ Some latent demand may be attracted by the bus and A_2 (500 + 500). ⇨	A_1	A_2	B_{50}	Total
Persons/hour	7000	2000	3000	12000		6000	2600	3400	12000		6000	3100	3500	13000
Vehicles/hour	7000	1000	60	8060		6000	1300	68	7368		6000	1550	78	7628
Veh/hour/freeway lane Veh/hour/HOV lane*	2000 → 2333 0 → 1000 + 60 x 1.5 = 1090					2000 1300 + 68 x 1.5 = 1402					2000 1550 + 78 x 1.5 = 1667			
LOS for freeway lane LOS for HOV lane	E → F E → B					E C					E C/D			
Average vehicle occupancy	Total 1.49		A_1 and A_2 only 1.12			Total 1.63		A_1 and A_2 only 1.17			Total 1.70		A_1 and A_2 only 1.21	
% pass/h by transit	25.0%					28.3%					26.9%			

* Car equivalency factor of 1.5 is used for buses in order to determine the LOS (HCM Chapter 12-10)

(continued on next page)

TABLE 2 (*continued*)

A/B. ADD A BUS LANE

	Present volumes + immediate shift				⇨	Transitional state				⇨	Ultimate state			
Vehicle classes	A_1	A_2	B_{50}	Total	Due to the big difference in LOS some shift from A_1 to B_{50} and A_2 to B_{50} is expected. ⇨	A_1	A_2	B_{50}	Total	The bus attracts latent demand (1000 bus captives + 1000 of those who have choice). Some latent demand is assigned to A_1 and A_2 (500 + 500). ⇨	A_1	A_2	B_{50}	Total
Persons/hour	7000	2000	3000	12000		6500	1500	4000	12000		7000	2000	6000	15000
Vehicles/hour	7000	1000	60	8060		6500	750	80	7280		7000	1000	120	8120
Veh/hour/freeway lane Veh/hour/bus lane	2000 → 2000 0 → 60 x 1.5 = 90					1800 80 x 1.5 = 120					2000 120 x 1.5 = 180			
LOS for freeway lane LOS for bus lane	E → E E → A					D A					E A			
Avarage vehicle occupancy	Total 1.49		A_1 and A_2 only 1.12			Total 1.65		A_1 and A_2 only 1.10			Total 1.84		A_1 and A_2 only 1.12	
% pass/h by transit	25.0%					33.3%					40.0%			

A/H ADD A NEW HOV LANE

	Present volumes + immediate shift				⇨	Transitional state				⇨	Ultimate state			
Vehicle classes	A_1	A_2	B_{50}	Total	No modal shift is assumed among the existing riders. ⇨	A_1	A_2	B_{50}	Total	All three classes will attract the latent demand (1000 + 1000 + 500). ⇨	A_1	A_2	B_{50}	Total
Persons/hour	7000	2000	3000	12000		7000	2000	3000	12000		8000	3000	3500	14500
Vehicles/hour	7000	1000	60	8060		7000	1000	60	8060		8000	1500	70	9570
Veh/hour/freeway lane Veh/hour/HOV lane	2000 → 1750 0 → 1000 + 60 x 1.5 = 1090					1750 1000 + 60 x 1.5 = 1090					2000 1500 + 70 x 1.5 = 1605			
LOS for freeway lane LOS for HOV lane	E → C/D E → B					C/D B					E C/D			
Average vehicle occupancy	Total 1.49		A_1 and A_2 only 1.12			Total 1.49		A_1 and A_2 only 1.12			Total 1.51		A_1 and A_2 only 1.16	
% of pass/h by transit	25.0%					25.0%					24.1%			

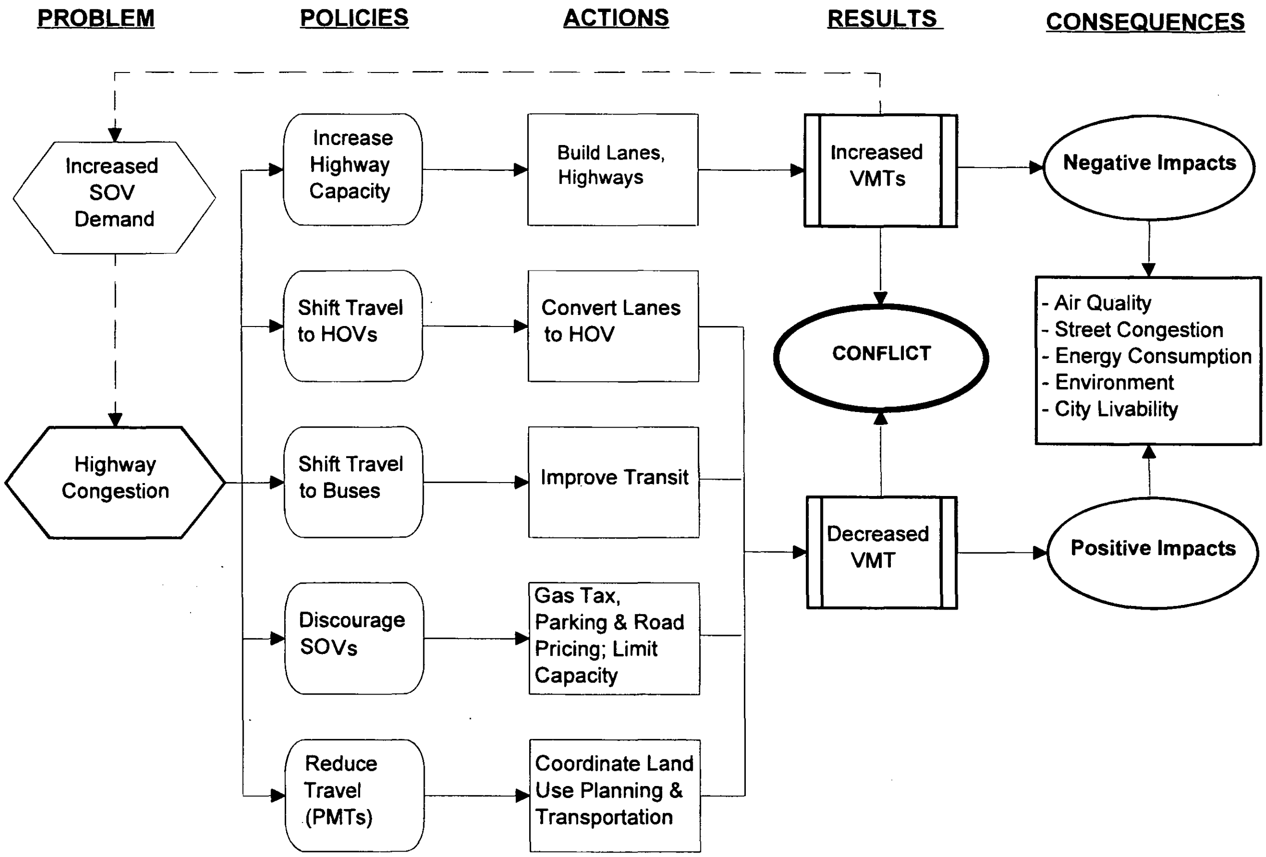

FIGURE 4 Consequences of different policies for relief of highway congestion.

ciency and social benefits. The Santa Monica Freeway decision by one judge who had little understanding of the complex urban transportation problems should not emasculate freeway planning and operations forever.

Second, conditions in urban transportation have changed greatly since 1977: so have public attitudes. In many cases there has been strong support for conversion to HOV lanes (*9*), but highway departments failed to use it; instead, they adopt the simplistic, traditional solution of constructing more lanes. These practices should be carefully reexamined.

Improving Definition of HOV

Although there is a rather strong consensus that the SOVs are by far the least efficient mode of travel from the systems point of view (although very attractive from the individual's point of view), the trend has been to classify all vehicles with 4+, 3+, or even 2+ occupants into one indistinguishable "HOV" category. This is in many situations unjustifiable.

Wherever there is present or potential substantial bus ridership, buses should be given exclusive priority over all other vehicles, not only because they are public rather than private service, but also because of their far greater physical productivity than all other highway passenger vehicles. In the example from Dallas (*5*), the introduction of an HOV lane increased the volume of HOV by 45 percent, but it also increased the SOV volume by 20 percent (consistent with the results from the described model). Thus, although HOV (without buses) have an average occupancy of 2.15, approximately two times greater than vehicles in general purpose lanes, buses have an average occupancy of 28, or approximately 11 times greater than the HOV. It would be logical to give full preference to buses, which have a far greater productivity than all other vehicles.

CONCLUSIONS

The trend of changing busways into HOV, and then from 4+ to 3+ and 2+ HOV facilities, is a clear case of backsliding of bus priorities. It represents a major obstacle to creation of *Bus Transit Systems* in U.S. cities (*2*). *These changes have practically eliminated busways as an option for high performance transit with strong image of independence from general traffic.*

Having lost the ability to secure separation of buses by regulation, cities that want to build transit systems competitive with auto travel must use physical separation of transit rights-of-way. Consequently, although busways are one of the alternatives for introducing high performance transit in other countries, U.S. cities now practically have rail modes as the only option.

HOV facilities lose many of the advantages that busways had. This is most obvious for the 2+ HOV facilities, which actually have the same traffic composition as the general purpose lanes except that they do not permit trucks and SOVs. The speed, reliability, safety, and driving comfort are negatively affected, and buses lose

both their superior service and the distinctive image that they have on busways. Competition to buses is not only assisted by allowing carpools into bus lanes, but often auto drivers stop at bus stops and "steal" bus passengers (there have even been studies on how to encourage this phenomenon!). This has led to further diversion of transit riders and eventual degradation of bus services.

As another element of downgrading bus services, many HOV facilities and bus services are limited only to peak hours, and during other hours the HOV lanes revert to lanes for general traffic. Buses are now again mixed with other traffic with only a slight distinction of HOV facility; they operate for a limited number of hours and thus do not have an image of permanence and reliability. They simply represent peak hour capacity enhancing commuter services, rather than a distinctive high quality transit that serves the city throughout the day.

RECOMMENDATIONS

Transportation policies influencing modal split in our metropolitan areas are crucial for solving many urban problems. The policies toward buses should be based on careful consideration of long-term comprehensive system impacts, rather than on short-term operational changes aimed at increasing vehicle-carrying capacity of the highway. To achieve this goal the following revisions of policies and practices are recommended:

1. The trend in most cities developing HOV facilities has been to change from the best to the least favorable priority for transit. This is directly counteracting the goal of discouraging use of SOV, required by the CAAA as well as by the ISTEA. FTA should adopt a clear policy of maximum upgrading of *buses operated as regular, all-day bus service*, rather than buses as supplemental commuter services on an auto-oriented freeway network.
2. The concept of *busway* should not be considered superseded by the concept of *HOV facility*. Regardless of the successes of HOV facilities in regulating flows of different vehicle categories, in many cases *exclusive busways* and *bus lanes* should be used as the basic elements in creating high quality regular bus services. Such facilities are a *sine qua non* for introduction of *bus transit systems*, which have a great, presently underused potential in many cities and metropolitan areas.
3. Busways such as those in Ottawa, Pittsburgh, and other cities should not be downgraded by referring to them as "HOV facilities."
4. Conversion of existing general purpose into priority lanes should be preferred to adding of new lanes. It creates an automobile disincentive and transit incentive at the same time.
5. Transit funds should not be used for construction and operation of HOV facilities unless it is clearly shown that the competitive position of transit with respect to other modes would be improved significantly.
6. Any conversion of the type of facility (busway, HOV 4+, etc.) should be subjected to the environmental impact statement process because it has major impacts on the transportation system and urban environment.

ACKNOWLEDGMENTS

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PART 3

Technology

Automated People Mover System Planning Cost Model Using Visual Basic

SRINIVASA R. MANDALAPU AND WILLIAM J. SPROULE

Cost models were developed for a research project to examine fixed rail service to airports. One proposal for a station located on a rail line near the airport called for an automated people mover (APM) system or shuttle buses that would link this station with the airport terminal area. A model was developed and used in the research to determine planning parameters and cost for an APM system. The model is used to calculate the total cost, annual operating cost, equivalent annual cost, cost per passenger, and other operational details such as average operating speed, travel time, number of cars required, and guideway configuration (single or dual shuttle, pinched loop). The inputs to the model can be grouped into four categories: general information, construction details, operational characteristics, and operating hours and passenger information. Default values based on historic and typical data are incorporated in the model, but the user can specify or change individual values. The model was written using Visual Basic 3.0. Menus make the model user-friendly. The model gives planners an easy-to-use method for determining planning costs and characteristics for an APM system. The model, its limitations, and an example application are described.

Automated people mover (APM) systems are often considered for major activity centers and airport applications. These systems provide circulation and distribution capabilities in high-density developments (*1,2*). During the preliminary planning of such systems, it is necessary to consider various options. An analysis will usually include an approximate cost of each option, and operational requirements. A model was developed for planners to use during the conceptual planning stage. This paper describes features and limitations of the model.

The model was developed for a research project that examined fixed rail service to airports. The efficacy of APM links between nearby rail station(s) and airport terminal(s) (*3*) was studied. Although the model was developed for an airport, it can easily be adapted for other major activity centers.

APM SYSTEMS

APM systems are a class of transit systems in which fully automated unmanned vehicles operate on fixed guideways along an exclusive right-of-way. The electrically powered vehicles may operate either as single units or in trains (*4*).

More than 60 APM systems operate around the world, and several more are under construction or are being planned. APMs have found applications in major activity centers such as inner cities, airports, and amusement parks. APM systems reduce walking distances and ease congestion in and around high-density developments. One of the most common applications of APM systems has been at airports. Of the 18 airports with APM systems, 3 link terminals with fixed rail stations: (Birmingham, U.K.; London Gatwick; and Paris Orly airports) (*2,4,5*). Several airports, such as Oakland, San Francisco, and Boston Logan International, are considering similar links to rail lines.

The basic components of an APM system include right-of-way, guideway, stations, power supply and distribution systems, control and communication systems, vehicles, and maintenance facilities. The guideway is typically elevated or in-tunnel as an exclusive right-of-way is required. The costs of control and communication systems are higher than other transit systems because of the degree of automated operations. The cars or vehicles on APM systems are typically about the size of a standard urban bus. Generally, less seating is provided and more area is allocated for standing as the ride is usually short. The operating and maintenance costs include guideway maintenance costs, such as heating and cleaning of the guideway, energy costs, vehicle maintenance costs, and administrative costs. Because of the differences in physical configurations and operating characteristics, it is difficult to estimate costs for a typical installation. However, the average unit costs of North American APM system components that were used in the model are presented in Table 1 (*2,6*). The costs were adjusted to 1993 dollars using the *Engineering News Record* Cost Index (*7*).

VISUAL BASIC

Visual Basic is one of the programming systems to create event-driven applications in the Windows environment. This system allows a user to create attractive applications with graphic interface. In traditional procedural application, execution starts with the first line of executable code and follows a determined path through the application and call procedures as needed. In event-driven programs (or Visual Basic applications), a user action or system event executes an event procedure. At different stages of the application, the user will have various choices and the application responds to the user's choice. This creates a friendly interface with the application (*8*). Although other programming systems are available to create event-driven programs, Visual Basic was chosen to create the APM Cost Model because of its simplicity and flexibility.

Visual Basic Version 3.0 is used to develop the model. This is Microsoft Windows (3.1 Version) application developed on an IBM-compatible 386 computer with a super VGA card. The model can be run on a similar or higher configuration.

MODEL

The objective of the model is to calculate the total cost of the project, equivalent annual cost, annual operating cost, cost per passen-

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TABLE 1 Unit Capital Costs and Operating and Maintenance Costs of North American APM Systems

	Cost (millions, 1993 U.S.)
Capital Costs	
Right-of-way cost (per km)	5.69
Guideway underground (per km)	7.41
Guideway at-grade/elevated	3.99
Stations (per station)	1.05
Vehicle (per vehicle)	1.01
Control and communication systems (per km)	2.40
Power Utilities (per km)	0.54
Maintenance and support facilities (per km)	1.45
Operating and Maintenance Costs	
$/Passenger.km	0.19
$ /Veh. km	6.00
$ /Veh.hour	123.00

Source: Characteristics 1992, Tsukio 1985.

ger, and other operational details such as number of cars required during peak hours of operation, and number of trains required for peak-hour and off-peak-hour operation. The flow chart shown in Figure 1 presents the general interaction of different components of the model. The inputs to the model are grouped in four categories:

- General information,
- Construction details,
- Operational characteristics, and
- Operating hours and passenger information.

The general information includes length of the route, numbers of stations planned, prevailing interest rate, and inflation rate. The number of stations can be entered directly; the default value is 2. The default interest and inflation rates are set at 7 percent and 3 percent, respectively. These rates change periodically. Since these rates are applicable for the life of the project, generally accepted rates for the life of the project may be chosen. The effect of these rates is not as significant if the project life is long, and the effect is not critical when comparing different alternatives with the same interest and inflation rates. The interest rate and inflation rate are used to calculate the capital recovery factor (Equation 1). The expected life of components of APM systems used in this research are presented in Table 2 (*9*). Equivalent annual costs were determined using the capital recovery factor (*10*).

$$\mathrm{CRF} = I_{ef}(1 + I_{ef})^n/[(1 - I_{ef})^{n-1}] \quad (1)$$

where

CRF = capital recovery factor,
n = expected life of component in years, and
I_{ef} = combined interest-inflation rate

$$= (1 + I_p) * (1 + i_{in}) - 1 \quad (2)$$

where I_p is the prevailing interest rate, and I_{in} is the inflation rate.

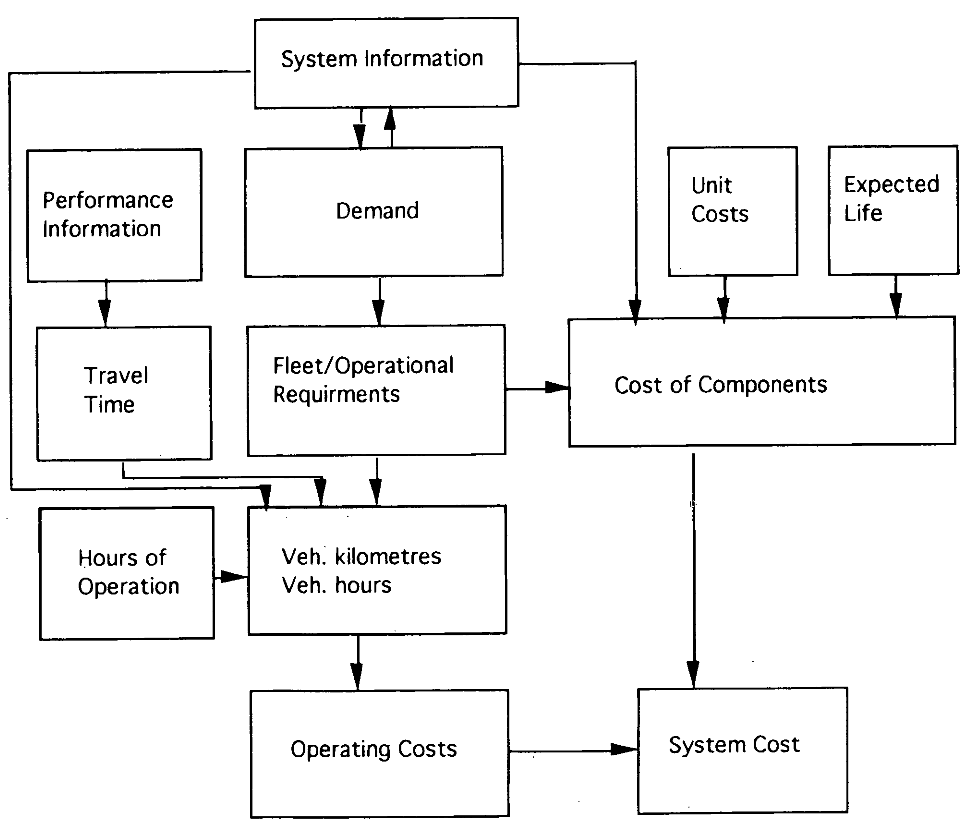

FIGURE 1 Cost model flow chart.

TABLE 2 Expected Life of APM System Components

Component	Expected life (years)
Tunnel, Elevated, or Cut and Cover structures	100
At-grade stations	50
Underground stations	100
Track structure	30
Power supply and distribution system	30
Control and communications	25
Vehicles	25
Maintenance and storage facilities	50

The second category identifies the percentage of the guideway that would be underground, elevated, or at-grade. The number of underground stations is calculated from the length of construction below-grade, and the number of elevated stations is calculated from the length of the elevated construction. The remaining stations are assumed to be at-grade.

The third category requires performance characteristics of the proposed system. The round-trip time is calculated based on the performance characteristics of the system using the equations of dynamics. The characteristics needed are (*a*) dwell time at stops, (*b*) maximum speed of the train, and (*c*) acceleration and deceleration rates of the train. The default values for these characteristics are chosen from the existing systems and are set at 30 sec, 42 km/hr, 1.1 m/sec^2, and 1.1 m/sec^2, respectively. The hours of operation of peak-hour service and off-peak hour service are defaulted at 4 and 16 hr, respectively.

The fourth category identifies average daily passengers, the percentage of average daily passengers in the peak hour, headway information, vehicle capacity, round-trip time, and hours of operation. The default for the peak-hour passengers of the average daily passengers is set at 10 percent. The defaults for peak and off-peak headways are set at 10 and 15 min, respectively. Since cars at most existing airport systems have a capacity of about 80 passengers, the same was chosen as default.

Peak-hour passenger demand is calculated by considering the peaking, directional split, and occupancy rate. Fleet calculations are done based on the round-trip times and passenger demand. The vehicle kilometers are calculated by considering both peak and off-peak operations, and weekday and weekend operations. The operating and maintenance cost is calculated based on vehicle kilometers traveled.

The model takes the cost data of the components and calculates the equivalent annual cost and average total cost of the system. The number of cars required for operation and trains during peak and off-peak hours is calculated. The model assumes 90 percent occupancy of cars, 60-40 split between the peak and off-peak direction of traffic. Ninety percent of fleet size was assumed to be required for peak-hour operation. The model calculates number of car kilometers, operating cost, cost per passengers, number of trains during peak and off-peak hours, number of cars required for peak-hour operation, and number of cars per train during peak hours and off-peak hours. It also determines the travel time for a single trip.

The model also selects the type of guideway and operation, such as shuttle operation on a single guideway, double shuttle on a dual guideway, or pinched loop operation on a dual guideway. If a system operation requires one train, the model selects a shuttle service on a single guideway. If two trains are required for operation, a dual guideway is selected with either double shuttle operation or pinched loop operation. If more than two trains are required, the pinched loop operation is selected. The total cost of guideway depends on which guideway (single, dual, or pinched loop) is selected for the operation.

The model output is displayed in two parts. The first part displays the operating requirements, such as type of guideway required, travel time, fleet requirements, number of cars per train, and number of trains per day. The second part displays the annual passengers, total cost of system, operating and maintenance costs, equivalent annual cost, and cost per passenger. File options such as file open, file close, save data, and save results are also available.

LIMITATIONS

The model calculates the approximate costs of an APM system, which are useful for preliminary planning purposes. In detailed planning, more specific information and data will be available and may not match the assumptions made in the model.

The defaults used in the model and typical range of values are presented in Table 3. The length of guideway and passenger information must be entered to run the program, however, other input data can be set to default values by option.

EXAMPLE

The following example is chosen to demonstrate the model:

- Guideway length: 4.0 km.
- Number of stations planned: 6 (includes 4 en route stations).
- Interest rate: 10 percent.
- Inflation rate: 4 percent.
- Percentage of tunnel construction: 10 percent.
- Percentage of elevated construction: 70 percent.

TABLE 3 Model Defaults and Possible Range for APM Characteristics

Characteristic	Default Value in Model	Range
Interest rate (%)	7	prevailing rate
Inflation rate (%)	3	prevailing rate
Number of stations	2	> 1
Underground construction (%)	0	0 to 100
Elevated construction (%)	100	0 to 100
At-grade construction (%)	0	0 to 100
Peak hour factor	0.1	0.05 to 0.2
Peak headway (min.)	10	1.5 to 30
Off-Peak headway (min.)	20	1.5 to 60
Capacity of car	80	36 to 100
Dwelling time (sec.)	30	20 to 60
Cruise speed (kmph)	42	25 to 47
Acceleration rate	1.1	0.5 to 1.1
Deceleration rate	1.1	0.5 to 1.3
Peak hour operation (hrs.)	4	2 to 6
Off-peak operation (hrs.)	16	15 to 20

- Percentage of at-grade construction: 20 percent.
- Expected average daily passengers: 8,000.

The remaining input data assume default values.

Figures 2 through 6 show the input windows of the model. The model is run for these data, and results are presented in Figures 7 and 8.

CONCLUSIONS

A simple tool for estimating the costs of APM systems is presented for preliminary planning purposes. The model can be used to calculate total cost, annual operating cost, equivalent annual cost, cost per passenger, and other operational details for a proposed APM system.

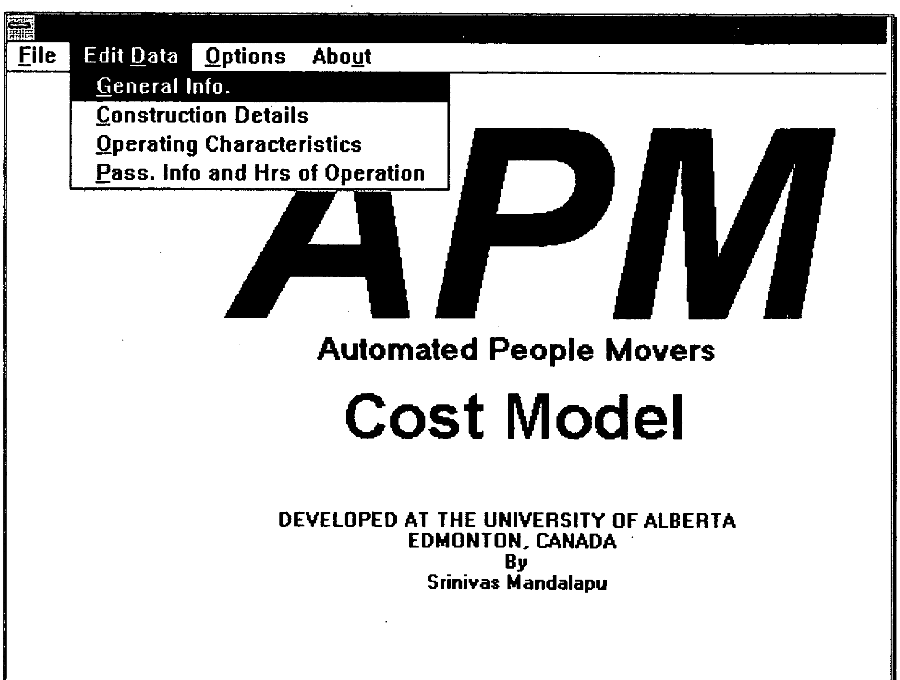

FIGURE 2 Opening window of model.

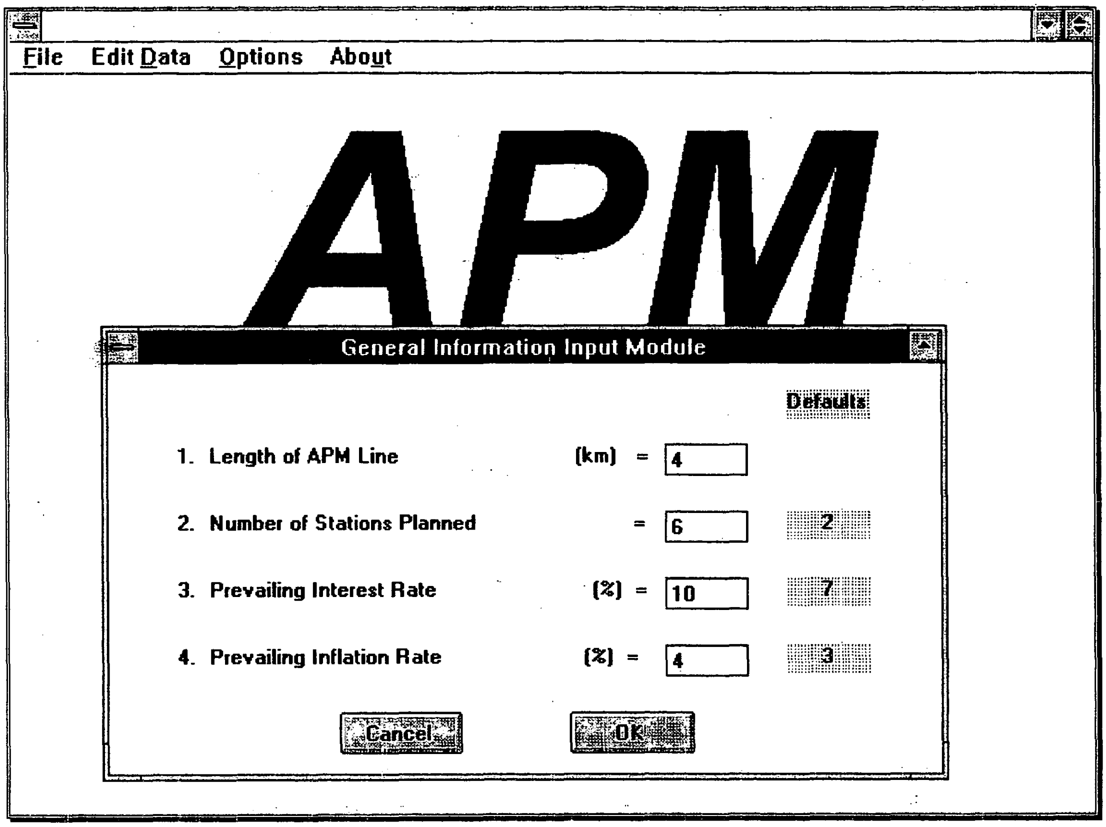

FIGURE 3 General information input window.

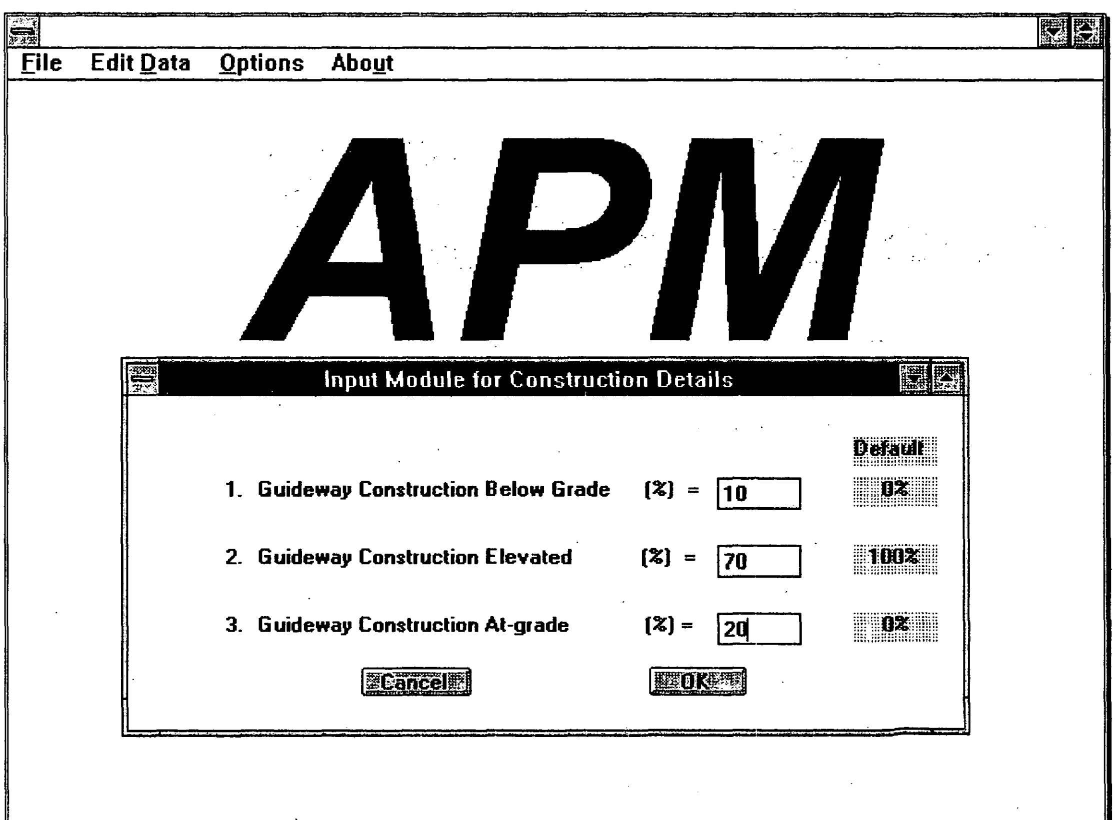

FIGURE 4 Construction details input window.

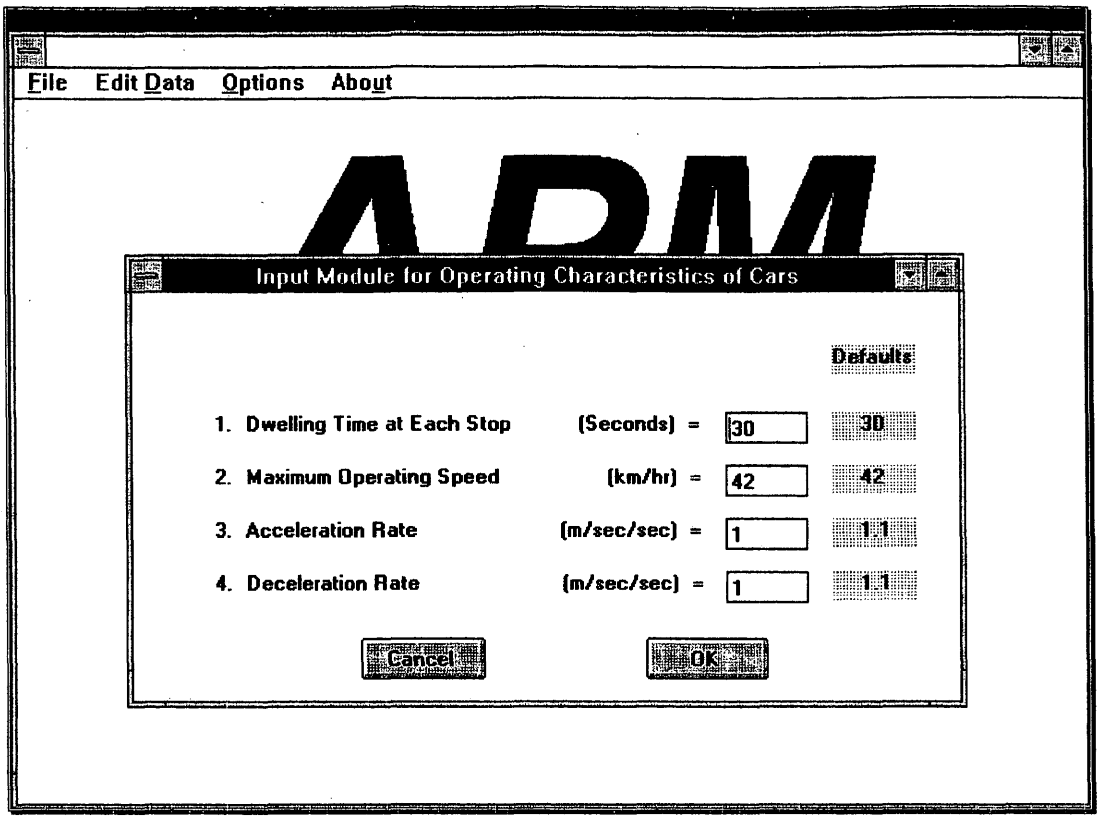

FIGURE 5 Operating characteristics input window.

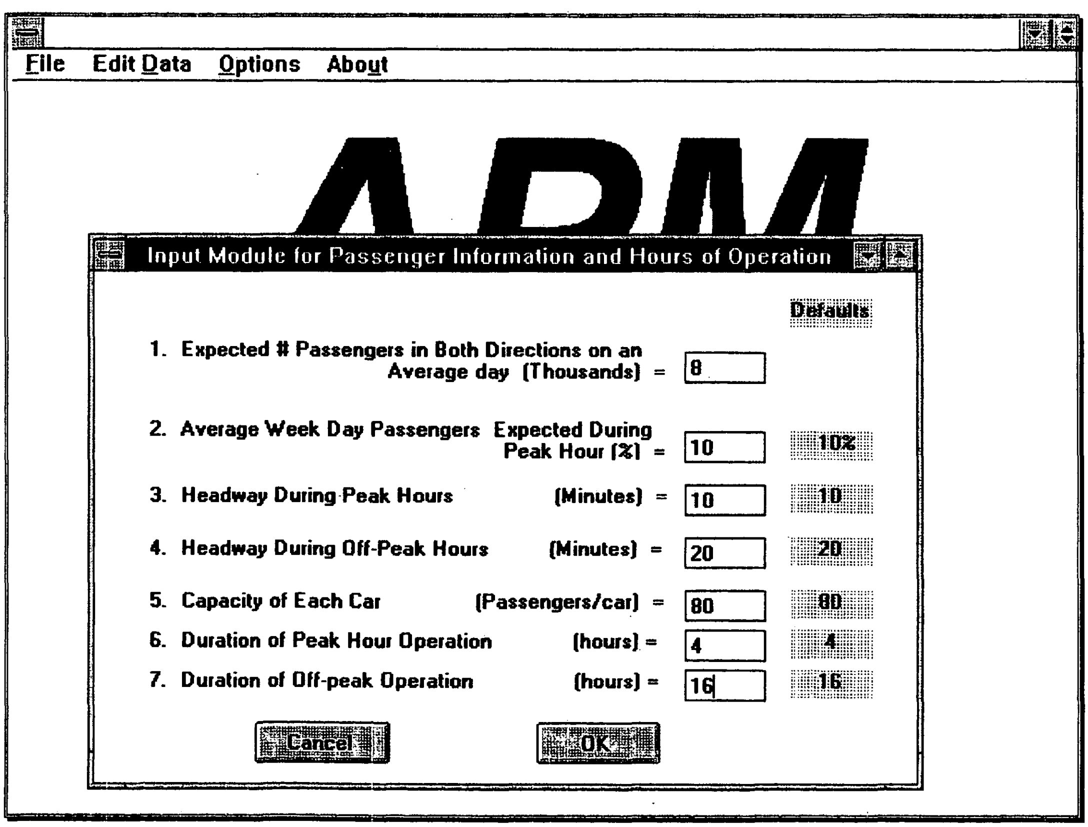

FIGURE 6 Operating hours and passenger information input window.

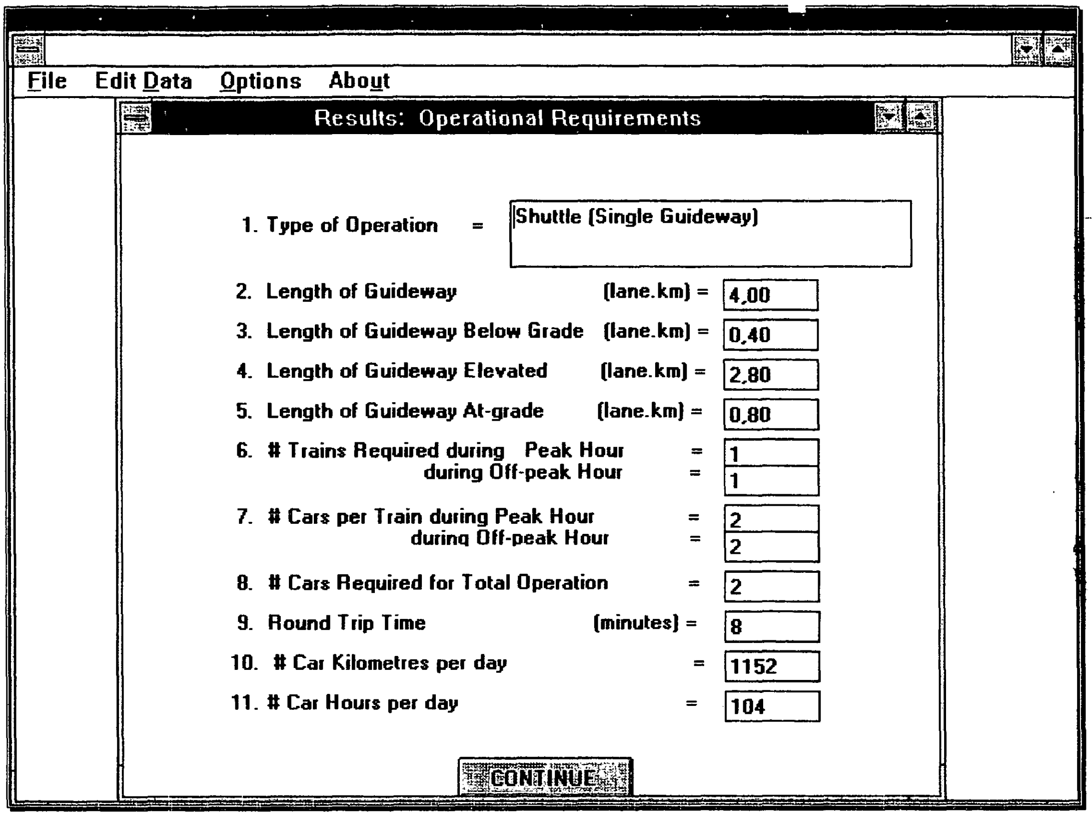

FIGURE 7 Output window for operating details.

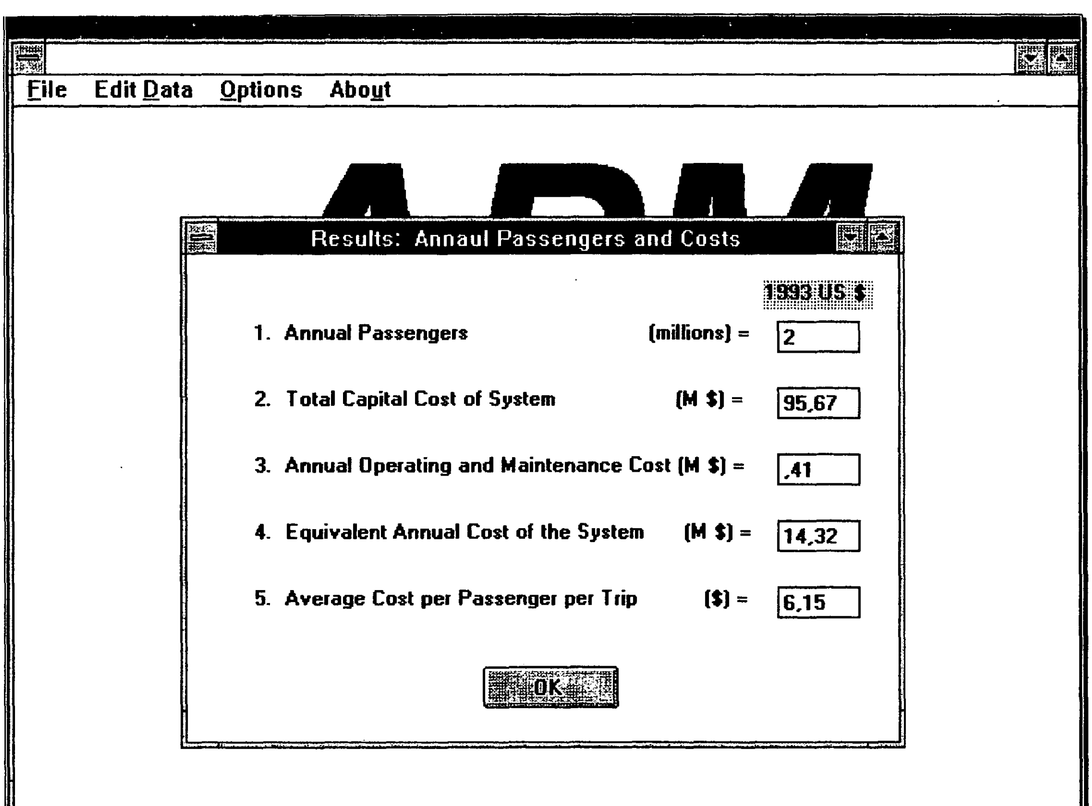

FIGURE 8 Output window for cost details.

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Cost/Revenue Analysis for Mission Valley Transit Development

THOMAS M. RICHERT AND JOHN GLANDER

In economic terms, the development of a light rail project is compared with a personal automated people mover project in the Mission Valley section of San Diego, California. The two developments are analyzed as investments in the public transportation infrastructure and the differences between the two as investments are evaluated.

Five miles north of downtown San Diego is Mission Valley, a commercial center with a collection of offices, shopping centers, and hotels. Mission Valley generates 110,000 internal daily trips, nearly all by automobile (*1*). As a result, traffic in the area can become congested, with over half the time spent on a given trip consumed by waits at intersections. It is suspected that the congestion limits commerce, by discouraging discretionary trips. Examples of discretionary trips include lunches and extensions of shopping trips to additional shopping centers. Two organizations are proposing solutions to alleviate these conditions, the San Diego Metropolitan Transit Development Board (MTDB) and a local transportation advocacy group, the San Diego Maglev Organization. Figure 1 locates Mission Valley within the San Diego region.

MTDB has completed the design for an extension of the San Diego Trolley system into Mission Valley. The trolley route runs along a line from Old Town, near Interstate 5, 9.8 km (6.1 mi) west to Jack Murphy Stadium, near Interstate 15. The MTDB has planned nine stations, each serving existing or planned activity centers. According to published accounts, difficulties in obtaining environmental approvals may delay construction. The trolley route traverses wetland and flood plain areas, and these environmental conditions require significant mitigation measures.

In the summer of 1994, the San Diego Maglev Organization (SDMO) endorsed a separate transportation improvement plan for Mission Valley. The group recommended a 43.5-km (27-mi) network of personal automated people movers (APMs), also known as personal rapid transit, as the best method for conveying people throughout the commercial center. It would serve all areas served by the trolley, and extend west toward Sea World and the Sports Arena, while serving the hotels and office buildings south of Interstate 8. The small guideway would be built next to existing streets and developed areas, and, therefore, will be environmentally benign.

COST COMPONENTS

It is possible to classify costs for both the trolley and personal APM systems into three basic component groups. The first component group includes the guideway, stations, and any central facilities, including maintenance buildings and control centers. A second group includes vehicles and vehicle accessories. A third group includes systems for controlling vehicle operations, including both hardware and software components. Cost comparison tables for the trolley and personal APM systems follow. Table 1 compares capital cost, and Table 2 compares operating cost. Trolley costs were provided by the MTDB. Personal APM costs were developed from information provided by various automated people mover manufacturers with systems in operation.

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Guideway, Stations, and Central Facilities

The vehicle guideway is the most significant capital cost for both the trolley and the APM. Stations, maintenance facilities, and offices represent fewer significant expenditures. The guideway for the trolley is, in part, constructed as an earthen berm, and in other parts as an elevated concrete structure. Guideway widths are up to 6 m (20 ft). The personal APM guideway is constructed of steel, and with a width of 1¼ m (4 ft) is much smaller.

Capital costs for the trolley infrastructure are $208 million, $10.6 million/lane-km ($17 million/lane-mi). Capital costs for the APM infrastructure are $175 million, $4 million/lane-km ($6.5 million/lane-mi). As compared to the trolley, the comparatively low unit cost is a result of a smaller guideway size. The small size provides three advantages: (a) guideway sections can be manufactured in factory conditions, (b) the guideway can be assembled quickly with less expensive construction equipment, and (c) the personal APM serves a wider area with more stations, improving system accessibility.

The MTDB projects maintenance and administrative costs for the trolley at $0.39/passenger-km ($0.62/passenger-mi), with the administrative portion being one-half of that cost. APM network maintenance and administrative costs are estimated to be $0.03/passenger-km ($0.05/passenger-mi). While part of the difference in costs may be because of the relative size of administrative staffs, it is mostly because of the greater use rate expected for the personal APMs.

Figure 2 illustrates the service area distinctions between the trolley and personal APM for a subregion within Mission Valley, including Fashion Valley Shopping Center, Hazard Center, and Mission Valley West Shopping Center. The solid thick line represents the trolley alignment, with the two rectangular blocks locating planned stations. The personal APM guideway is a series of connected loops, running parallel to surface streets. Note that one loop runs around the perimeter of the Fashion Valley Shopping Center. Small solid circles locate possible APM stations. In the same service area in which the trolley has two stations, 21 stations serve the APM network. More off-line stations could be added to the network, if suggested as needed by the transportation marketplace.

FIGURE 1 Mission Valley location map.

Vehicles

The trolley and personal APM approaches differ dramatically in vehicle size and number. The trolley is on the scale of the traditional, large-passenger vehicle first used to allow a single operator to transport large groups of people. Using computer automation, the APM vehicles are much smaller, holding up to three passengers. The small vehicle strategy provides the transit operator with a strategy for serving the varied needs of thousands of passengers.

Capital cost for a two-car trolley vehicle is $1.2 million, or $18,750 per available seat. Estimated capital costs for an APM vehicle are $45,000, or $15,000 per available seat. Despite the narrow difference, the APM has a higher level of comfort and safety built into the APM vehicle. The APM also bears the cost of communications and entertainment consoles. Although the trolley offers additional standing room, from a cost-per-seat basis, large passenger vehicles are not necessarily more efficient than small passenger vehicles. Small vehicles are more efficient in terms of the ratio of passenger-kilometers to available seat-kilometers (2).

The primary operating cost for propelling the two different vehicles is for electric power. It requires further analysis to learn how the trolley and APM compare with respect to energy use. The constant acceleration and deceleration of the heavy trolley vehicle should require significant amounts of energy. The APM does not stop at intermediate stations, and therefore needs less power for acceleration.

Control Systems

The San Diego Trolley is a manually driven system, with the operator controlling vehicle speed, and an engineer controlling track switching. The technology used for trolley control systems is essentially unchanged from century-old railroad technology. Personal APMs are automatically controlled vehicles, with a handful of operators remotely supervising the operations of hundreds of vehicles. The APM uses state-of-the-art control system technology only available for the last 5 years, given enhancements of the computer microprocessor.

Capital costs for the trolley control systems are small, consisting of a few rail switches and signal lights. Estimated costs for Mission Valley are $231,000/lane-km ($372,000/lane-mi). The APM requires an extensive communications system, networking local information processors with vehicles and the central command station. The cost for this system is estimated at $847,000/lane-km ($1,363,000/lane-mi). Greater costs are a result of additional communication hardware installed on the guideway, and the cost of programming a site-specific network.

The cost situation reverses with respect to operating costs. Since each trolley vehicle requires an operator, the cost per seat-

TABLE 1 Capital Cost Comparison

Component	Trolley Per Lane-Km	Trolley Mission Valley	Personal APM Per Lane-Km	Personal APM Mission Valley
Administration	$306,000	$6,000,000	$260,000	$11,300,000
Engineering	$433,000	$8,500,000	$155,000	$6,750,000
Right-of-Way	$1,731,000	$34,000,000	$0	$0
Prof. Services	$51,000	$1,000,000	$281,000	$12,200,000
Constr. Mgmt.	$611,000	$12,000,000	$143,000	$6,200,000
Construction	$6,200,000	$122,000,000	$1,912,000	$83,100,000
Utility Relocat.	$143,000	$2,800,000	$0	$0
Ctrl. Systems	$231,000	$4,540,000	$847,000	$36,800,000
Vehicles	$1,003,000	$19,700,000	$2,174,000	$94,500,000
Contingency	$986,000	$19,366,000	$440,000	$19,150,000
Totals	**$11,695,000**	**$229,906,000**	**$6,212,000**	**$270,000,000**

TABLE 2 Operating Cost Comparison

Component	Trolley Annual	Trolley Passenger-Km	Personal APM Annual	Personal APM Passenger-Km
Administration	$1,248,000	$0.20	$246,000	$0.002
Maintenance	$1,228,500	$0.195	$2,075,000	$0.016
Prof. Services	In Admin.	$0.00	$246,000	$0.002
Insurance	In Admin.	$0.00	$164,000	$0.001
Security	In Admin.	$0.00	$410,000	$0.003
Promotion	In Admin.	$0.00	$164,000	$0.001
Pass. Services	In Admin.	$0.00	$410,000	$0.003
Operators	$468,000	$0.075	$1,230,000	$0.009
Power	$97,500	$0.016	$3,280,000	$0.025
Reserves	$0	$0.00	$410,000	$0.003
Totals	**$2,964,000**	**$0.486**	**$8,610,000**	**$0.065**

kilometer to control the vehicle is $0.02. Since a single APM operator can handle up to 360 vehicles and the average vehicle speed is higher, the cost per seat-kilometer to control the vehicle is $0.003. This is 17 percent of the cost to control the trolley. On an annualized basis, the cost per seat-kilometer for the trolley control system is $0.025 and for the APM is $0.006.

REVENUE

Revenue from passenger fares is only one source of income available to transit operators. Two other sources include services offered on board transit vehicles and advertising promotions. Most transit operators do not offer on-board services, although a few have experimented with ideas like teaching classes on commuter train cars. Most transit operators only lightly use advertising as a source of income.

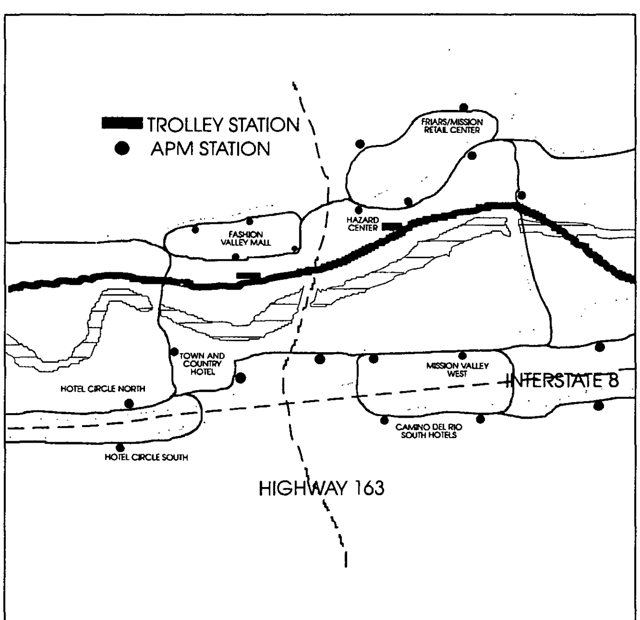

FIGURE 2 Close-up view of trolley and people mover alignments.

Passenger Fares

Fares for the trolley range from $1.00 to $2.25 per passenger, and are based on the number of zones through which a passenger travels. The MTDB establishes fare levels as a matter of policy. An APM operator should base fares on vehicle-kilometers traveled, with discounts available for volume customers. APM fare levels will depend on market considerations.

The Mission Valley trolley route is expected to attract 4,000 passengers each day, with fares averaging $1.40. This will produce an annual fare income of $1.5 million, and represent a market share of 3 percent. The MTDB anticipates that the farebox recovery rate will be 50 percent, consistent with existing trolley route performance, and likely the best light rail recovery rate in the United States. The average cost to ride the trolley will be $0.23 per kilometer ($0.37 per mile), with the average trip lasting 6 km (3.75 mi). As Figure 3 illustrates, nearly all of the revenue generated by the trolley comes from fares.

SDMO expects the APM to attain higher ridership levels. Two primary reasons are the greater level of individual service, and that every activity center in Mission Valley can be served by the APM. The organization anticipates that the APM will capture a 30 percent share of the area's internal trips, and induce additional trips equaling 10 percent of current trips, for a total of 45,000 trips per day. Ridership forecasts using methods employed by the MTDB for an earlier people mover study support this level of use (*1*). SDMO expects the average trip length to be 11 kilometers (7 miles), at an average charge of $0.10 km ($0.16 mi), producing an annual income from fares of $13.1 million.

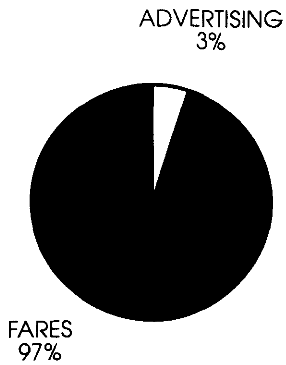

FIGURE 3 Trolley revenue breakdown.

On-Board Services

Of all the advantages of personal APMs over traditional light rail transit, the most important is the ability to offer services during a trip, in a consumer-oriented environment. Besides providing a high level of privacy, the APMs also cater to consumer needs such as convenience, timeliness, and intangibles resulting in feelings of *Glow, Tingle, and wow* (*3*).

The Mission Valley Trolley would receive no revenue from onboard services. The large-passenger trolley vehicles do not easily adapt to the provision of such services. Trolley rail infrastructure does not support the communication networks required for most information-based services. Furthermore, services could not be delivered to customers with any degree of privacy.

The APM would generate revenues from an array of services offered to passengers. Revenue will come from both passengers and commercial sponsors. For example, an investment broker will be paying a fee to be the sole provider of investment services on the APM network. Many passengers will be willing to pay for telephone services, or entertainment services, such as video games. The marketplace will decide precisely which services are offered. The operator would expand popular services and end unpopular services. As Figure 4 illustrates, the revenues generated from services are half as much as revenues generated by fares.

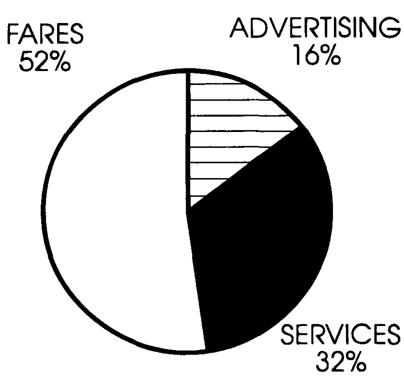

FIGURE 4 Personal APM revenue breakdown.

Advertising and Promotions

Public transportation has capitalized on advertising and promotion opportunities in a small way. Most transit operators rely on vehicle display signs, which generate a small revenue. Advertising revenue has not been aggressively pursued, most likely because transit operators have always seen themselves exclusively as providers of a basic transportation commodity. The challenge for operators is to see themselves as serving other, consumer-oriented needs, such as the need for information related to personal commerce.

The Mission Valley Trolley will gain a small income from advertising placards within the vehicles and kiosks at the trolley stations. Like most transit operators, MDTB does not forcefully pursue promotion opportunities. Furthermore, the limited ridership provides advertisers with a small target audience, decreasing the value of transit advertising space.

The APM will pursue advertising and promotional opportunities aggressively. Commercial sponsors can paint vehicles with their corporate colors and logos. For example, Coca-Cola may wish to have two dozen vehicles painted with the design of its *Diet Coke* can. This type of dedication of an entire vehicle to an advertisement has already been done for buses by public transit agencies, in cities including Phoenix and Santa Ana. Commercial sponsors may also want to have promotions tied to the APM.

PUBLIC TRANSIT AS INVESTMENT

A remarkable aspect of the Mission Valley APM project is its responsiveness to treat expenditures in the public infrastructure as an investment. Traditional public transportation ignores these types of economic considerations. However, with a market-oriented transit system, for-profit investment in transit may yet become a reality.

Funding Strategy

Public transit funding has traditionally come from a combination of federal and state sources. Most other transportation funding is based on expenditures by both the public and private sectors. For example, the public sector usually builds roads and highways with money generated by taxes and vehicle-related fees. Most of the vehicles traveling on the roads and highways are cars, buses, and trucks purchased by private individuals or by private-sector organizations.

The proposal for financing the Mission Valley APM network creates two related financial entities. The first entity is a guideway district, responsible for developing and maintaining the guideway infrastructure. A second entity is an operating company, responsible for providing and operating APM vehicles. Ownership of the guideway district might be public, public and private, or completely private. The operating company would be best managed as a private, for-profit business, responsive to the needs of the local transportation marketplace. Figure 5 illustrates the relationships established under this dual entity structure.

One emphasis in planning the APM financial structure is to create an organization driven by market forces. This organization will then provide the level of transportation and related services demanded by the public. As demonstrated in all areas of an economy, the appropriate reaction to market forces by a provider of goods or services yields an optimum level of public service (*4*).

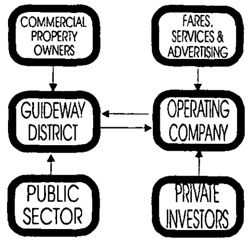

FIGURE 5 APM funding structure diagram.

APM Guideway District

The purpose of the APM guideway district is to raise capital for guideway construction and maintenance. For Mission Valley, it is proposed that the city of San Diego provide escrow funding for the District, whose members will include property owners within Mission Valley. Both the city of San Diego and local commercial property owners will enjoy benefits from APM development, and therefore should play a leading role in funding the project.

The guideway district pays for guideway development in two ways. The first source of income is from lease payments made by the operating company for use of the guideway. A second source of income is special assessments made against district members. A premise behind these assessments is that a higher lease rate earned by the properties outweighs the cost of the assessment. Furthermore, showing a lower need for parking areas and reduced traffic impacts of higher building densities may allow property owners to negotiate high floor-area-ratios with city planning officials and the City Council.

From an investment standpoint, the guideway district is comparable to the traditional public utility. The members of the district guarantee bondholders a minimum level of financial performance. These members work together to ensure the financial soundness of the guideway infrastructure. Concurrently, these members share in the benefits of increased commercial activity encouraged by the personal APM network.

APM Operating Company

The purpose of the APM operating company is to provide, operate, and maintain vehicles to serve passengers using the APM network. In San Diego, it is possible that the operating company could be funded as a start-up. A more likely scenario is that an existing company will view this as a business growth opportunity, and create a division to serve this need. SDMO has identified several prospective companies that could serve in this role.

All of the operating company revenues are related to system usage. The company would decide fares by the amount of ridership these fares will encourage. Revenues from on-board service sponsors licensing access to customers will depend on the size of the market from which they can draw. Merchandising sales will depend on the popularity of the system, an extension of its usage. Operating costs will also vary based on system usage, although any scenario will be exceeded by vehicle depreciation costs.

The operating company is a higher risk investment than the guideway district, with a greater potential for large profits. A poorly used system will not produce the returns needed to pay for a heavy investment in vehicles. Moderate traffic on the system will allow a reasonable rate of return on investment. The proposed APM network can hold heavier-than-expected traffic flows, and would result in elevated profits for investors in the operating company. Figure 6 illustrates three projected return on investment scenarios for the operating company, based on different ridership levels.

CONCLUSION

A key element of the transportation planning process is an analysis of capital and operating costs. However, to gain an accurate perspective of the cost of a transportation improvement plan, these costs must be considered in relation to the income it will generate. Key elements that traditional costing approaches overlook include market share and use of capital. If an investment in transportation cannot attract a significant portion of the market, the expense is an ill-considered use of public funds. When a guideway costing nearly $12.5 million/lane-km ($20 million/lane-mi) to build is used only once every 15 minutes, capital is being used inefficiently.

Whether financed by the public or private sector, or both, transportation project managers should consider the return on investment. Public bodies need to conserve financial resources for projects that truly meet public needs. Market considerations are, therefore, an appropriate element of transportation planning. With these considerations in place, planners and elected officials may begin to reconsider whether spending $70,000 per passenger to build transit systems is the correct use of public funds. Traditional investment analysis tools provide an existing framework for making these decisions.

Few light rail systems like the trolley would be built without funding from the federal government (*5*). The Mission Valley People Mover proposed by the SDMO shows promise as a successful transportation project, because it is fiscally responsible in its investment as a capital project. Not only is the project financially viable, it can become a catalyst for economic growth through a renewed promotion of commerce within Mission Valley. Significantly, the project provides these benefits while enhancing the natural environment. The SDMO hopes to get this proposal accepted by another organization, the Regional Transportation Technology Alliance (RTTA). RTTA is a San Diego organization established to help San Diego companies reach transportation markets. If the proposal is accepted, RTTA could then begin coordination efforts between the

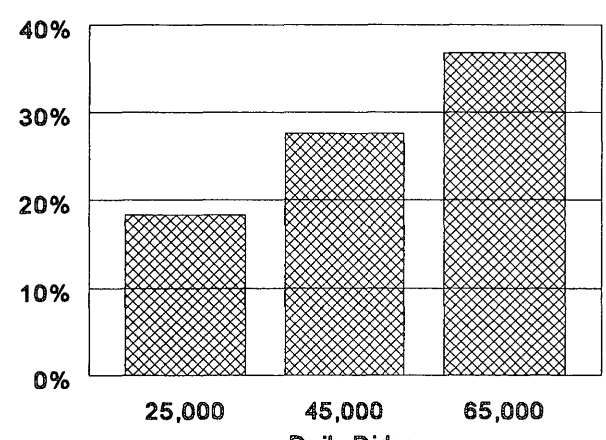

FIGURE 6 APM return-on-investment scenarios.

city of San Diego and Mission Valley property owners. The conclusions reached in this paper will then be tested by the development of a Personal APM network within the next 3 years.

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Perspective on Maglev Transit and Introduction of Personal Rapid Transit Maglev

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A critical review of maglev trains and conventional wheeled trains is presented in an attempt to identify the performance advantages of maglev. Traditionally claimed advantages of maglev were not found to hold up to wheeled train systems incorporating similar non-contacting propulsion; however, performance advantages were identified for velocities greater than 500 mph (805 km/hr). Because travel at atmospheric pressure is not practical at these high velocities, an analysis was made for applications in tubes of reduced pressures. The feasibility of a personal rapid transit (PRT) system designed with maglev suspension and for travel in tubes of reduced pressure is evaluated. The PRT maglev appears to have superior service capabilities yet no obvious technological barriers. An economic comparison to maglev train systems suggests that the PRT maglev would cost about 40 percent less while providing appeal to a broader audience. Proposed performance advantages of the PRT maglev include reduced energy consumption, reliance on electrical power, and significantly reduced transit times compared to air or train systems. A practical approach to implementation is presented and consists of initially using lower velocities, higher tube pressures, and PRT vehicles connected as train units. Proposed evolution of the system includes attaining higher velocities and incorporating superconductive elements in the rail embodiments.

As noted by Sinha (*1*), it was not until the 1960s that fast electromechanical control gears and the advent of solid-state electronics made maglev vehicles feasible. In 1958 Polgreen (*2*) filed for one of the first maglev patents on a maglev transit system based on the repulsion of permanent magnets placed on the vehicle and along the guideway. Shortly thereafter, Silverman (*3*) filed for a patent based on attractive levitation using overhead rails and electromagnets on the vehicle. These patents during the late 1950s and early 1960s constitute the genesis era of maglev technology.

While maglev systems could be conceived of in the early 1960s, it was not until the late 1960s that technical innovations such as stable suspension, low-speed switching, and manageable rail tolerances made maglev transit a reality. Powell (*4*) led the way in truly feasible systems with the unprecedented introduction of (*a*) inductive suspension allowing vehicle-rail gaps greater than 3 in., (*b*) electrodynamic lateral stability, (*c*) incorporation of superconducting magnets, and (*d*) non-contact propulsion via jet engines. During this pragmatic era other advances were made, including (*a*) switching (low speed) without moving parts (*5,6*), (*b*) linear induction motors that allowed the engine noise and fuel weight to be removed from the train (*7,8*), and (*c*) control methods for stable suspension (*9,10*).

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These and other advances led to several maglev demonstration projects (*11*) in the early 1980s. Throughout the 1980s attractive electromagnetic suspension systems were advanced in Germany, and repulsive suspension (electrodynamic suspension) systems were advanced in Japan. During this time no significant projects were sponsored by the U.S. government. The EDS system technology developed during this era is currently being offered for sale by the HSST Corporation of Japan.

The latest era of maglev transit in the United States is perhaps best described as the romantic era, spawned by a growing fascination with the idea of rapid transit over a cushion of air without wheels. Federal funding made available in the early 1990s was motivated by a desire to gain superiority in this intriguing technology. The most significant development of this era was a report of maglev system cost estimates titled, *Compendium of Executive Summaries from the Maglev System Concept Definition* (*12*). While several U.S. markets have considered implementing maglev train systems, no routes greater than a few miles appear to be likely in the near future.

MAGLEV SUSPENSION VERSUS WHEELED SUSPENSION

Cited advantages of maglev trains over wheeled trains (*1,12*) include the following:

1. Wheels produce medium to high environmental noise levels.
2. Wheeled systems rely on propulsion through wheel-rail friction, and the high aerodynamic drag forces lead to upper speed limits due to limited wheel-rail adhesion.
3. Maglev vehicles can accelerate and decelerate rapidly and bank steeply on curves.
4. Suspension through point contact (up to 70,000 psi or 482 MPa) on wheeled systems leads to increased structural requirements and increased wear and maintenance.
5. Maglev trains have a certain romantic appeal.

Advocates or wheel-based trains point to an already extensive rail network to justify high-speed, wheel-based systems. Existing rail networks may not be the only reason to continue using wheel-based systems. As discussed subsequently, several cited advantages of maglev have a weak foundation.

Although wheels are generally noisier than magnets, at high velocities aerodynamic noise greatly exceeds that of wheels (J. Harding, former director of U.S. Maglev Initiative, personal communication, July 1993). In perspective, minimal noise reductions are achieved by high-speed maglev.

In a similar comparison of propulsion systems, linear synchronous motors (LSM) are capable of overcoming greater aerodynamic drag than wheels and have greater acceleration and deceleration capabilities than wheels. This non-contacting propulsion can be used with wheeled suspension and maglev systems alike. Combinations of LSM propulsion with wheeled suspension would provide needed propulsion without the expense of an entirely new rail system. The Detroit Metro already uses non-contacting linear induction motors (LIM) for propulsion (*13,14*). Among its many advantages over conventional wheel propulsion are lighter-weight vehicles, reduced height of train cars (*15*), and improved traction in all weather conditions, velocities, and grades. Figure 1 shows how the LSM propulsion system of the Magneplane concept (*12*) can be readily incorporated into the vehicles and tracks of a conventional train system. Cited advantages 2 and 3 are specific to LSM propulsion, not maglev suspension, and can be attained by wheeled and maglev systems alike.

An analysis of maintenance costs is simplified when assuming that maintenance costs are directly proportional to the weight of the vehicle. Such an assumption would be exact for a hypothetical system designed to have the same weight on all wheels, and in which reductions in weight would result in eliminating some wheels.

For wheeled propulsion, additional weight helps provide needed traction; however, lighter-weight vehicles would be preferred with LSM propulsion. A 70 percent reduction in vehicle weight would be feasible (*1*) and would result in a 70 percent reduction in maintenance costs. The application of high performance polymers and shock absorbers incorporating magnetic forces could further reduce maintenance costs.

Despite their complexities, maglev trains tend to have a romantic appeal. This appeal and several successful demonstrations of maglev systems make maglev trains a tempting alternative. However, for typical applications the slightly higher cost of maglev train systems and the advantages of using existing routes for wheeled alternatives make wheeled systems the more practical choice.

Maglev trains have limited advantages and significant disadvantages compared to high-speed wheeled trains using the latest non-contacting propulsion technology. To that end, the most advantageous applications of maglev appear not to be with conventional train systems. Alternatively, transit in low-pressure environments and transit by PRT vehicles are two applications in which maglev appears to have performance advantages.

USE OF PRT VEHICLES FOR INTERCITY TRAVEL

PRT concepts were considered dead in 1992, but the funding of the PRT2000 (*16*) demonstration may revive the expectations of PRT systems (*17*). In particular, PRT systems have the advantages of (*a*) reducing traffic congestion through automation, (*b*) reducing travel time by providing nonstop service from origin to destination, (*c*) reducing travel time by having access to a continuous supply of vehicles rather than periodic, and (*d*) relying on electrical energy.

Disadvantages (personal conversation with J. Perkowski, Bechtel, San Francisco, May 1994) identified during the 1970s included (*a*) performance limitations of available control technology, (*b*) perceived high cost of the extra number of vehicles, (*c*) distasteful appearance inside cities, and (*d*) potentially poor ride quality due to

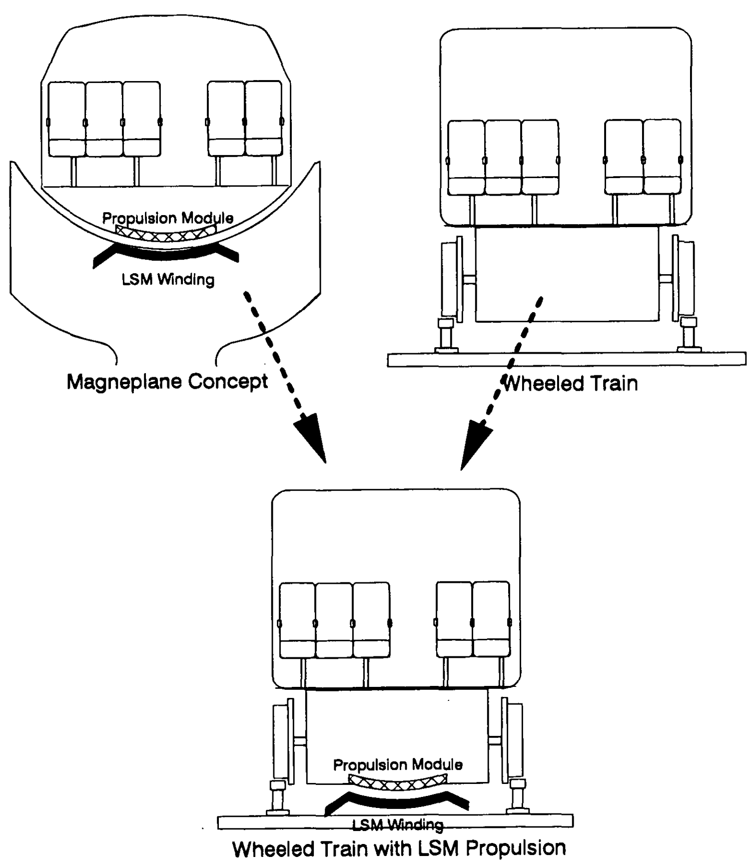

FIGURE 1 Concept for using LSM propulsion with conventional train.

routing problems. Advances in electronics since the 1970s should eliminate some of these disadvantages. Improvements in control technology and the ability to mass produce smaller vehicles are two examples. Remaining disadvantages on appearance and routing are design-specific.

Routing is made easier and more accommodating due to the small cross-sectional areas of the PRT tubes as illustrated by a comparison of the PRT structure with the Bechtel concept (*12*) structure. The over-under arrangement of Figure 2 could be made even more accommodating by separating the bi-directional tubes when necessary for routing. Single-vehicle tubes of 6 ft in diameter could actually go through buildings. The low-pressure environment and maglev suspension reduce noise levels and make such routing practical. Tube walls could be designed similar to the enclosed walkways presently used to connect buildings over busy streets in cities. Routing at-grade and under highways would also help alleviate distasteful appearances. In addition, reduced pressures would allow smaller tubes to be used and these tubes would have greater routing flexibility. The use of maglev suspension would also reduce vehicle maintenance costs. All in all, the combination of PRT with maglev is a good match.

A common concern with maglev for intracity transit is the high magnetic drag at low velocities for EDS suspension. This problem could be addressed by using control technologies that provide nonstop service to minimize low velocity travel and by incorporating magnets in rails at station locations. Nonstop service would also allow higher velocities to be effectively used and would improve system performance. Cruising velocities greater than 100 mph (161 km/hr) would be practical in many cities due to (*a*) greater acceleration, (*b*) nonstop service, and (*c*) transit corridors of reduced pressure.

Finally, a PRT maglev operating in tubes of reduced pressure would be practical for intracity and intercity service with the same system. PRT systems may not have been considered for routine intercity service previously; however, reduced aerodynamic losses in low-pressure tubes, and the dynamic formation of trains would

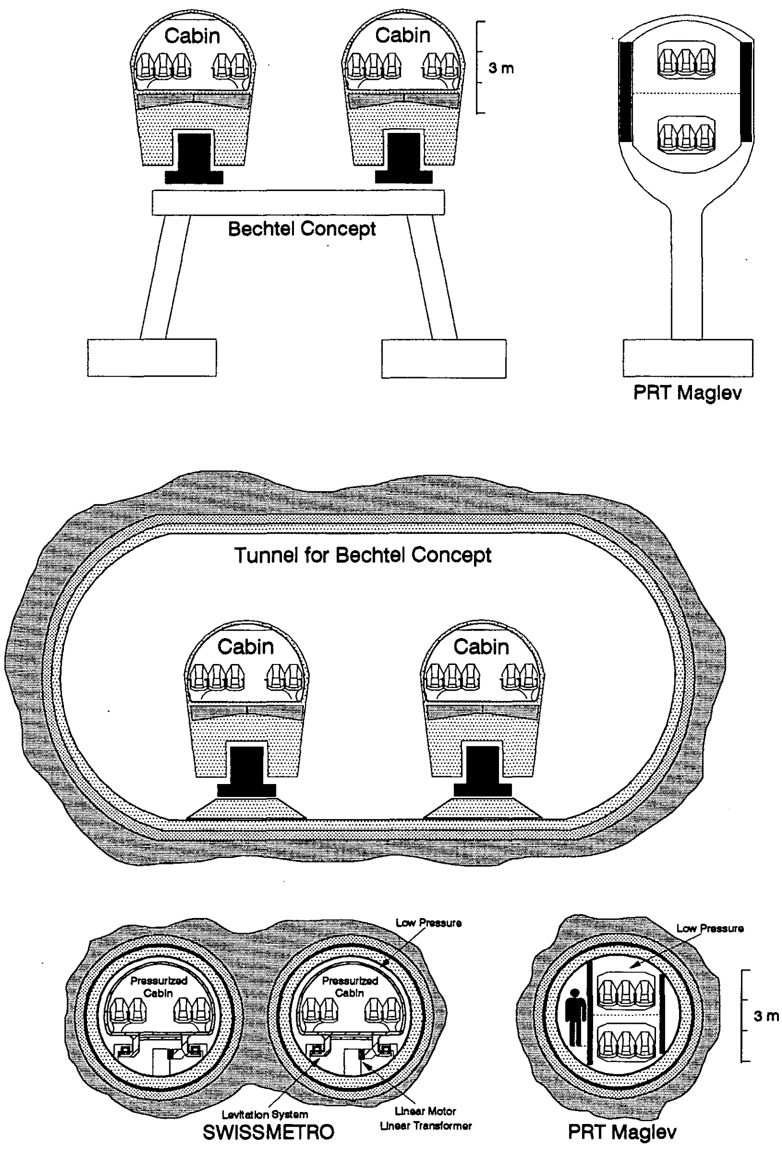

FIGURE 2 Comparison of elevated (*top*), underground (*middle*), and passageway (*bottom*) guideways.

alleviate the disadvantages for this application. Intercity transit is perhaps the best application of PRT, since it is during intercity transit that passengers spend hours awaiting the departure of jets or making connections. Proposed intercity service of SWISSMETRO (*18,19*) would have transit times of 12 min between cities, innately eliminating advantages of larger train-size vehicles.

Figure 2 compares the guideway of a PRT maglev to that of SWISSMETRO and the Bechtel concept. For the PRT maglev, vehicular suspension structures are located in front of and behind the passenger cabin. A cost comparison is given in Table 1 (*20*).

TRANSIT IN TUNNELS AND AT REDUCED PRESSURES

Goddard (*21,22*) first proposed transit (non-maglev) in evacuated tubes; however, it was not until the 1973 RAND study (*23*) detailed the synergism of maglev and low-air resistance that high-speed transit in evacuated tunnels became feasible. Development of these concepts continue with NASA's New Millenniums Concept (J. Rather, NASA Headquarters) and with SWISSMETRO (*18,19,24*). Modifications to the base concept include using gravity to store energy (*25,26*) and extending the concept to PRT (*27,20*). The extension to PRT service can actually have a greater impact on transit time than higher velocities.

The 1973 RAND study laid the course for maglev transit in evacuated tubes and identified all-encompassing technologies that were available in 1973. It also identified the greatest hurdle to implementation: tunneling technology, or rather, tunneling costs.

Suppes (*20,27*) addressed these tunneling costs by identifying methods for reducing tunnel diameters, reducing the number of necessary tunnels, and allowing above-ground tubes. Both reduced tunneling costs and at-grade routing were made possible by using smaller vehicles that could travel in smaller tubes. Figures 2 and 3 illustrate the vehicle and tube sizes for the PRT maglev. As shown in Table 1, these PRT tubes would actually cost less than high-speed train routes.

SWISSMETRO uses two tunnels connecting the stations (see Figure 2), and the tunneling costs represent about 75 percent of the capital costs. The PRT maglev could offer bi-directional service in one tunnel (see Figure 2). Eliminating one tunnel would reduce the SWISSMETRO cost by about 37.5 percent.

Initially proposed tunnel pressures for SWISSMETRO and the PRT maglev are similar to those surrounding supersonic aircraft at cruising altitudes. As on aircraft, the passenger compartments would be pressurized to maintain passenger comfort. By using pressures ranging from about 0.01 to 0.1 atm, SWISSMETRO would use smaller-diameter tunnels to reduce capital costs while simultaneously reducing the energy consumed by the trains. Key advantages of SWISSMETRO to the Swiss public are reduced energy consumption and reduced environmental impacts due to smaller tunnels.

For many commuters, the concept of travel in low-pressure environments is distressing; however, low-pressure travel environments are routinely used by commercial aircraft. While the human body is accustomed to pressure of 1 atm (101 kPa) on the earth's surface, at typical passenger jet cruising altitude of 30,000 to 40,000 ft (9000 to 12000 m), the pressure ranges from 0.30 to 0.20 atm (30 to 20 kPa). In aircraft, scoops and compressors gather air to maintain pressure in the passenger cabin. Similar methods would be used for SWISSMETRO and the PRT maglev. It would be prudent to design initial PRT maglevs to operate at the lower pressures (0.2 atm) presently used by commercial aircraft to minimize initial development needs. Optimal pressures for low-pressure applications would depend on travel velocity and would vary from approximately 0.2 atm (20 kPa) to approximately 0.001 atm (0.1 kPa).

ENERGY CONSUMPTION

Aerodynamic Drag

The upper curve of Figure 4 estimates (but does not account for transonic and supersonic variations in drag) a constant aerodynamic drag and shows how pressure can be reduced to compensate for otherwise increased drag at higher velocities. Optimal pressures depend on many factors, including the dynamic use of train units, and the use of aerodynamic designs, tube diameters, and technology on propulsion systems. The walls of the tube would increase drag, and for purposes of this study the walls are assumed to double the

TABLE 1 Cost Estimate Summary of Average Maglev Train System to PRT Maglev System

	Bechtel System Reduced 1 Cost ($ million/mile)	PRT A Maglev ($ million/mile)
Structure Only	7.7	3.4
System Guidance	0.9	0.9
System Propulsion & Levitation	4.5	2.25
Guideway Electrification	-- Provided by Utility Companies	
System Guidance, Command, & Control	1.1	1.1
Stations & Parking	1.0	0.5
System Evacuation Facilities		0.5
Vehicles (5000 PRT cars) (6 passengers per car)	2.7	1.35
Total of Above	**17.9**	**10.0**
Annual Energy Consumption **($0.08/kWh, 10 million roundtrips)**	0.85	.38

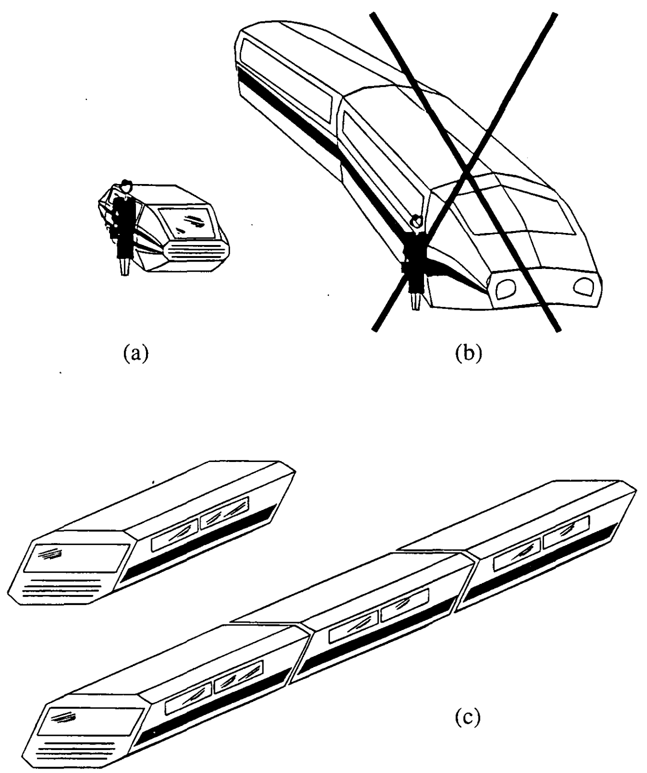

FIGURE 3 Schematic view of PRT maglev (*a*) next to maglev train (*b*); alternative PRT maglev design (*c*) is streamlined as connected train unit.

aerodynamic drag. To streamline the PRT maglev trains, the lower vehicle design of Figure 3 would be preferred.

To calculate the drag (R_a) of a train of length L and perimeter P_c, A. I. Totten (*28*) has proposed Equation 1:

$$R_a = [0.0020\, P_c \left(\frac{L}{100}\right)^{0.8} + K]\, v_x^2 \qquad (1)$$

Equation 1 accounts for formation of train units. Wall effects were incorporated into Equation 1 by multiplying R_a by a factor of 2. Air density is taken into account by multiplying by a further factor equal to the tunnel pressure in atmospheres pressure.

To minimize systematic errors, calculations using Equation 1 were made relative to the Bechtel concept. The perimeter of a train is assumed to be approximately 2.7 times greater than that of the PRT maglev, and the length of the PRT maglev train is a factor of two greater due to only having three passengers seated across rather than six (although only five are pictured, the Bechtel concept proposes six seats across) as with the Bechtel concept. Another 50 percent increase in length is added to accommodate improved comfort and PRT vehicle constraints. In total, a PRT maglev train would have an average length approximately three times greater than a train accommodating the same number of passengers.

On the basis of this analysis summarized in Table 2, at 300 mph (482 km/hr) and 0.2 atm (20 kPa) of pressure, the PRT maglev would have 63 percent less aerodynamic drag than a 300-mph (482-km/hr) train operated at atmospheric pressure. Using similar calculations at 500 mph (805) and 0.05 atm (5 kPa), the PRT maglev would consume 75 percent less energy than the train to overcome aerodynamic drag. To reduce greenhouse gas emissions, combinations of low pressure and velocity could be used to reduce energy consumption to 50 percent, 20 percent, 10 percent, . . . of the energy consumed by the best available alternatives.

Magnetic Drag

For electrodynamic suspension, magnetic drag losses are proportional to the weight of the vehicle and are inversely proportional to travel velocity. The generally accepted form of the drag equation is given by Equations 2 and 3 for high velocities.

$$F_y \propto \frac{n\, I^2}{h} \qquad (2)$$

$$F_x \propto \frac{-1}{\sigma\, t\, v_x}\; F_y \propto \frac{-n\, I^2}{\sigma\, t\, h\, v_x} \qquad (3)$$

where

F_y = vehicle weight,
n = total number of coils in magnets,
I = current in each coil,
h = height of levitation,
t = thickness of conductive track, and
σ = conductivity of track.

For the Bechtel 64 Mg maglev train traveling at a velocity of 300 mph (483 km/hr), the magnetic drag energy consumption is estimated at 0.64 MW, while the aerodynamic drag energy consumption is estimated at 5.4 MW. Aerodynamic drag dominates the energy consumption for both the Bechtel concept and the present

TABLE 2 Factors Used To Compare Aerodynamic Drag of PRT Maglev to Bechtel Concept

	PRT A Relative to Train	PRT C Relative to Train
Pressure (atm)	0.2	0.05
Perimeter	1:2.7	1:2.7
Length (m)	$3^{0.8}$	$3^{0.8}$
Wall Effects	2	2
Velocity	$(300/300)^2$	$(500/300)^2$
% PRT Aerodynamic Drag Relative to Bechtel Concept	**37%**	**25%**

PRT maglev concept operating at 0.2 atm (20 kPa). At 500 mph (805 km/hr) and approximately 0.03 atm (3 kPa), magnetic and aerodynamic drag would be approximately equal, and at less than 500 mph (805 km/hr) and 0.01 atm (1 kPa) the presence of magnetic drag significantly diminishes advantages of lower tube pressures.

Analysis such as this can be used to define feasible pressure versus velocity profiles such as that shaded in Figure 4. Figure 4 is specific to the PRT maglev. Larger vehicles, lower magnetic drags, and different vehicle-tube clearances would change the window of opportunity.

System Evacuation

Comparison with Train Systems

Energy consumption for tube evacuation would originate from three needs (*a*) periodic "total" tube evacuation, (*b*) evacuation associated with vehicle/passenger entry and departure, and (*c*) air leaks of the tube system. Of these, further information is needed to evaluate the impact of air leaks. In practice the cost of leaks would justify use and development of advanced leak detection methods and coatings, which would bring leaks under control.

The cost of total tube evacuation would be incurred periodically when the tube is exposed to atmospheric pressure for maintenance or for emergency procedures (e.g., emergency evacuation by flooding the tubes with air and having passengers walk to a tube exit). Standard adiabatic compression calculations were used to estimate the compression energy. Compression was modeled as a dynamic process with tube pressure decreasing as evacuation progressed.

For four tube evacuations per year, a compression efficiency of 80 percent, and a tube length of 800 km, 3.6, 5.6, 8.4, and 9.2 million MJ are required to remove 16 Gg of air and produce a pressure of 0.2, 0.1, 0.01, and 0.001 atm, respectively. As listed in Table 3, this translates to 360 to 920 J per passenger mile or < \$0.00002 per passenger mile. A similar calculation for the evacuation of the volume of a vehicle exterior for entry of a vehicle into the tube equates to < \$0.0001 per passenger mile.

While periodic tube evacuations and vehicle entries have evacuation costs that level out at lower pressures, compression costs associated with continuous removal of air (from leaks) increase rapidly with lower internal pressures. At pressures less than 0.02 atm (2 kPa), these compression costs could become significant. Insufficient data are available to make estimates on these costs.

Comparison with Air Travel

In addition to comparing evacuation costs of the PRT maglev to train system costs, these evacuation costs should also be compared to corresponding costs for air travel. For air travel, energy is expended to overcome earth's gravity to achieve higher altitudes where lower pressures are available. At a mass of 500 kg/seat and a cruising altitude of 12,200 m (40,000 ft), 59.8 MJ of energy are consumed in overcoming gravitational forces. This compares with approximately 2.5 MJ of evacuation energy per passenger. Considering other factors such as energy for aircraft takeoff and the initial and final travel at atmospheric pressure by the aircraft, more than 40 times more energy is consumed to transport a passenger to low pressures by an aircraft than would be needed to maintain or enter low pressures in PRT maglev tubes on the earth's surface.

DISCUSSION OF RESULTS

System Costs

The cost estimates of Table 1 include both capital and energy consumption costs. A basis of 10 million round trips per year (3,500 passengers per hour per direction for 8 hr a day for 365 days in a year) was used to allow capital and energy consumption costs to be compared.

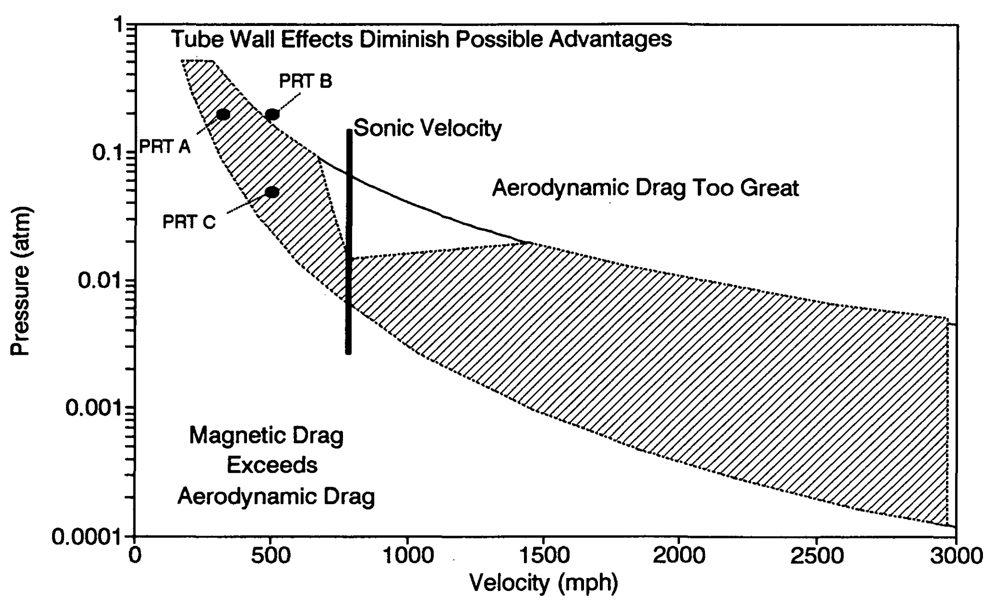

FIGURE 4 Feasible combinations of pressure and velocity for PRT maglev, which would offer reduced aerodynamic drag. On bottom line of region magnetic drag is equal to aerodynamic drag.

TABLE 3 Comparative Energy Consumption of Various Travel Modes

	Weight (kg/seat)	Cruise Velocity (km/hr)	Energy Consumed (Wh/Seat km)	Energy & Capital (¢/mile)
PRT Maglev	533	483	88	**5.900**
Aerodynamic Drag				1.400
Magnetic Drag				0.470
Periodic Evacuation				0.012
8% Capital Interest				4.000
Bechtel Concept	533	483	198	**11.410**
Aerodynamic Drag				3.780
Magnetic Drag				0.470
8% Capital Interest				7.160
Automobile[1]	300	90	105	
DC-9[1]	467	909	656	
B-757[1]	509	852	352	
TGV[1]	900	260	35.4	
EDS Maglev Train[1]	215	450	93.2	
PRT Maglev (0.2 atm)	533	805	198	
PRT Maglev (0.05 atm)	533	805	66	

Note: **[1]Sinha, 1987. Energy sources include gasoline for the automobile, kerosene for aircraft, and electrical for others. Comparative energy consumption of various travel modes.**

Energy consumption is based on Bechtel's (*12*) one-way trip energy consumption of 19,000 kW·h for a 497-mi (800-km) trip. (The 19,000 kW·h is from Table A-3 of Reference 12 and is based on the total trip and not just cruising velocities.) At 60 percent occupancy, 120 seats per vehicle, and $0.08 per kW·h, the electrical energy costs $42.2 per passenger round trip or $0.85 million per year per mile of bi-directional track. As shown in Table 2, the 0.2-atm 300-mph PRT maglev has about 37 percent of the aerodynamic drag of Bechtel's concept, or about $0.38 million/year per mile of bi-directional track with similar magnetic drags. These costs, as well as vacuum and magnetic drag costs, are also summarized in Table 3.

Capital costs are based on a direct comparison to Bechtel's reduced first cost estimate (*12*), which uses a higher cost for electrical power ($0.08 per kW·h versus $0.055) with the advantage that local electrical companies would construct and manage guideway electrification facilities. Cost savings in the PRT maglev capital reside in (*a*) reduced structure costs, (*b*) reduced propulsion costs, (*c*) reduced costs for stations and parking, and (*d*) reduced vehicle costs.

A 40 percent reduction in structure costs is based on a less expensive combined structure illustrated in Figure 2. A further 25 percent reduction (*12*) is based on at-grade construction, which is feasible due to a smaller cross section of the PRT maglev route.

Reduced propulsion system costs are claimed due to a 55 percent reduction in the combined aerodynamic and magnet drag of the PRT maglev, as well as the use of a train unit, which is three times longer for the PRT maglev. In total, the cruising propulsion requirements of the PRT maglev are only 15 percent of those of Bechtel's concept on a thrust per length of guideway basis.

Reduced station costs are associated with the smaller size of stations and incorporation with local metro service. Reduced vehicle costs are based on reaction injection molding production methods and shorter transit times, leading to a need for fewer seats.

In a final comparison of costs and energy consumption, Table 3 compares the present calculations to those calculated in the analysis of a Canadian maglev system (*1*) as well as to the Bechtel concept. The largest expense with maglev trains is the interest on capital, the second largest expense is for electrical power. Costs to produce a tube pressure of 0.2 atm are negligible. A cost estimate including interest and energy costs amounts to a mere $0.059/mi of travel.

The advantages of train systems over aircraft can be readily seen. The savings in energy between the 300-mph, 0.2-atm PRT maglev (483 km/hr, 20 kPa) and a B757 translate to about 264 W·h per seat per kilometer or about $0.013 per mi of track at an energy cost of $0.03/kW·h.

Comparison of Performance with Air Travel

An initial PRT maglev system operating at 300 mph and 0.2 atm (483 km/hr and 20 kPa) would be faster and more convenient than any other land-based transportation system; however, air travel would have advantages at greater distances. To calculate the point at which air travel would have reduced transit times compared to the

PRT maglev, certain assumptions must be made on the transit to airports, wait before departure, layovers, and wait after arrival. Table 4 lists the assumptions used for a comparative analysis. The source of the data includes published sources (*29*), airlines (recommendations on when to arrive at airport before departure), and personal experience.

The only difference between the two air transit scenarios is that Air 1 is a direct flight and Air 2 includes a layover. The main difference between the PRT maglev scenarios is that PRT A operates at a maximum velocity of 300 mph (483 km/hr) and PRT B operates at a maximum velocity of 500 mph (805 km/hr). Both PRT maglev systems assume access from several locations within both cities and therefore have the average 10-min transit time to the station.

As illustrated in Table 4, a PRT maglev with a maximum velocity of 300 mph (483 km/hr) would have shorter transit times than air travel at distances less than 907 mi (1,460 km). With a maximum travel velocity of 450 mph (724 km/hr), the PRT maglev would have shorter travel times for all travel within the continental United States. Based on these results, initial PRT maglev systems having a maximum travel velocity of 300 mph would be the most efficient means of transportation for destinations up to 907 mi distant. A later increase in velocity to 500 mph led to service better than any alternative in the continental United States.

Transportation Network

The PRT maglev system could become a transportation network similar to the present highway system based on the interstate highway network. Local metro PRT maglev tubes would be connected to interstate tubes, and each section would have a speed limit (speed set-point) for normal operation. Propulsion power would be supplied by linear motors along the tracks. Auxiliary propulsion from the vehicle would allow deviation from the speed set-point to allow the dynamic formation of trains to accommodate entering and exiting traffic. As high-temperature superconductivity becomes reality, electric-powered cars could be manufactured with magnetic suspension systems located within the four quarter-panels and, similar to high-occupancy vehicle (HOV) lanes, wheeled vehicles could literally drive onto and into a maglev transit corridor where automated maglev suspension would take over for much of the trip.

Local metro service could provide much-needed pollution-free service to cities. For cities, typical maximum upper speed set-points would initially be approximately 100 mph (161 km/hr). Depending on the distance of travel, service could be in low-pressure tubes or open to the atmosphere. The interstate network would be connected to local metro lines, and for the interstate network initial upper speed set-points would be approximately 300 mph (483 km/hr) with later speed set-points up to 3,000 mph (4,830 km/hr).

The network of local, intercity, and even transcontinental routes would provide PRT service from a location close to travel origination to a location close to the final destination. The low-pressure environments would make very fast travel possible and minimize environmental impacts. PRT operation would be similar to an elevator's, in which reservations are not necessary and railway stations are equipped with elevator entrances at multiple locations within cities. The high energy efficiency, low maintenance (due to very few moving parts and isolation from environment), and comparatively low capital costs make PRT maglevs cheaper than other modes of transportation. Reliance on electrical power allows ecological impact and cost to be reduced as new technology improves electrical power generation.

Areas for Advancement

The PRT maglev concept is new, and as such, is subject to improvements.

One important area already emphasized is operation at reduced pressures. It would be advantageous to operate initial systems at 0.2 atm (20 kPa) since this is an established standard for commercial aircraft, the equipment is available, and the public has already accepted transit with vehicle exteriors at these pressures. Advancing to travel at increasingly low pressures leads to increased velocities, reduced energy consumption, and reduced travel times.

Improved tunneling, structures, and routing methods could reduce costs by reducing the guideway structural costs. Much could be gained from additional research and development on this subject.

Additional advantages could be realized by reducing the vehicle weight. Weight reductions should be able to match the specific weights for an automobile (300 kg/seat). Reduced vehicle weight leads to reduced forces on guideways and reduced magnetic drag.

Another improvement would be to incorporate superconducting rails for repulsive levitation. The National Maglev Initiative (NMI) study (*12*) lists magnetic drag as ranging from 6 to 40 kW/ton for conventional conductors. Superconducting rails would reduce these values manyfold and allow lower pressures to be used to reduce energy consumption costs to approximately $1 for a 1600-km round

TABLE 4 Comparison of Air and PRT Maglev Transit

Assumptions	Air 1	Air 1	PRT A	PRT B
Transit to Port (min)	30	30	10	10
Parking to Takeoff (min)	45	45	10	10
Average Transit Velocity (mph)	440	440	250	400
Cruise Velocity (mph)	560	560	300	500
Layover (min)	0	50	0	0
Baggage Claim (min)	15	15	1	1
Time to Parked Vehicle	10	10	5	5
Transit to Destination (min)	30	30	10	10
Total Transit Times for Distances of:				
907 miles	254	304	254	172
1,389 miles	319	369	369	244
6,893 miles	1070	1120	1690	1070
10,560 miles	1570	1620	2570	1620

trip. Such advances would make parcel service (*30*) of all sized packages feasible with maglev. Automated transit during off-hours could ship such freight with minimal increased capital and significantly increased profits. Without superconducting rails, freight could be shipped at costs of approximately $0.000023/kg/mi during off-peak hours (11:00 p.m. to 6:00 a.m.) at lower velocities of approximately 200 mph.

CONCLUSIONS

Compared to 300-mph (483-km/hr) maglev trains, a 300-mph, 0.2-atm (20-kPa) PRT maglev would require approximately 56 percent of the infrastructure cost at $10 million per mi compared to $17.9 million per mile of bidirectional guideway. The energy requirements of the 300-mph maglev would be approximately 45 percent of that corresponding to a train system. Such a 300-mph, 0.2-atm PRT maglev would operate at low pressures typically encountered by commercial aircraft, and no new developments or breakthroughs would be needed for maintaining cabin pressure.

A similar PRT maglev system at 500 mph (805 km/hr) would offer a 25 percent reduction in travel time due to higher velocities and even further time reductions due to PRT service. However, a 500-mph, 0.2-atm PRT maglev would consume a similar amount of energy as the 300-mph Bechtel concept and would have similar system costs. An option for alleviating the higher costs at 500 mph is to reduce internal tube pressures to between 0.03 atm and 0.1 atm (3 to 10 kPa). Increasing velocities to 500 mph and decreasing pressures to 0.05 atm could be performed as evolutions to an initial system operated at 300 mph and 0.2 atm.

The proposed PRT maglev is similar to SWISSMETRO, which is being developed in Europe; however, the PRT maglev would require 37.5 percent less capital in the form of tunneling costs. In addition, many U.S. routes would have preferred routing at-grade instead of in underground tunnels. At-grade routing would reduce costs but may limit travel velocities. For the present study, acceleration and comfort considerations were defaulted to be those used by the NMI studies (*12*).

Based on the results of this preliminary study, a PRT maglev designed with a cruising velocity of 300 mph in tubes at 0.2 atm would be faster than present alternatives up to distances of 907 mi (1,460 km). In addition, the energy needed to maintain the tube vacuum is at least 40 times less than the energy needed to attain altitudes of similar low pressure. The PRT maglev would evolve such that lower tube pressures and increased velocities would allow it to shorten travel times for all travel routes viable with surface routing. A mature system would feature velocities up to 3,000 mph (4,830 km/hr) and connections between Asia and America.

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Feasibility of Electric Bus Operations for Austin Capital Metropolitan Transportation Authority

THOMAS FOWLER AND MARK EURITT

An increase in air pollution and dependence on foreign oil in the United States has led to a growing interest in alternative fuel vehicles (AFVs). The transportation sector's significant contribution to these problems has prompted federal and state regulations that now require large public fleets to convert to AFVs. In the transit industry, a variety of AFVs are available that meet federal and state requirements. The results of a study that focused on buses powered by electricity, one such alternative fuel, are presented; Austin's Capital Metropolitan Transportation Authority (Capital Metro) was used as a case study in attempts to determine the technical and economic feasibility of electric bus operations. The results of the research indicate that electric buses are feasible on Capital Metro's low-mileage circulator routes in the central business district.

Increasing air pollution and dependence on foreign oil in the United States have led to a growing interest in alternative fuel vehicles (AFVs). The transportation sector's significant contribution to these problems has prompted federal and state regulations that now require large public fleets to convert to AFVs. In the transit industry, a variety of AFVs are available that meet federal and state requirements, including compressed natural gas (CNG), liquefied natural gas (LNG), propane, and battery-powered electric. Each type of alternative-fueled bus is considered a low-emission vehicle, but only electric buses offer the advantage of zero tailpipe emissions and fuel flexibility. Unfortunately, there are technical and economic disadvantages of electric bus operations. Electric buses have a limited range, require several hours to recharge their batteries, and have a substantially higher capital cost than other types of alternative-fueled buses. Before electric buses can be considered as a feasible AFV, the technical capabilities and costs of electric buses must be determined.

This paper includes an overview of the current state of electric bus availability, performance, and use; a methodology for selecting bus routes appropriate for electric bus operation in Austin, Tex.; and a discussion on the costs and benefits of electric bus operations compared to Austin Capital Metro's diesel and CNG bus operations. This paper is a summary of a study performed by The University of Texas Center for Transportation Research for the Southwest University Transportation Center, funded by Texas Oil Overcharge funds.

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ELECTRIC BUS AVAILABILITY, PERFORMANCE, AND USE

Availability

Specialty Vehicle Manufacturing Corporation, located in Downey, Calif., is the largest manufacturer of dedicated electric buses. The Chattanooga Area Regional Transportation Authority (CARTA); the City of Monterey, Calif.; and the Georgia Power Corporation are all operating 22-ft (6.7-m), 22-passenger electric buses manufactured by this company. In addition to the 22-ft (6.7-m) bus, Specialty Vehicle Manufacturing Corporation offers a 22-ft (6.7-m), 21-passenger trolley; a 22-ft (6.7-m), 22-passenger shuttle; a 29-ft (8.8-m), 28-passenger bus; and a 31-ft (9.4-meter), 28-passenger bus.

Advanced Vehicle Systems, Inc. was formed in Chattanooga, Tennessee, as a sister company of Specialty Vehicle Manufacturing Corporation to meet the growing electric bus demand of CARTA for electric buses. In 1993 CARTA operated four 22-ft (6.7-m) Advanced Vehicle Systems buses. Advanced Vehicle Systems offers the same vehicle models as Specialty Vehicle Manufacturing Corporation and is designated as the eastern United States supplier of Specialty Vehicle Manufacturing Corporation's line of electric buses.

Marketing of the vehicles produced by both Specialty Vehicle Manufacturing Corporation and Advanced Vehicle Systems is provided by the Electric Vehicle Marketing Corporation, based in Palm Desert, Calif.

Bus Manufacturing U.S.A., Inc., located in Goleta, Calif., built eight 22-ft (6.7-m) open-air shuttles for the Santa Barbara Metropolitan Transit District (MTD). The shuttle accommodates 22 seated passengers and 7 standing passengers.

Nordskog Industries, Inc., of Redlands, Calif., built three electric shuttles for the Sacramento Municipal Utility District (SMUD). Nordskog Industries has been building electric vehicles for applications in airports and industry for more than 40 years. The company is currently producing a 14-passenger and a 20-passenger electric shuttle.

APS Systems (Oxnard, Calif.), Futura Propulsion Systems (Mission Viejo, Calif.), and NEVCOR (Stanford, Calif.) are each developing electric buses, but in 1993 they had not produced an electric bus that was in service.

Performance Characteristics

Table 1 identifies cost, performance, and specifications of several models of battery-powered electric transit vehicles manufactured by

TABLE 1 Electric Bus Cost, Performance, and Specifications

Performance Measure	Advanced Vehicle Systems Inc./ Specialty Vehicle Manufacturing Corporation		
	Trolley (3122T)	22' (6.7-m) Bus (3122B)	31' (49.9-m) Bus (5131)
Base Price	$140,000	$140,000	$215,000
Maximum Speed (mph) / (km/hr)	30 / 48.3	35 / 56.3	45 / 72.4
Range per charge	75-100 / 121-161	75-100 / 121-161	50-75 / 80-121
Length (ft/m)	22 / 6.7	22 / 6.7	31 / 49.9
Height (in/cm)	103 / 261.6	99 / 261.5	94 / 238.8
Width (in/cm)	81 / 205.7	92 / 233.7	96 / 243.8
Seating Capacity (passengers)	21	22	25
Gross Vehicle Weight (lbs/kg)	12000 / 5443	16000 / 7258	19200 / 8709
Regenerative Braking	Yes	Yes	Yes
Battery Type	Lead Acid	Lead Acid	Lead Acid

Sources: Electric Vehicle Marketing Corporation, 1992; Electric Transit Vehicle Institute, 1993.

Advanced Vehicle Systems, Inc. and Specialty Vehicle Manufacturing Corporation.

The base price of an electric bus is high relative to that of a diesel-powered bus. For example, the purchase price of the 30-ft (9.1-m), 29-passenger Gillig Phantom bus operated by the Capital Metropolitan Transportation Authority (Capital Metro) is $174,000. The purchase price of the 31-ft (9.4-m), 25-passenger Advanced Vehicle Systems battery-powered electric bus operated by CARTA is $215,000—$41,000 higher than the cost of the comparable diesel-powered bus.

Maximum speed of each bus, while low relative to that of internal combustion engine buses, should be adequate for most shuttle routes and bus routes located in downtown areas. The range per charge for the buses limits daily operation to approximately 10 hr depending on the type of route on which the bus is operated. The experience of agencies operating the 22-ft (6.7-m) bus manufactured by Advanced Vehicle Systems, Inc. and Specialty Vehicle Manufacturing Corporation reveals an actual range of 65 to 75 mi (104.6 to 120.7 km) per charge.

The use of regenerative braking on these buses extends their operating range. The Santa Barbara MTD estimated that the use of regenerative braking provides an extra 1.5 hr of service per charge for its shuttles (*1*).

Agencies Operating Electric Buses

CARTA and the Santa Barbara MTD both have been operating electric buses for several years and provided extensive information about the performance and operating costs of electric buses. The experiences of these two areas have been discussed to a limited extent by Gleason (*1*) and Dugan (*2*).

Chattanooga Area Regional Transportation Authority

The Chattanooga experience with battery-powered electric buses began with the revitalization of the city's central downtown area. CARTA opted for a shuttle circulator system to provide transportation to visitors of the 2-mi (3.2-km), four- to six-block-wide revitalized central downtown area. A unique and innovative shuttle to match the downtown area was desired. Given the city's recent commitment to environmental issues, an environmentally friendly shuttle was also desired. Electric buses fit the role of a unique, innovative, and environmentally friendly vehicle, and they were chosen to operate on the downtown shuttle route.

CARTA operated two Specialty Vehicle Manufacturing Corporation and four Advanced Vehicle Systems, Inc. battery-powered electric buses on its downtown shuttle route in 1993. Eight additional buses were ordered from Advanced Vehicle Systems, Inc. in 1993 including one 31-ft (9.4-m), 28-passenger electric bus. Funding has been approved for the purchase of 10 more electric buses in 1994, which will bring CARTA's total electric bus fleet to 24 buses. Initial costs of the Specialty Vehicle Manufacturing Corporation buses were approximately $140,000 per bus. The 31-ft (9.4-m) bus to be manufactured by Advanced Vehicle Systems, Inc. has a purchase price of $215,000. Fuel costs for the electric buses have been in the range of 4.5 to 5.7 cents/mi (2.8 to 3.5 cents/km) and maintenance costs have been estimated at 35 cents/mi (21.8 cents/km). For a comparable diesel bus, fuel costs are about 18 cents/mi (11.2 cents/km) and maintenance costs are about 70 cents/mi (43.5 cents/km). The electric buses have had a range of approximately 65 mi (104.6 km) and are operated 7 to 8 hr on their shuttle route.

Santa Barbara Metropolitan Transit District

Like CARTA, MTD procured a fleet of electric shuttles to operate on a downtown route. The downtown-waterfront shuttle serves Santa Barbara's commercial district and waterfront.

The first electric shuttle bus, manufactured by Bus Manufacturing, U.S.A., Inc., began operation in January 1991. Manufacturing of additional buses was subcontracted to Specialty Vehicle Manufacturing Corporation. In 1993 MTD operated eight 22-ft (6.7-m) electric shuttle buses on its downtown-waterfront shuttle route. The shuttles are scheduled for at least 10 hr of service per day, and some have operated for as long as 12 hr in a single day. Their range has been approximately 85 mi (136.8 km) on a single charge. Recharging occurs overnight to take advantage of off-peak electric utility

rates. Fuel costs for the MTD electric shuttle buses are estimated at 2.9 cents/mi (1.8 cents/km), while fuels costs for the diesel buses operated in Santa Barbara are estimated at 16 cents/mi (9.9 cents/km). The range of the electric shuttle buses was found to be highly sensitive to the operating characteristics of the bus drivers. Slow rates of accelerations and thoughtful deceleration that make the best use of regenerative braking systems can increase the range of the electric shuttle buses.

MTD has expressed great satisfaction with its electric shuttle buses. Between 1991, when electric shuttle buses first began replacing diesel buses, and 1992, ridership on the route had increased 800 percent to nearly 1 million passengers per year (*1*). MTD attributed much of this increase to the use of electric buses and has had many requests to introduce or extend the electric shuttle bus service to other parts of the city. MTD has yet to compile the data collected from these experiences into a comprehensive study of the feasibility of electric bus operations, describing the decision to introduce electric buses into service partially as a "leap of faith."

APPLICATIONS FOR ELECTRIC BUSES

Capital Metro Route Services

Capital Metro currently provides service throughout a 471-mi^2 (1,219.9-km^2) area that encompasses the cities of Austin, Cedar Park, Leander, Lago Vista, Jonestown, Pflugerville, Manor, San Leanna; the unincorporated area of Precinct 2 in Travis County; and the Anderson Mill area in Williamson County.

Capital Metro offers a variety of route services to the public, including metro routes, flyer routes, 'Dillo routes, express/park and ride routes, and the University of Texas shuttle routes.

Capital Metro offers 40 metro routes, which provide local service throughout the Austin area. Most metro routes run north-south and pass through the downtown area, although several cross-town and feeder routes do exist. Service on all routes begins by 6:30 a.m. on weekdays and continues as late as midnight. Weekend service is also provided on most routes. The one-way fare for adults is 50 cents.

Flyer routes combine local service within various neighborhoods with express service to downtown Austin. There are currently seven flyer routes, which are operated only on weekdays during morning and late afternoon periods. A one-way adult fare of 50 cents is charged.

Four express/park-and-ride routes provide express service from free park-and-ride lots to downtown Austin. The IRS/VA Express, North East Express, and Pflugerville Express routes are operated only on weekdays during morning and late afternoon periods. The Leander Express is operated continuously throughout the day on weekdays and Saturdays. A one-way fare of $1.00 is charged for adults.

'Dillo service is provided on three routes and acts as a circulator service in downtown Austin, the Capitol Complex, the University of Texas campus, and the Austin Convention Center. 'Dillo buses operate using diesel engines but resemble older versions of electric trolleys. The Convention Center/UT 'Dillo offers service during weekdays and Saturdays, while the Congress Capitol 'Dillo and the ACC/Lavaca 'Dillo offer service on weekdays only. 'Dillo service is free, and a free park-and-ride lot located near Palmer Auditorium is serviced by each of the 'Dillo routes.

Twelve shuttle routes provide service to the University of Texas campus when classes are in session. Shuttle routes operate full weekday schedules and most provide limited service on Sundays. Students pay a fee each semester for unlimited use of the shuttle buses, as well as metro route buses, during the semester. The adult one-way fare for nonstudents is 50 cents.

Criteria for Route Selection

The selection of Capital Metro routes most feasible for the implementation of electric buses is based primarily on route service area and route characteristics.

Route Service Area

One of the most important considerations for route selection is that of the area serviced. In order to maximize the benefits of zero tailpipe emissions, electric buses should be operated in densely developed areas such as central business districts (CBDs). This allows transit agencies to operate buses in urban areas (where air pollution is generally a problem) without adversely affecting air quality.

Routes that place buses in highly visible areas should also be considered. The absence of exhaust fumes and the quiet operation of an electric bus distinguishes it from a standard transit bus. Most people realize the importance of clean air and will appreciate the efforts of a transit company to reduce air pollution within a city.

The decisions to use electric buses on routes in Santa Barbara and Chattanooga were partly because of the clean image of electric vehicles. Both Santa Barbara and Chattanooga operate their electric buses in dense areas of the city popular with local residents and tourists. The Santa Barbara and Chattanooga transit agencies found that the public appreciated their efforts to improve air quality, and the novelty of an electric bus increased ridership along the routes serviced by the electric buses.

Route Characteristics

Several route characteristics also influence the feasibility of electric bus implementation. These characteristics include

1. Maximum speed required along the route;
2. Number of stops along the route;
3. Service hours for the route;
4. Terrain along the route; and
5. Ridership on the route.

The highest operating speed of an electric bus is approximately 40 mph (64.4 km/hr). This relatively low maximum speed does not allow operation of an electric bus on a freeway, but it is generally adequate for operation in downtown urban areas and has not presented a problem in either Chattanooga or Santa Barbara. A careful evaluation of any route, on which an electric bus will be operated should be performed to determine if the maximum speed of the bus is adequate.

The number of stops along the route contribute to the effectiveness of a battery-powered electric bus compared to a diesel-powered or CNG-powered bus. During each stop for boarding and deboarding passengers, internal combustion engine buses emit pollutants and use energy while idling. The use of an electric bus on

routes with frequent stops eliminates pollutants resulting from periods of idling. Overall energy consumption is also reduced because the electric bus consumes no energy when stopping for passengers for traffic control signals, or for road congestion.

The maximum range of 70 to 75 mi (112.6 to 120.7 km) per charge limits the daily operation time of the bus. A bus that operates with an average speed of 10 mph (16.1 km/hr) will be limited to approximately 7 to 7.5 h of service per day, depending on the driving characteristics of the driver and the terrain on which the bus is operated. Quick accelerations and steep grades will reduce the range, while gentle accelerations, level terrain, and thoughtful use of the regenerative braking systems will increase the range.

Finally, ridership on the route must be considered to ensure that an electric bus, which seats less than half the passengers of a standard full-size, diesel-powered bus, can accommodate demand.

Recommended Routes

An evaluation of all metro routes, flyer routes, express routes, 'Dillo routes, and UT shuttle routes was made to determine which routes are most feasible for implementation of electric buses.

Infeasible Routes

An initial evaluation of all routes serviced by Capital Metro was made to determine which routes were not feasible for electric bus use. Routes were eliminated from consideration based on two criteria: (*a*) maximum speed required on the route and (*b*) area serviced by the route.

Routes that required buses to operate on freeways were eliminated from consideration because of electric bus speed limitations, as well as routes outside the CBD.

A route matrix was developed to indicate which routes operated on freeways and which routes operated outside the CBD. The matrix also indicates which routes are served exclusively by large transit buses (buses at least 30 ft [9.1 m] long). Routes that are served by smaller buses under 30 ft (9.1 m) are preferred because electric buses, most of which are also under 30 ft (9.1 m), would be adequate to accommodate ridership on those routes. However, service of a route by smaller bus is not a requirement for implementation of an electric bus. Headways can be shortened so that smaller buses can service routes where large buses currently operate. Also, ridership on a particular route may be low enough that smaller buses can accommodate demand.

The route matrix was applied to each type of route service offered by Capital Metro. A majority of metro routes operate primarily outside the CBD, providing service from less dense urban and suburban areas to the CBD. Because of their operation outside the CBD, all metro routes were eliminated from consideration.

All express/park and ride routes and most flyer routes were eliminated because of their routing onto freeways. Those flyer routes not operating on freeways require buses to travel fairly long distances without stopping for passengers and to operate outside the CBD. These flyer routes were also eliminated from consideration.

Finally, most UT shuttle routes operate outside the CBD, and several operate on freeways. UT shuttle routes meeting either of these criteria were eliminated from consideration.

Selected Routes

Based on the initial evaluation criteria, three 'Dillo routes and two UT shuttle routes were selected for possible implementation of electric buses. 'Dillo routes include the Convention Center/UT 'Dillo, Congress Capitol 'Dillo, and ACC/Lavaca 'Dillo; UT shuttle routes include the Forty Acres and West Campus routes. These routes were selected initially because of their continuous service in high-density areas, which provides exposure for the electric buses and maximizes the zero tailpipe emissions benefits.

The three 'Dillo routes and two UT shuttle routes are all located in areas that make electric bus utilization a feasible alternative. Selection of the best fit route was based on three additional criteria:

1. Number of bus stops per mile (km) along the route;
2. Average speed of the bus on the route; and
3. Daily ridership.

The number of bus stops/mi. (km) indicates the frequency of stops the buses make during service of the route. As explained previously, the greater the frequency of stops, the more beneficial electric buses are relative to ICE buses. The Congress Capitol 'Dillo had the greatest number of bus stops per mile with 24 stops on a route of 3.9 mi (6.3 km), equivalent to 6.2 stops per mile (3.9 stops per kilometer).

Low average speeds on routes allow electric buses to service the route for a longer period of time throughout the day, which is crucial because of the current range limitations of electric buses. The Congress Capitol 'Dillo also had the lowest average speed of any selected route, completing a 3.9-mi (6.3-km) route in 32 min, which averages to a speed of 7.3 mph (11.7 km/hr).

Finally, weekday ridership surveys were obtained from Capital Metro to ensure that the smaller electric vehicles had the capacity to handle ridership demand on selected routes. In the case of replacement of 'Dillo service with electric buses, ridership is not a major consideration because the electric buses seat approximately the same number of riders as the 'Dillo buses. Based on the ridership data for the 'Dillo routes, currently manufactured electric buses with seating capacities of 22 passengers are adequate to accommodate ridership demand on the 'Dillo routes. However, the high weekday ridership of the Forty Acres and West Campus UT shuttle routes may prove troublesome for the smaller electric buses. In all probability, current headways of buses on these routes during peak demand times would need to be reduced by using additional buses to meet ridership demand.

Final Route Recommendations

Of the four selected routes, the Congress Capitol 'Dillo route offers the most feasible route for electric buses. The operation of this route in a high-density urban area takes full advantage of the benefits of a zero-emission vehicle. Operation of the Congress Capitol 'Dillo along Congress Avenue from Town Lake to the Capitol will provide much exposure for the electric buses to both Austin residents and out-of-town tourists. The high frequency of bus stops along the route and low average speed will help minimize the negative effects of the 70- to 75-mi (112.6 to 120.7 km) range. The current average operating speed of the Congress Capitol 'Dillo of 7.5 mph (12.1 km/hr) allows electric buses to operate continuously for approximately 10 h before requiring a recharge.

COSTS AND BENEFITS OF ELECTRIC BUSES

Capital Costs

The costs of several models of diesel, natural gas, and electric buses are included in Table 2. Costs for the diesel and natural gas buses represent the total cost of each bus, including such features as wheelchair lifts and air conditioning. Electric bus costs represent the total bus cost and include the cost of a separate battery charger unit.

The Capital Metro buses presented in Table 2 represent all bus types purchased in the last 5 years. The two models of CARTA's electric buses currently in operation are not equipped with air conditioning or heating units from the manufacturer. CARTA has installed propane-fueled heaters on several buses but has not equipped any buses with air conditioning. The MTD electric bus is an open-air shuttle. These open-air shuttles have an overhead roof but do not include doors or passenger windows.

In addition to the cost per bus, Table 2 also gives the cost per passenger seat for each bus. This was calculated by dividing the cost of the bus by the seating capacity to determine the cost of a bus to provide service to one passenger. The least expensive units based on cost per passenger seat are the diesel-fueled Gillig Phantoms. MTD's open-air electric shuttle also had a low cost relative to the other buses, but it is not suited for service in cold or inclement weather. The TMC RTS CNG buses represented the mid-price range based on cost per seat. CARTA's electric buses and the CNG-fueled trolley were on the high side of the cost per passenger seat estimates.

Fuel Costs

The fuel costs per mile of the electric buses are well below those of diesel and CNG buses, 12.4 cents/mi (20 cents/km) and 8.1 cents/mi. (13 cents/km), respectively. CARTA's electric buses consume 1.5 to 1.9 kWh/mi (0.93 to 1.2 kWh/km) of travel, and, unlike diesel and CNG buses, which idle and continue to consume fuel when stopped, electric buses do not consume any electricity when stopped. CARTA's estimate of 4.5 to 5.7 cents/mi (2.8 to 3.5 cents/km) is below the fuel costs of the diesel and CNG buses, even when measured by passenger seat per mile. MTD's estimate of 7 cents/mi (4.4 cents/km) is also below the fuel costs of diesel and CNG buses. When measured based on fuel costs per passenger seat per mile, fuel costs of the MTD electric shuttle are equivalent to the fuel costs for CNG buses and below the fuel costs for diesel buses.

Maintenance Costs

Maintenance costs for Capital Metro's diesel and CNG buses are estimated at 30.8 cents/m (49.6 cents/km). Maintenance costs for CARTA's 22-ft (6.7-m) electric buses, 28.9 cents/mi (46.4 cents/km), also include the cost for battery replacement. It is estimated that battery life is consumed at 1,500 recharge cycles (*1*). CARTA's buses have experienced only approximately 500 cycles at this time, and CARTA expects to pay $12,000 per battery pack for replacement (*1*).

Specific maintenance data were not available from MTD, but MTD's initial estimates for battery cycle life and replacement costs matched those of CARTA.

Total maintenance costs, including battery replacement costs, are lower for electric buses compared to diesel and CNG buses. However, if compared on a cost per passenger seat basis, the maintenance costs of the electric buses are actually higher than those of diesel and CNG buses.

The reduced maintenance costs of electric buses (due to their lack of transmissions, cooling systems, and tune-ups) are partially offset by the costs for battery maintenance and replacement. Maintenance costs will remain comparable if a larger electric bus is compared

TABLE 2 Capital Costs of Buses

Transit Agency	Bus	Fuel Type	Length	Seating Capacity	Cost	Cost per Passenger Seat
Capital Metro	1993 TMC RTS[a]	CNG	40' (12.2 m)	41	$247,000	$6,024
Capital Metro	1993 Chance Trolley ('Dillo)	CNG	28.8' (8.8 m)	28	$209,000[b]	$7,464
Capital Metro	1989 Gillig Phantom	Diesel	35' (10.7 m)	39	$187,000	$4,795
Capital Metro	1989 Gillig Phantom	Diesel	30' (9.1 m)	29	$174,000	$6,000
CARTA	1994 Advanced Vehicle Systems 31' Bus	Electric	31' (9.4 m)	25	$220,000[c]	$8,800
CARTA	1993 Advanced Vehicle Systems 22' Bus	Electric	22' (6.7 m)	22	$145,000[c]	$6,591
MTD	1992 Bus Manufacturing U.S.A, Inc. 22' Open Air Shuttle	Electric	22' (6.7 m)	22	$125,000[c]	$5,682

[a]Capital Metro currently operates 30 of these buses.
[b]This is an experimental leased vehicle.
[c]Includes $5,000 cost of battery charger.

with a diesel and a CNG bus because bus size does not have a significant impact on maintenance costs. (It would, however, increase the fuel costs because of the larger battery pack required for bigger buses.) Unfortunately, CARTA did not have estimates on maintenance costs for its 31-ft (9.4-m), 25-passenger bus, which only recently began route service. The maintenance costs for this bus should be similar to the maintenance costs for the 22-ft (6.7-m), 22-passenger electric bus. If this is true, maintenance costs per passenger seat on the 31-ft (9.4-m) electric bus would be 1.9 cents/mi (1.2 cents/km), still higher than the diesel and CNG costs per passenger seat but lower than the maintenance costs per passenger seat for the 22-ft (6.7 m) electric bus.

Emissions

The primary benefit of electric buses is zero tailpipe emissions. There are, however, emissions associated with electricity generation that must be accounted for, but total fuel-cycle emissions of electric buses are still less than those of diesel and natural gas buses. A pollutant cost index is developed in this section to determine the damage cost of individual pollutants. These pollutant costs are then applied to the emissions levels of each bus to estimate the pollutant damage costs for operating each bus.

Pollutant Costs

There are several methods that can be used to measure the social costs of pollutants (*3*). The damage cost method evaluates damage in the form of medical injuries, death, lost earnings, and physical damage to property and agriculture. External social costs reflect the actual expenditures used to compensate for these damages. The revealed preference method measures how much people would be willing to pay to avoid a particular externality. Real estate property values are often used as a measure of the price a person will pay to avoid an externality such as noise or air pollution. Finally, the optimal control costs method measures the cost of reducing an externality to some limit that is considered optimal. For example, if the Environmental Protection Agency (EPA) ambient air standards are considered optimal, the social costs of a particular pollutant are then the cost to reduce the level of that pollutant to the EPA standards.

A literature review revealed four studies that attempt to estimate pollutant costs on a cost per unit weight basis: Small (*4*), Haugaard (*5*), Massachusetts Department of Public Utilities (*6*), and Ottinger et al. (*7*). All of the studies use the damage cost method for estimating pollutant costs. Table 3 presents pollutant cost estimates for each of the studies in 1993 dollars. While it would be valuable to discuss these studies in greater detail, such a discussion is beyond the scope of this paper.

Total Fuel-Cycle Emission

Total fuel-cycle emissions are determined for the CNG, diesel, and electric buses. Total fuel-cycle emissions include emissions due to feedstock extraction, feedstock transportation, conversion of feedstock into end use fuel or electricity, transportation of end-use fuel, and tailpipe emissions of vehicles. Estimates for total fuel-cycle emissions are given in Table 4. Emissions for the CNG and diesel buses are divided into two categories, fuel-cycle and tailpipe emissions. Fuel-cycle emissions are defined in this paper as all emissions associated with the total fuel-cycle other than tailpipe emissions.

Emissions from the operation of CNG buses are estimated for fuel-cycle emissions, which include emissions from extraction, transportation, and compression of the fuel, as well as emissions from the tailpipe. Values given in Table 4 for fuel-cycle emissions are based on a study by Darrow (*8*) prepared for the Gas Research Institute. The study uses a small van as a base vehicle for calculations of grams per mile equivalent emissions. The estimates for CNG bus emissions in Table 4 are adjusted to reflect the lower fuel efficiency, and therefore higher emissions, of the CNG buses.

Tailpipe emissions for the CNG buses are based on the engine manufacturer's estimates of tailpipe emissions in grams per brake horsepower hour. Using a conversion factor determined by Kitchen and Damico (*9*), grams per brake horsepower hour are converted to grams per mile for a vehicle operating in the CBD driving cycle. The CBD driving cycle attempts to simulate driving in a dense urban environment with the vehicle operating at an average speed of 12.4 mph (19.9 km/hr).

Diesel bus fuel cycle emissions are based on Darrow's (*8*) emission estimates for a gasoline-powered vehicle. (Darrow did not include a diesel-powered vehicle in his study.) Estimates for diesel bus emissions are adjusted to reflect the lower fuel economy of the diesel buses compared to the gasoline van used in Darrow's study.

Tailpipe emissions for the diesel buses are based on Kitchen and Damico's (*9*) study. In their study, emissions per mile are determined for a diesel bus operating with an engine comparable to those in Capital Metro's diesel buses. The emissions are estimated using the CBD driving cycle.

Electric vehicle emissions are based on emissions associated with feedstock extraction and electricity generation. There are zero tailpipe emissions associated with electric buses.

Feedstock extraction emissions include emissions from mining and drilling, and emissions from the transport of feedstock fuel. Darrow's study (*8*) estimates the emissions in grams per mile based on an electric van with an electricity consumption rate of 0.48 kWh/mi (0.30 kWh/km). Darrow's estimates of emissions on a per mile basis were increased for use in the study on which this paper is based to appropriately reflect the greater electricity consumption of the electric buses.

TABLE 3 Pollutant Costs (cents/g, January 1993 dollars)

Study	CO	HC	NO_X	SO_X	Part.
Small	0.0019	0.0294	0.097	0.120	0.057
Haugaard	0.0029	0.0384	0.122	0.155	0.142
Ottinger	*	*	0.180	0.448	0.262
Massachusetts Department of Public Utilities	0.096	*	0.822	0.189	0.506

*Values not given

TABLE 4 Bus Emissions [g/mi(g/km)]

Bus	CO	HC	NO_x	SO_x	Part.
Capital Metro CNG[a]					
Fuel Cycle	0.40 (0.25)	0.62 (0.39)	3.26 (2.03)	1.96 (1.22)	0.04 (0.02)
Tailpipe	3.38 (2.10)	1.25 (0.78)	10.68 (6.64)	*	0.13 (0.08)
Total	**3.78 (2.35)**	**1.87 (1.16)**	**13.94 (8.66)**	**1.96 (1.22)**	**0.17 (0.11)**
Capital Metro					
Diesel[a]	0.50 (0.31)	1.58 (0.98)	1.41 (0.88)	0.27 (0.17)	0.08 (0.05)
Fuel Cycle	26.8 (16.66)	1.4 (0.87)	27.6 (17.15)	*	3.1 (1.93)
Tailpipe	**27.30 (16.97)**	**2.98 (1.85)**	**29.01 (18.03)**	**0.27 (0.17)**	**3.18 (1.98)**
Total					
CARTA 22' Electric Bus[b]					
Feedstock Extraction	0.06 (0.04)	0.08 (0.05)	0.23 (0.14)	0.03 (0.02)	0.01 (0.006)
Power Plant	0.12 (0.07)	0.04 (0.02)	4.38 (2.72)	7.87 (4.89)	0.01 (0.006)
Tailpipe	0.0	0.0	0.0	0.0	0.0
Total	**0.18 (0.11)**	**0.12 (0.07)**	**4.61 (2.87)**	**7.90 (4.91)**	**0.02 (0.012)**
MTD 22' Electric Bus[c]					
Feedstock Extraction	0.04 (0.02)	0.06 (0.04)	0.16 (0.10)	0.02 (0.01)	0.01 (0.006)
Power Plant	0.07 (0.04)	0.02 (0.01)	2.77 (1.72)	5.56 (3.46)	0.01 (0.006)
Tailpipe	0.0	0.0	0.0	0.0	0.0
Total	**0.11 (0.07)**	**0.08 (0.05)**	**2.93 (1.82)**	**5.58 (3.47)**	**0.02 (0.012)**

*Values not given

[a]Based on Cummins L10 Engine (Kitchen and Damico, 1992).

[b]Electric bus energy consumption estimated to be 1.9 kWh/mile (1.18 kWh/km) (Hartman, 1993), emissions data based on data from SCEVC (1992) and Hamilton (1992).

[c]Electric bus energy consumption estimated to be 1.2 kWh/mile (0.75 kWh/km) (Gleason, 1992), emissions data based on data from SCEVC (1992) and Hamilton (1992).

Electricity generation emissions vary depending on the fuel used to produce electricity. Based on an analysis of power generation in Austin, it is assumed that half of the electricity is produced from natural gas plants and that half is produced from coal plants. Estimates of emissions from these power plants are used to determine the emissions per mile of electric buses because of electricity generation.

Damage Costs Due to Emissions

Based on the information in Table 3, pollutant damage values used in this analysis are 0.0024 cents/g for carbon monoxide, 0.0339 cents/g for hydrocarbons, 0.133 cents/g for nitrogen oxides, 0.155 cents/g for sulfur oxides, and 0.154 cents/g for particulates. Using these values and the information given in Table 4, the damage costs of pollutants are calculated per distance of operation of the buses. These damage costs are based only on emissions from the tailpipe of the vehicles and from the generation of electricity.

Analysis

FTA requires that 35- to 40-ft (10.7- to 12.2-m) buses purchased with their assistance operate a minimum of 500,000 mi (804 500 km) or 12 years. Smaller buses have shorter FTA life-span requirements; however, for the purpose of this analysis, it is assumed that all buses analyzed are operated for 500,000 mi, at which time they are retired and retain no value.

Refueling infrastructure and operating costs are not considered, although it is important that these costs can have a significant effect on the cost of bus operations. Construction costs for Capital Metro's CNG refueling station were approximately $2.7 million, and operating costs for the station are approximately 10 cents/gal equivalent of fuel distributed.

Total costs are recalculated for Capital Metro's 40-ft (12.2-m) TMC RTS CNG bus, 35-ft (10.7-m), diesel-power Gillig Phantoms; and 30-ft (10.7-m) diesel-power Gillig Phantoms; CARTA's 31-ft (9.4-m) and 22-ft (6.7-m) electric buses; and MTD's 22-ft (6.7-m), open-air shuttle. The purchase costs of the buses are added to the fuel costs, maintenance costs, and air pollution costs of operating each bus for 500,000 mi (804 500 km). (Capital Metro's 1993 Chance Trolley is not included in either scenario because an actual purchase price is unknown and maintenance costs for the trolley are not available.)

Table 5 presents the results. The total cost is lowest for the three electric bus models. Over a lifetime of 500,000 mi (804 500 km), electric buses generate an average fuel cost savings of $71,333 compared with diesel buses and $36,333 compared with CNG buses. Maintenance cost savings for the electric buses compared to diesel and CNG buses are approximately $16,000. Pollution costs are lowest for the electric buses, averaging $8,267 over 500,000 mi. Pollution costs are highest for the diesel buses at $22,800 and moderate for the CNG bus, at $11,300.

On a cost-per-passenger-seat basis, electric buses compare less favorably with diesel and CNG buses. The 40-ft (12.2-m) CNG bus and the 35-ft (10.7-m) diesel bus have the lowest cost per passenger seat. Cost per passenger seat for the electric buses is compara-

TABLE 5 Total Social Costs of Buses, 500,000-mi Vehicle Life

Bus	Purchase Cost	Fuel Cost per mile (km)	Maintenance Cost per mile (km)	Pollutant Damage Costs per mile (km)	Total Cost[g]	Cost per Passenger Seat[g]
40' (12.2 m) CNG	$247,000	13¢[a] (8.1¢)	49.6¢[e] (30.8¢)	2.26¢ (1.40¢)	$571,300	$13,934
35' (10.7 m) Diesel	$187,000	20¢[b] (12.4¢)	49.6¢[e] (30.8¢)	4.56¢ (2.83¢)	$557,800	$14,303
30' (9.1 m) Diesel	$174,000	20¢[b] (12.4¢)	49.6¢[e] (30.8¢)	4.56¢ (2.83¢)	$544,800	$18,786
31' (9.4 m) Electric Bus	$220,000	5.1¢[c] (3.2¢)	46.4¢[f] (28.9¢)	1.85¢ (1.15¢)	$486,750	$19,470
22' (6.7 m) Electric Bus	$145,000	5.1¢[c] (3.2¢)	46.4¢[f] (28.9¢)	1.85¢ (1.15¢)	$411,750	$18,716
22' (6.7 m) Electric Shuttle	$125,000	7¢[d] (4.4¢)	46.4¢[f] (28.9¢)	1.26¢ (0.78¢)	$398,300	$18,105

[a]Based on average Capital Metro CNG fleet fuel costs.
[b]Based on average Capital Metro diesel fleet fuel costs.
[c]Average value of CARTA's high and low end fuel costs estimate.
[d]MTD estimate.
[e]Maintenance costs are based on Capital Metro's 1994 fleet maintenance budget.
[f]Maintenance costs are based on CARTA's 22-foot (6.7- m) and are assumed to be the same for the Advanced Vehicle Systems 31-foot (9.4-m) bus and the Bus Manufacturing, U.S.A. Inc. 22-foot (6.7-m) shuttle.

ble to those for the CNG trolley (not shown in Table 5) and the 30-ft (9.1-m) diesel bus.

On routes where peak ridership is often less than seating capacity, larger diesel and CNG buses can be replaced with electric buses. In these cases, electric buses offer a cost savings, based on purchase, maintenance, fuel costs, and air pollution compared to diesel and CNG buses.

Finally, the analysis does not include a study of fueling infrastructure. Including the CNG station development and operating costs, estimated to be about $0.30/gal equivalent by the Department of Energy, increases the total cost of the CNG bus to $620,628, or $15,137 per passenger seat.

CONCLUSIONS

Technical feasibility can be measured through objective criteria such as range, maximum speed, and size of an electric bus. Determining economic feasibility is a great deal more difficult. Valuing the monetary benefit from emissions reductions is inaccurate, as displayed by the disparity in results of the pollutant costs studies discussed previously. Several economic factors that contribute to the feasibility of electric bus operations were not considered in the study. Benefits of a reduction in dependence on foreign oil resulting from the use of electric vehicles, energy conservation, and decreases in noise pollution are all valuable attributes of battery-powered electric buses to which it is extremely difficult to accurately assign monetary values.

Based on the review of the current state of electric bus availability, performance, and use, electric buses are technically feasible for operation in transit services. Electric buses provide adequate range, speed, and size to service a variety of routes. Transit officials must be fully aware of the limitations of the buses, however, and be sure to select routes suitable for electric bus operations. One such decision process for route selection is presented in this paper.

Operation of electric buses can be economically feasible if their smaller passenger seating capacity is adequate to serve present demand. The fuel and maintenance costs of electric buses are below those of diesel and natural gas buses, and over their expected service life, the fuel and maintenance savings can make electric buses an attractive alternative fuel option.

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PART 4

Ridesharing and High-Occupancy Vehicles

Profile of Employee Transportation Coordinators

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Employee transportation coordinators (ETCs) represent a new level of governance mandated by government regulation and maintained by public and private corporations and businesses. They represent the shared burden that employment sites are being asked to support to improve air quality and reduce traffic congestion by reducing the average passenger occupancy (APO) to the target level at the site. The success of a site's meeting its target APO depends on ETCs' interpersonal skills within the site and their ability to recognize the opportunities and barriers around them. The results of the survey indicate the difficulty that firms have in meeting their mandatory APO target. While it is still early in the program, only 44 percent of the sampled ETCs and an estimated 9 percent of the population believe that their sites will meet their targets within the appropriate time frame. More ETCs than their supervisors feel complying with the employee trip reduction program as an essential task to clean air and reduce congestion. More than half of the supervisors are perceived by ETCs as supporting only the paperwork requirements in the process of compliance and implementation. As for attitudes toward performing necessary tasks within the site, ETCs rate each task uniformly more important than their supervisors. ETCs have negative attitudes toward proposing parking charges and rideshare benefit strategies to meet the targets. Furthermore, ETCs believe that proposing tough policies will harm their careers. Without strengthening the ETC's position with respect to top management and their supervisors, attainment of the commuting mandates will occur in few cases; whereas stress and high job turnover will epitomize the ETC's position.

The Clean Air Act Amendments of 1990 require employers in areas of severe ozone nonattainment to implement transportation control measures or employee commute options (ECO). New Jersey's Employee Trip Reduction Program (ETRP) requires that an employee transportation coordinator (ETC) be assigned to work sites of over 100 employees by every affected employer. This has been done to ensure that affected employers make a good-faith effort to move the site's current average passenger occupancy (APO) level to its target APO by November 15, 1996.

The compliance plan submitted by the affected employers 2 years before its target deadline describes a set of ECO that, according to Section 108f of the Act, will demonstrate compliance with the target APO. The resulting plan will require the consumption of resources at the site; therefore, the site's top management team (TMT) must approve the plan. In addition, implementing an ECO compliance plan requires employees' cooperation in that it encourages a change in their daily travel behavior. Communication with employees requires that ETCs work with departments as well as union bargaining units.

What constraints and opportunities do ETCs face when they seek support from the TMT and department heads? The human side of the ECO implementation process is examined as it forms a benchmark from which changes in corporate responsiveness to ECO can be proposed and measured. The study begins with an examination of the study methods and is followed by an exploration of the conditions surrounding the ETC position, the source of organizational support, and the barriers to ECO implementation.

Real resources will be needed to address the problem. However, mobilizing the resources for use in the ECO implementation process requires firms to reallocate existing budgets. ETCs and their departments must negotiate with other departments and motivate the TMT to accept the program. To acquire resources and perform organizational tasks, ETCs must be motivated to act in the best interest of the program. The support of the top management team, the ETC's supervisor, and other departmental heads is essential (*1*). This research is designed to explore the organizational support mechanism underlying current ECO activity.

THEORETICAL MODELS

The theory of reasoned action underlies the analysis of opportunities and constraints ETCs face in firms. Attitudes of the ETC toward performing each task are matched with the ETCs' perceptions of their immediate supervisor's attitudes as the critical precursors to meeting the compliance plan's target APO. According to the theory, both classes of attitudes determine the degree of intention for ETCs to perform the activities needed to implement the ECO plan (*2*).

To work successfully within an organization, ETCs must obtain support from their supervisors and cooperation from employees. The tasks ETCs must perform include: (*a*) notifying and educating management, (*b*) motivating and training employees, (*c*) designing workable programs, (*d*) holding informational sessions with employees, and (*e*) assigning specific targets for different departments, etc. Each of these tasks requires that the ETC act creatively and efficiently to achieve their objective. The theory of reasoned action also suggests that ETCs who believe that the outcome of performing essential tasks will support their career will be more likely to perform these tasks. Similarly, where the ETC's supervisor is viewed by the ETC as supportive of the efforts to implement the ECO program, the incentive to act creatively and efficiently on the program will be stronger than in the case where the supervisor is viewed as an obstacle.

The second theoretical model used to guide the research is the Theory of Intraorganizational Power (*3,4*). The theory suggests that the ETC's department will have more power than other departments, as the ETC's department shares important beliefs with the TMT and as the department reduces uncertainty faced by the organization from external or internal contingencies such as penalties from state and federal ETRP law (*5,6*). A range of values or beliefs

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has been identified by Enz (*4*) as contributing to an index of departmental power; these include professionalism, ethics, aggressiveness in the market, profits, employee morale, and reaction to employee failure.

ETRP regulations and penalties are external contingencies faced by firms. In a command and control regulatory climate, program effectiveness hinges on the level of certainty perceived by the affected community for the program's enforcement. Specifically, control of the external and internal contingencies depends on the way ETRP is defined by the TMT, by the level of support given to the ETC's department, and by the level of resources mobilized to deal with ETRP.

In summary, ETCs' attitudes and their perceptions of supervisors' attitudes can be either barriers or motivations for actions in meeting a target APO. As motivational factors, they are necessary conditions for a successful program. However, they are not sufficient. For a target APO to be achieved, the ETC must use intraorganizational power or influence to change commuting behavior or work schedules across all departments. Thus, an examination of the ETC as a decision-maker as well as the examination of intraorganizational power is needed to forecast ETC's success.

RESEARCH DESIGN

The study is exploratory, describing the conditions in which ETCs operate and develops indicators that predict the effectiveness of various ETC behaviors in meeting their site's target APO. The data gathered to meet these objectives have been from ongoing survey research being performed in New Jersey. The draft instruments were pilot-tested on ETCs and staff members of a Transportation Management Association (TMA). These early tests indicated that successful administration requires that the survey be administered anonymously. The final questionnaire is 18 pages, printed on a laser printer requiring 25 min on average to complete. A copy of the questionnaire can be obtained from the authors.

Questionnaires

The questionnaires are divided into three parts. The first part is descriptive. Information is requested on the length of time ETCs have been on duty, the activities they perform, characteristics of their departments and firms, and confidence level they feel their firms will meet target APO by November 15, 1996.

The second part is an attitudinal study motivated by the work of Ajzen and Fishbein (*2*). The study examines the attitudes held by the ETCs toward implementing the ECO plan and performing actions needed to achieve the site's APO goal. In addition, the same set of questions is asked to examine the perceptions held by ETCs regarding their supervisors' attitudes toward the ETC performing APO target-related tasks.

Questions in the third part of the survey explore the relation between perceived values and power assigned to the ETC's department. Here, power is viewed as the ability of the ETC's department to influence other departments' implementation of ECO strategies. Organizational theory suggests that power assigned to he ETC's department will be positively related to the degree of similarity shared by the ETC's department and TMT in terms of general values in running the organization and specific values about the compliance plan.

Sample

The target population for the study consists of ETCs working at employment sites within New Jersey. The actual sampling frame consists of ETCs employed in New Jersey who have attended networking and training sessions held by TMAs or whose names are listed with TMAs. The TMAs estimated that 20 percent of the affected employers within their regions participated in the training programs. The sampling frame permitted a high response rate for the survey; omitted from the frame are sites and ETC whose firms have not registered with the state Bureau of Employee Trip Reduction. We recognize that the individuals attending the training and networking sessions will represent firms actively involved in the ECO implementation process. As a consequence, there will probably be an upward bias in the estimates of overall success of ECO programs.

EMPIRICAL FINDINGS

The ETC is not yet a fully defined job classification (*7*). In all cases surveyed, employee transportation coordination is a set of duties added onto the existing duties of a current employee located at the work site. The ETC has been placed in a wide range of subunits. The subunits can be roughly categorized into six categories: (*a*) human resources, (*b*) external affairs, (*c*) facility management, (*d*) security, (*e*) administration, and (*f*) other. Table 1 displays the percent distribution of the respondents by departmental category.

TABLE 1 Percentage Distribution of ETCs by Departmental Category

Departmental Category	Percent Distribution*
Human Resources	44.0
External Affairs	15.0
Facility Management	15.0
Security	11.0
Administration	8.0
Other**	7.0
Total	100.0

*Column values are subject to rounded errors.
**The Other category includes finance and teaching.
Sample size: 107 ETCs.

Most ETCs belong to human resources departments. This department is responsible for all matters related to employees such as recruiting employees and employee relations. The second most common placements for the ETC are departments of external affairs and facility management. The external affairs category brings together a disparate set of departments such as those that deal with new governmental regulations and community affairs. ETCs whose previously reported jobs were project coordinator, engineer, and shipping manager are categorized into the facility management department. Third in ranking for ETC placement are the departments of security and administration. The security deals with safety, fire protection, emergency cases, and parking management. The administration department consists of staff functions supporting the TMT. Finally, the "other" category combines ETCs from functions such as teaching and finance.

The ETCs surveyed come from a wide variety of situations and firms. Table 2 shows that the employment sites represented ranges in size from 103 employees to 4,100 employees. Thirty-four percent of the sites have unions. Thirty-six percent of the ETCs are the heads of their departments and 17 percent also supervise other ETCs outside their sites. The period since ETCs have been on duty ranges from 1 day to 8 years, with a median value of 7.4 months. The average work time devoted to the ETC duties is about 25 percent. Eighty-five percent of the ETCs indicated that their previous job required much interaction with other departments. Therefore, previous experience in the art of interaction and negotiation appears to be an important precondition for the ETC assignment.

Organizational Structure

Formal organizational structure can influence the process that ETCs must follow to get ECO strategies approved. Table 3 organizes the departments in which the ETC are located into one of two categories: flat and hierarchical. The hierarchical category is further partitioned into high, middle, and low, depending on the ETC responses to questions asking if there are other departments in their organization that are lower or higher in the structure of the organization than their department. The table shows that 33.6 percent of ETCs reside in firms with flat organizational structures. The hierarchically organized firms placed the ETC high in 34.6 percent of the cases. About 6.5 percent of ETCs' departments are located lowest in the hierarchically organized firms.

It is unclear what precise role organizational structure will play in the ultimate success of the ECO program. However, ETCs responding to a question evaluating their site's chances of success-

TABLE 2 Descriptive Statistics for ETC and ETC's site

Size range of site	Low: 103 employees
	High: 4100 employees
ETC is a Department Head	36 %
ETC Supervises other ETCs	17 %
Median time serving as ETC	7.4 Months
Percent work time serving as ETC	25 %
Experienced interacting with other departments	85 %
Sites with unions	34 %

°Column values are subiect to rounded errors.

TABLE 3 Organizational Structure and Location of ETCs Department by Hierarchical Type and Percentage Expecting to Meet Target APO Date

Organizational Type	Percent ETCs	Percent ETCs who forecast meeting the Target APO °
All Sites	100.0	44
Flat	33.6	36
Hierarchical	66.4	49
High	34.6	62
Middle	21.5	39
Low	6.5	14

°ETCs were asked to indicate the likelihood of meeting their site's target APO by November 15, 1996. Those who indicated a greater than even chance to meet the goal were counted as forecasting its achievement. The percentages are based upon organizational type.

fully making their target APO in 1996 indicate that formal structure may make a difference. Table 3 shows that ETCs located in departments that are high in a hierarchically organized firm are most likely to feel confident regarding their meeting the target than other ETCs. ETCs whose placements are lowest in a hierarchical structure report the lowest level of predicted APO goal achievement. This is reasonable in that placement in a high-ranking department places the ETC at an advantage when attempting to negotiate and convince other department heads and their employees of the importance of the ETRP program (*8*).

Attitudes and Constraints

This section examines both ETCs' attitudes toward performing the organizational tasks that lead to ECO implementation and the assessment of their department's influence among departments at the employment site. It also examines the role of the ETCs' supervisor in supporting compliance efforts. In the latter case, the attitudes of the supervisors are those reported by the ETCs (*2*). This is appropriate in that the ETCs' actions are determined by their perception of the rewards and penalties to be derived from actions taken in support of the ECO plan.

Attitudes Toward Performing Organizational Tasks

By November 15, 1994, ETCs must have performed a set of procedural tasks or activities that will have provided their site with a certified ECO Compliance Plan. For the plan to be successful, the ETC should have the organizational motivation and support to implement it. The ETCs are not required to demonstrate substantive changes in APO until 1996. The activities undertaken in the interim period will determine the plan's success. Based upon interviews held with directors of TMAs and ETCs who have been active for the past year, a series of activities linked to the acquisition of organizational support were identified and included in the ETC survey. Activities necessary for ETCs to perform include: (*a*) informing the top management team of critical contingencies faced by the site and asking their help in motivating department heads and employees, (*b*) contacting department heads and requesting their cooperation, (*c*) promoting the ECO program at the site, and (*d*) preparing incentives to encourage employees' participation in the ECO program. ETCs were asked to check the activities they have already performed as well as indicate their perceived degree of importance related to these activities on a scale of 1 "extremely unimportant" to 7 "extremely important" with 4 being neutral. In addition, the ETCs were asked to rate their supervisor's view of the importance of performing each activity. Table 4 displays the survey's results.

Table 4 ranks the 12 activities by the percent of ETCs who have already or are currently performing the activity. Most ETCs have or are performing tasks related to contacting the site's TMT and department heads. Seventy-seven percent of the sampled ETCs say that they have informed the TMT of the site's target APO, and 62 percent have briefed them on the set of strategies they feel necessary to meet the target APO. Slightly over half of the sampled ETCs have met with departmental heads while 28 percent have begun the effort to meet with employee groups.

The last task of the list, assigning each department a voluntary target APO to meet the site's target, was added into the survey after most of the sample had been collected. About 60 ETCs responded to the question. Where successfully implemented, this task spreads the burden for both implementing the ECOs and achieving the target APO from the ETC to supervisors in all departments. It also can form the basis for a management plan supporting the implementation of the ECO. As a derivative benefit, it can reduce employees' role ambiguity in the implementation process because the employees' immediate supervisor is brought into the goal achievement process (*8*).

When evaluating the importance of each activity shown in Table 4, ETCs rate the tasks other than setting departmental targets with importance greater than neutral. The highest ratings involve activities that inform or request support from the top management team or departmental heads. Table 4 indicates ETCs report that their supervisors rate each activity as less important than the ETCs. Since the supervisor acts as a gatekeeper who controls the outreach efforts and creativity of the ETC, Table 4 indicates the existence of potential barriers to the successful implementation of ECO plans.

Beliefs Toward ETRP

Beliefs or values about the importance of the actions taken are viewed as the basis for many of the attitudes decision-makers hold regarding their activities. ECO programs are required by government to advance clean air and reduce congestion. To the extent that this belief is held by ETCs and their supervisors, the more likely that strong ETRP programs will be submitted to top management and sold enthusiastically to other department heads and employees. Table 5 displays the responses ETCs made to statements of four beliefs that can determine their intention to perform necessary ECO-related activities.

Table 5 shows that ETCs' beliefs toward complying with ETRP are more strongly associated with the social goals of the Clean Air Act Amendments than are their supervisors'. Thirty-six percent of the ETCs see clean air and congestion relief as the basis for their activities; on the other hand, only 11 percent of their supervisors are perceived by ETCs as accepting these same values. By far, the broadest belief held by ETCs' supervisors underlying ETRP activities is the inherent need to meet the state's regulatory requirements. Therefore, the activities that most supervisors will urge ETCs to perform will be those that meet the formal or paperwork requirements of the law. The popularity of such an attitude held by supervisors is also shown in our interviews with ETCs. One ETC stated his supervisor's attitude toward complying with ETRP program as, "We will consider all options including doing nothing in order to minimize the influence of compliance on our business." Ten percent of ETCs perceived that their supervisors believe the ETRP program will disappear before November 15, 1996, while 4 percent of ETCs hold the same beliefs. If both the ETC and the supervisor hold the lowest level of belief, the Theory of Reasoned Action tells us that ETCs will have little intention to perform meaningful tasks in the ECO implementation process.

Issue-Specific Attitudes Toward ECO Strategies

The importance of ETCs' attitudes and their perception of the attitudes of supervisors and top management team members is seen at the level of specific ECO activities. ETCs feel stressed when proposing trip-reduction strategies to both the top management team and their supervisors. Two strategies were asked in the survey: $1.00 daily parking charge for drive alone and $3.00 daily rideshare ben-

TABLE 4 Percentage of Activities Completed and Rating of Activities According to Their Importance in Successful ETRP

Task Description	Percent of ETCs Completing the Activity**	ETC Rating*	Supervisor Rating
a. Meet with site's top management team to inform them of the site's target APO	77.5	6.15	5.64
b. Meet with site's top management team to brief them on the potential strategies that may be needed to meet the site's 1996 target APO.	62.6	6.28	5.69
c. Meet with department heads and request their cooperation.	53.3	6.10	5.40
d. Prepare fliers to promote the ETRP program	40.2	5.60	4.67
e. Prepare newsletters to promote the ETRP program	35.5	5.39	4.56
f. Held focus group meetings to promote ETRP program.	28	5.53	4.60
g. Have member of site's top management team address all employees and request their cooperation and encouragement in the ETRP program	27	5.64	5.22
h. Have member of site's top management team address all department heads and request their cooperation and encouragement in the ETRP program	22.4	5.70	5.22
i. Construct a rideshare matching list	20.6	5.59	4.83
j. Prepare the initial program plan that will offer commuter prizes to promote ETRP	17.7	4.84	4.02
k. Have received a written approval by a member of the site's top management team for that person to address at a future date all department heads and request their cooperation and encouragement in the ETRP program	12	5.14	4.61
l. Assign each department a voluntary and suggestive target APO to contribute to the sites' overall target APO.	***	3.78	3.55

*Rating scores range from 1 "extremely unimportant", to 7 "extremely important".
**Survey was held during the month of June, 1994.
***ETCs were not asked this part of the question.

TABLE 5 Percentage Distribution of ETC Responses to Four Statements Regarding Beliefs in Complying with ETRP

Belief Statement	Percent ETCs Choosing Belief Statement*	Percent Supervisors Perceived by ETC to accept Belief Statement
1. ETRP is essential because rapidly increasing numbers of SOV drivers will damage the air we breathe and increase traffic congestion	36	11
2. We will do what the state requires us to meet the target APO within two years	24	23
3. We will do what the state requires us to meet the regulatory requirements of the state's ETRP program	32	50
4. We do not care much about the ETRP program because we believe it will disappear before the date we are required to meet the target APO.	4	10

* Columns subject to rounding error.

efit for ridesharers. ETCs were asked to check appropriate values where 1 equals "extremely bad" and 7 corresponds to "extremely good", with 4 being neutral in correspondence with their attitudes. Table 6 shows that ETCs' attitudes toward proposing both of the two strategies are below neutral, ETCs feel slightly better toward proposing rideshare benefits than parking charge. ETCs probably sense that proposing a parking charge would more severely influence employees' morale than proposing a rideshare benefit.

ETCs perceive their supervisors as less supportive of the strategies than ETCs themselves. Finally, Table 6 indicates that ETCs feel stressed in informing the top management team that their site will fail to meet its November 15, 1996 target APO. This suggests that ETCs are in an awkward position in which they receive little support from either their supervisors or the TMT, while simultaneously being required by law to bring their sites into compliance by November 15, 1996.

ETCs were also asked how likely they feel it will help their career advancement to propose parking charges or rideshare benefit programs. Table 7 shows that proposing a parking charge is viewed as unlikely to enhance the ETC's career, while proposing the rideshare benefit is slightly more likely to enhance their career in contrast to the parking charge proposal. However, the difference between attitudes toward proposing these two strategies is not significant. Clearly, both views are negative in terms of the personal cost of acting in the best interests of the ETRP program.

Perceptions of Departmental Power

If ETCs' own attitudes and their supervisors' attitudes act as a motivation for ETCs to perform ETRP activities, ETCs must use influence or power as a tool to achieve what they believe. Five questions were asked of ETCs to determine their perceived level of power. Each question is structured as a seven-level Likert scale. Figure 1 displays the average ranking for each indicator of power.

On average, all five indicators of power or influence are found within the upper range of the influence scale. Power theory (*4*) suggests that the higher level the power they perceive they have, the

TABLE 6 ETCs' Attitudes Toward Performing Actions in the Face of TMT

Actions	To TMT*	To Supervisors*
Proposing $1.00 Parking charge	2.46	2.61
Proposing $3.00 rideshare benefit	3.61	3.83
Informing The TMT of failure to meet the target APO	3.60	**

* Rating 1 "extremely bad" with 4 being neutral, and 7 "extremely good".
** No question is available for supervisors' attitudes toward ETC's informing failure of the sites' meeting the target APO.

TABLE 7 ETCs' Beliefs Toward How Likely It Will Help Their Career to Propose ECO Strategies

Actions	Rating score°
Proposing $1.00 daily parking charge	5.89
Proposing $3.00 daily rideshare benefit	5.74

° Rating 1 "extremely likely" with 4 being neutral and 7 "extremely unlikely".

more actively ETCs will perform at the site. ETCs feel most influential in promoting a guaranteed ride home and they believe that they have above average influence in affecting the outcomes of the ECO program. However, ETCs feel least confident about their department's general power in their company. The relatively modest value for general power suggests that, on average, ETCs will not be motivated to work at their creative peak in the performance of critical organizational tasks needed to meet the target APO. Recognizing the low level of perceived support ETCs receive from the TMT in proposing tough strategies (Table 6), the higher values obtained for indicators of issue-specific power suggest that strategies with little TMT support will be pursued.

Perceived Achievement Rates

How well will be state progress toward achieving the mandated reduction in dependence on the private automobile? Overall, 44 percent of the sampled ETCs feel positive toward their sites' meeting the APO target by November 15, 1996. However, the self-selected nature of the sampling frame suggests that for the ETC population as a whole, the perceived success rate will be far smaller. If it is assumed that the 80 percent of employers who did not send ETCs to training sessions are disinterested and unsupportive of the program, the 44 percent perceived success rate should be discounted to approximately 9 percent.

1. In general, how much influence do you feel your department has in your company?

No influence — 4.98 — A great deal of influence

1 2 3 4 ↑5 6 7

2. Specifically, how much influence do you feel your department has in affecting the outcomes of the ECO program?

No influence — **5.32** — A great deal of influence

1 2 3 4 5↑ 6 7

3. Specifically, how much influence do you feel your department has in promoting the acceptance of a Guaranteed Ride Home Program?

No influence — **5.63** — A great deal of influence

1 2 3 4 5 ↑6 7

4. What is the degree of influence your department has in its ability to convince top management that the target APO is for real?

No influence — **5.41** — A great deal of influence

1 2 3 4 5 ↑ 6 7

5. What is the degree of influence your department has in its ability to convince top management that poor public transportation resources around the site will require them to approve a strong ECO plan?

No influence — **5.00** — A great deal of influence

1 2 3 4 ↑ 6 7

FIGURE 1 Measures of general and specific intraorganizational influence or power perceived by ETCs to exist within their departments.

CONCLUSIONS

Achieving the target APO by the required date will be a daunting task. The job facing ETCs will draw on all of their interpersonal relations skills. Caught between top management and their supervisors on one hand, and other department heads and employees on the other, ETCs are in a stressful situation. While 44 percent of the sample currently feel their site will meet the commuting mandates, 50 percent of the ETCs indicate that their supervisors will provide only the support necessary to meet the paperwork mandates of the law; another 10 percent will not even do that. According to TMA estimates, the sample is over-represented with ETCs from large firms and from firms that are motivated to support the ETRP program. The percent of firms or employment sites that currently feel that they will meet the APO target is estimated to be under 10 percent. The ETC's career is perceived to be most threatened by pursuit of ECO programs that are most likely to change commuting behavior and bring the site into compliance with the law. Given the American penchant for the single-occupant vehicle, ETCs must find ways to work creatively and efficiently in meeting the site's target APO. Supporters of the ETRP provisions within the Clean Air Act must motivate and support the efforts of ETCs. Top management must be convinced of the value of the program; ETCs must spend more of their time educating the TMT regarding the underlying economic and health benefits that will accrue to firms and the region derived from the program's success. Supervisors and department heads must be convinced that the efforts of their ETCs are valuable and that changes in the employees' commuting or work schedules can have beneficial results for the firm. In summary, the responses suggest that the use of employer mandates is a questionable policy. Alternatively, public education, motivation, and voluntary compliance with meaningful clean air and congestion-relief programs should be considered by federal and state government.

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Comprehensive, Practical Employee Commute Options Guidebook for New York State

MITSURU SAITO, CLAIRE MCKNIGHT, AND ELENA PRASSAS

A comprehensive guidebook for practical employee commute options (ECO) was compiled for employers in New York State to provide them the technical expertise to develop an ECO program. This ECO guidebook is a result of literature search, employer survey, and the participation of advisory committee members consisting of people from the agencies that will be enforcing the state regulations that implement the federal Clean Air Act Amendments of 1990 and representatives of several organizations that have experience working with employers on commuter transportation in the New York metropolitan area. This study identified guaranteed ride home programs, parking management, and the commitment of upper management as three essential factors that will make an ECO program succeed. The strength of this ECO guidebook is an extensive discussion of each commute option and support strategy as well as a discussion of the entire process of developing and implementing an ECO program and the background of successful ECO programs. The description of each commute option or support strategy contains such topics as definitions, candidate employees, employee and employer benefits, employer's role, employer and employee costs, detailed implementation steps, successful cases, additional resources and readings, and sample program implementation schedules. A summary of the findings from the literature search and employer survey is presented, the responsibilities of the employee transportation coordinator are discussed, and the guidebook is introduced briefly.

The New York State Department of Transportation (NYSDOT) and the New York State Energy Office (NYSEO) have identified the New York metropolitan area as highly congested. To comply with the federal Clean Air Act Amendments (CAAA) of 1990, the NYSDOT and NYSEO train employers (especially those with 100 or more employees, who are required to participate) to develop employee commute options (ECO) programs. Through the University Transportation Research Center (UTRC) program of the U.S. Department of Transportation, they sponsored the development of an ECO guidebook (*1*). This guidebook is to be distributed to employers who, voluntarily or by requirement, undertake to start commute-reduction programs.

A UTRC project team from the City College of New York and Polytechnic University performed an extensive literature search on trip-reduction programs and surveyed selected employers to obtain their views on such programs. Most of the organizations were from the New York metropolitan area, and a few were from California. They were chosen from those that already have programs encouraging ridesharing and the use of public transit. The team also formed an advisory committee, whose members come from the agencies that will enforce the state regulations implementing the CAAA of 1990, as well as from several organizations that have experience working with employers on commuter transportation in the New York metropolitan area. For example, Transit Center, the agency that promotes the employer transit-subsidy program, and Long Island Transportation Management and Metropool, organizations that provide technical assistance to employers, were on the advisory board. The New York Chamber of Commerce was instrumental in soliciting feedback for the guidebook from several of its business members.

A summary of the efforts in preparing the guidebook is presented. First, a description of the state's requirements for an ECO guidebook is given, followed by the goal and objectives of the guidebook and major findings from the literature and employer survey. Then, the salient points of the guidebook are summarized. The guidebook is comprehensive and practical, prepared in plain English for future employee transportation coordinators (ETCs).

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REQUIREMENTS FOR ECO GUIDEBOOK

Past regulatory efforts to reduce pollution from automobiles, while successful in reducing pollutants per vehicle-mile, have been undermined by the increase in the total vehicle-miles that Americans drive. The CAAA of 1990 addresses the reduction of vehicle-miles through several measures, one of the most controversial of which focuses on commuting in single-occupant vehicles (SOVs). Unlike most regulations, final implementation will be done by large employers (public and private) rather than by governmental agencies specifically responsible for environment, transportation, or planning. Specifically, the regulations establish requirements for employers with 100 or more employees at a work site in a severe nonattainment area for ozone. These employers must show that the ratio of employees reporting during the peak period to the number of vehicles used for the commutes is equal to or greater than the average vehicle occupancy (AVO) targeted for the region where the worksite is located. The target AVO values are 25 percent above the AVO standards, which are computed using the 1980 and 1990 U.S. Bureau of the Census data and a linear projection. If this target is not met at present, the employers must make efforts to change commuting habits through ECO programs so as to achieve that AVO.

The new regulations require that organizations take on much more responsibility for how their employees get to work than they did in the past. These regulations ask most employers to reverse their involvement in commuting transportation. Few organizations are prepared for this role. Often, employers have provided free parking to their employees, which added to the incentives for employees to drive their own cars. The ECO regulations ask employers to reduce the number of commuters driving alone.

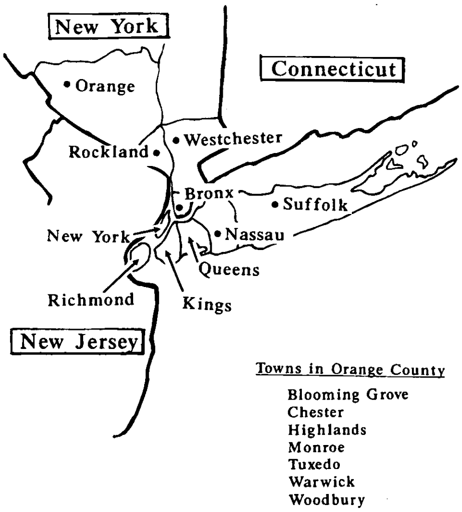

FIGURE 1 Counties and towns in ozone nonattainment areas in downstate New York.

Areas in New York State that are directly affected by the CAAA of 1990 are concentrated in the downstate region. The Environmental Protection Agency designated 9 counties, plus seven townships in a tenth county, in downstate New York as severe nonattainment areas for ozone. Figure 1 shows the locations and names of the affected counties and townships. These areas are grouped into four regions to apply state standards (*2*):

- Region 1: The county of New York (AVO = 7.81);
- Region 2: The counties of Bronx, Queens, Kings, and Richmond (AVO = 2.48);
- Region 3: The counties of Nassau and Suffolk (AVO = 1.46); and
- Region 4: The counties of Westchester and Rockland and, in Orange County, the townships of Blooming Grove, Chester, Highlands, Monroe, Tuxedo, Warwick, and Woodbury; any other contiguous counties or areas that are designated by the EPA as severe nonattainment areas for ozone (AVO = 1.56).

The regulations enacted by New York State to implement the federal CAAA of 1990 require that each county have a local administrative agency to monitor compliance and that each organization that must comply (i.e., that has a work site with 100 or more employees in the severe ozone non-attainment area) must designate one person, the ETC, to be responsible for preparing the compliance documents. Each organization must survey its employees to determine its current average passenger occupancy (APO). The concept of APO is similar to that of AVO. The APO is determined by individual organizations for their work sites, while the AVO is the target value determined for each region by the state, based on the 1980 and 1990 U.S. Bureau of the Census data. If the computed APO is below the target AVO for the area where the work site is located, the organization must prepare an ECO plan to show how they will achieve the target AVO. If their APO is equal to or greater than the target AVO, they must prepare a maintenance plan.

GOAL AND OBJECTIVES OF GUIDEBOOK

The goal of the ECO guidebook was to provide employers in New York State with technical information that is comprehensive and practical. It is written in plain English, in order to be readily understood by nontransportation personnel of an organization and to help them through the development and implementation of an ECO program.

The specific objectives of the guidebook were to accomplish the following:

1. Present the entire process of the program development in order for ETCs to gain an overview of the process;
2. Include sample forms and sample situations for easier comprehension of the concepts discussed in the guidebook;
3. Inform ETCs about potential barriers to developing ECO programs and how to overcome them;
4. Encourage ETCs to take a team approach involving management, union representatives, legal experts, information specialists, and so forth, as well as employees;
5. Include successful ECO programs as examples to illustrate in what circumstances particular commute options were successful;
6. Make the description of each commute option and each support strategy stand alone as much as possible so that sections for commute options and support strategies can be pulled out of the guidebook to circulate among those involved;
7. Include lists of administrative agencies, transportation management associations, and ride-matching organizations in New York to help ETCs access necessary information; and
8. Make the guidebook instructive for employers that are not affected by the NY ECO regulations either because they are not in the nonattainment areas or because they are below the threshold of 100 employees at a worksite.

RESEARCH FINDINGS

The project team drew together information from existing programs and studies, as well as the survey conducted as part of the project. Some of the earlier studies are listed in the reference section of this paper (*3–10*). Particularly useful were ECO programs in California that have already been implemented in response to California State Regulation XV, on which the federal regulations were modeled.

Most of the surveyed employers in the New York Metropolitan area developed ECO programs for other purposes than meeting the CAAA regulations. For instance, Cornell University developed a successful demand-management program with the goal of reducing the demand for parking on its campus so that they would not need to build a new parking garage. Similarly, Texaco in White Plains, New York, started its vanpool program in the 1970s primarily to alleviate some of the commute hardship of their employees who were being transferred to a suburban office. When the transfer took place, employees who did not own cars requested company-sponsored transportation. As a result of the success of the pilot program, vanpools are now operating at many of Texaco's major office facilities.

Certain lessons were learned from the various studies. For instance, the results from the first several years of California's ECO program suggested that ECO programs would not be an effective approach to clean air in California. The program there has had a small, probably insignificant, impact on total vehicle miles and on air pollution. This was partly because only 12 percent of the employers covered by the regulation achieved their target, but more because the vehicle-miles covered by the regulation were only a fraction of total driving in that state. Work trips make up only a quarter of total trips, and only trips to large work sites and only trips

during the peak period were included in the program. The decrease in vehicle-miles attributed to the programs was estimated to be less than 0.5 percent of total miles traveled. This amount was less than the annual growth in vehicle-miles of travel (VMT).

Although these results are discouraging, New York, particularly those counties that are in the nonattainment category, has a strong transit commute tradition that could help ECO programs succeed. Furthermore, over a longer period, there may be greater change in commuter behavior due to decreased availability of fossil fuels. Lessons from the California programs can make the New York programs more effective. For example, the most successful programs tend to combine several options and support strategies. Support strategies include policies that would make commute options more attractive, such as guaranteed ride home, parking management, flexible work hours, and the provision of shower facilities for employees who bicycle or walk to work.

Three support programs were essential to many successful ECO programs: guaranteed ride home, parking management, and upper management's commitment. Without a guaranteed ride home program, many employees will continue to drive their personal cars despite the advantages of alternative commute options because they are afraid of not being able to respond quickly to a personal emergency. This is particularly true of working parents with young children. Once they are assured that they can reach their homes or children quickly, through the use of a taxi, a company car, or other methods, they are much more willing to try other commute methods. A further finding is that most companies that have provided a guaranteed ride home reported that they were not paying a lot for it. Because the program was there for emergencies, it was not frequently used: it was the guarantee that gives the participants essential peace of mind.

A second support strategy that has been very effective is parking management, particularly reduction in free parking. Employers may find it difficult to take away free parking, a benefit that is often taken for granted and occasionally written into union contracts. One successful approach is to pay each employee a commute allowance which is equal to the fee for parking. Thus, an employee who chooses to continue to drive an SOV breaks even monetarily, while one who changes to another mode, transit for example, profits by the amount of the allowance. Parking-fee structures can also be designed to encourage carpooling and vanpooling by charging fees per vehicle that decrease with the number of occupants, or employees who have more than a set number of passengers can be given rebates. Cornell University used this type of parking-fee structure. The university's program was able to reduce the number of single-occupant drivers by about 26 percent within a year (*9*).

A third important factor for many successful ECO programs is the commitment of upper management. Only with strong management support can the ETC effectively enforce the ECO program. Upper management's commitment needs to be communicated to supervisors who directly deal with the commuting employees.

DEFINITIONS OF EMPLOYEE COMMUTE OPTIONS AND SUPPORT STRATEGIES

New York state grouped transportation demand management (TDM) measures described by the CAAA into two groups: employee commute options and support strategies. Commute options could involve modal changes by commuters from an SOV to high-occupancy vehicles (such as public transit, carpooling, and vanpooling) or to commute alternatives that do not involve motorized vehicles (such as bicycles or walking). Commute options could also involve changes in frequency or time of commuting, such as compressed work hours or telecommuting. Support strategies are ones that enhance the attractiveness of selected commute options, as defined in the previous section. By grouping programs into these two categories the relationship between commute options and support strategies was made clear. For instance, if use of public transit was selected as a commute option to reduce SOVs, then fare subsidies, guaranteed ride home programs, and so forth can be selected as support strategies to make transit use more attractive. Figure 2 shows the types of commute options and support strategies included in the New York ECO guidebook.

ROLE OF EMPLOYEE TRANSPORTATION COORDINATOR

The ETC is the key person to pull management, the union, and employees together to make an ECO program work. Having an ETC with the responsibility of carrying out the ECO program is a requirement for the employers covered by the metropolitan New York ECO regulations (*2*), and is recommended for voluntary programs. The ETC will guide the development of the ECO program

Chapter 1. How To Use This Guidebook
Chapter 2. What Do You Have To Do
Chapter 3. Putting Together An ECO Program
Chapter 4. Conducting A Survey
Chapter 5. Choosing Commute Options
Chapter 6. Marketing
Chapter 7. Monitoring and Evaluation
Chapter 8. Employee Commute Options
- Public Transit
- Vanpooling
- Carpooling
- Buspooling
- Bicycling
- Walking
- Variable Work Hours
- Telecommuting
- Other Commute Options

Chapter 9. Support Strategies
- Guaranteed Ride Home
- Parking Management
- Ridematching
- Joining or Starting a TMA
- Direct Financial Incentives
- Transportation Allowance
- Transportation Information Center
- Employer Policies
- Van Driver Incentives
- Assistance in Child Care
- Park-and-Ride Lots
- Shuttle Services

Glossary

Appendix A. Metropolitan NY ECO Regulations
Appendix B. List of Local Administrative Agencies
Appendix C. List of Existing TMAs in New York
Appendix D. List of Ridesharing Organization in New York
Appendix E. Guaranteed Ride Home Sample Forms
Appendix F. The Cornell University Example: A Summary
Appendix G. Federal Energy Policy Act

FIGURE 2 Table of contents of New York State ECO guidebook.

for the employer or for a specific work site of the organization, implement, market, manage and oversee, and monitor and evaluate the ECO program.

The guidebook provides sample job descriptions of future ETCs. The following are major tasks that ETCs may carry out; their actual duties will depend on commute options and support strategies chosen for their ECO programs.

- Conducting employee commute pattern surveys,
- Monitoring progress,
- Coordinating efforts,
- Providing personalized assistance,
- Cooperating with the local transit operators,
- Promoting the ECO program,
- Attracting new employees to the ECO program,
- Cooperating with the local administrative agency, and
- Keeping abreast of information about ECO programs.

In order to do all these activities, a potential ETC should have high motivation, an ability to work with people at all levels of the organization, creativity and independence in problem solving, commitment to following through and getting the details right, familiarity with marketing and promotion, and excellent interpersonal and communication skills.

PUTTING TOGETHER AN ECO PROGRAM

Figure 3 shows a flowchart of activities involved in putting together an ECO program at a work site. The entire procedure consists of the following activities:

- Establishing a schedule,
- Informing the participants,
- Getting management support,
- Forming a program team,
- Getting union support,
- Conducting a worksite analysis,
- Conducting a commute survey,
- Establishing the trip-reduction targets,
- Selecting commute options and support strategies,
- Preparing a budget,
- Preparing an implementation plan,
- Marketing the ECO program,
- Implementing the ECO program, and
- Monitoring and evaluating the ECO program.

Some of the activities need to be repeated throughout the preparation and implementation stages. For instance, employees, regardless of whether they participate in the ECO program, need to be informed of the progress periodically, and the program needs to be marketed continuously to retain present participants and to attract new participants.

CONDUCTING EMPLOYEE COMMUTE SURVEY

The employee commute survey is the most important source of information on employee travel patterns. If an employer is in an ozone nonattainment area, the local administrative agency will provide the employer with standard survey forms. The guidebook, however, contains sample forms with a sample problem for use by voluntarily-participating employers.

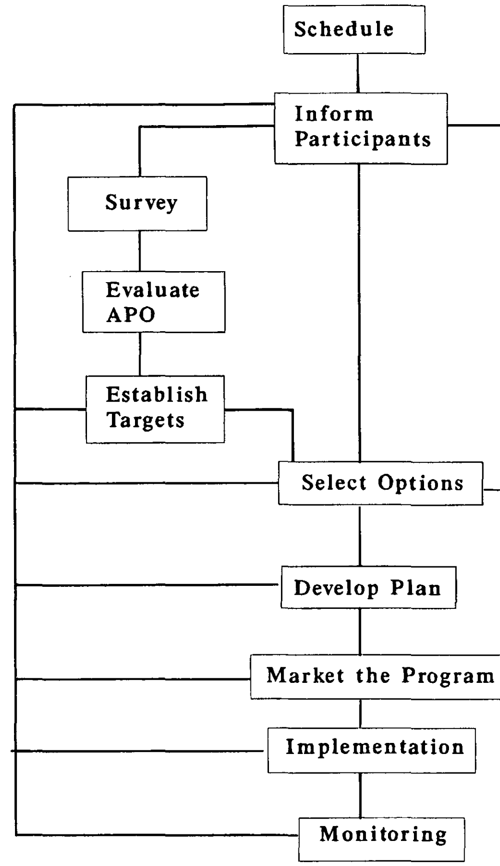

FIGURE 3 Flow chart for putting together ECO program.

Marketing of the employee commute survey was emphasized in the guidebook as necessary to getting an acceptable response rate to the survey. Employees must be told the purpose and importance of the survey. Several tips to boost the response rate were given, including posters, memos (on e-mail, if available), discussions with managers in advance, and incentives. The survey data must be analyzed properly. The NY ECO regulations require affected employers to collect information to determine their work sites' APOs, to compare with the target AVO of the area where the work sites are located and to estimate how many vehicle trips must be reduced to meet the target APO.

The sample employee commute survey has two parts: Part I for the APO survey (Figure 4), and Part II for employee attitude survey (Figure 5). The latter will be extremely important in selecting appropriate commute options and support strategies.

Based on the organization's current APO and the results of the attitude survey, the ETC needs to distribute the number of SOV trips to be reduced to various commute options, once an initial selection of options for the organization's ECO program is made. The ability to estimate the latent demand or attraction of employees to each commute option will be essential for the ETC to achieve the target trip reduction. At the beginning, the ETC needs to make an educated guess as to how many employees will actually be diverted to specific commute options in the ECO program; however, as time goes by, the ETC will learn more about the program's effectiveness and will be able to make better estimates.

The guidebook provides a sample estimation process, which uses the results of the commute survey and an attitude survey previously

PART I. APO Survey

(To be completed by the employer)

Company/Organization Name: ____________________

Work Location: ____________________

Commute information for week of: ____________________

(To be completed by employee)

Name: ____________________

1. a. Home City/Town: ____________________ b. Home Zip Code: __________

2. Usual Work Schedule: a) Report: _______ b) Leave _______ c) Hours worked per week: _______

3. What is the total length of your trip to work? a. Number of miles:______ b. Number of minutes: _______

4. Please answer the following questions using the table below.

A. Using the "Commute options" codes listed below, choose the one letter that best describes how you traveled to this work location each day last week. If you did not report to this work location on a given day, please choose one of the letters under "Reasons for not reporting". **If you used more than one mode of transportation, choose the letter that represents how you traveled for the last mode of the one-way commute trip (excluding walking as the last mode).**

B. Write in the approximate time you reported to work each day last week.

Example		Report Time
Monday	C	9 am

		Report Time
Monday	☐	______
Tuesday	☐	______
Wednesday	☐	______
Thursday	☐	______
Friday	☐	______

COMMUTE OPTIONS

- A Drive Alone
- B Drive Alone due to Disability
- C Public Transit (Subway, Bus, Ferry, Commuter Rail)
- D 2 Employee Vehiclepool
- E 3 Employee Vehiclepool
- F 4 Employee Vehiclepool
- G 5 Employee Vehiclepool
- H 6 Employee Vehiclepool
- I 7+ Employee Vehiclepool
- J Taxi/Car Service*
- K Motorcycle/Moped
- L Walk Only
- M Bicycle
- N Alternative Fuel Vehicle
- O Dual Fuel Vehicle
- P Other:..............................

REASONS FOR NOT REPORTING

- Q Telecommute Day (Work at Home)
- R Reported to Another Location/Business Trip
- S Compressed Work Week Day off.
- T Day Off (vacation, sick day, jury duty etc.)

* Use only if single passenger, if other adult passengers to the worksite shared the ride, count as vehiclepool.

FIGURE 4 Sample APO survey form.

completed. Figures 6, 7, and 8 show how this estimation may be done. In this example, the total number of affected employees was 250, with a response rate of 76 percent. Since the rate was less than 80 percent, it was necessary to compute the number of incomplete surveys and nonrespondents, which was found to be 57, as shown in Figure 6. Then, the number of weekly employee trips per category was converted to its vehicle equivalent using the criteria of the NY ECO regulations. There was a total of 900 employee trips, and its vehicle equivalent was 667.9 (Figure 7). Using the results from these forms, the current worksite APO was computed as 1.244 (Figure 8).

Next, it was necessary to estimate the number of vehicle trips to be reduced. The target APO for this example was 1.56. The maxi-

mum weekly vehicle equivalents was computed by dividing the number of affected employee trips by the target APO (1,185/1.56; see Figure 8). The estimated number of weekly vehicle trips to be reduced to meet target APO is computed by subtracting the maximum weekly vehicle equivalents allowed from the current total number of vehicle equivalents used in the worksite APO calculation. The value is 193 (that is, 953 − 760; see Figure 8) indicating the number of vehicle trips that must be reduced by a combination of commute options.

CHOOSING COMMUTE OPTIONS LOGICALLY

The key to a successful ECO program (that is, one that achieves the organization's targets with minimal cost and disruption) is providing a package of employee commute options that employees will want to use. This requires choosing options that are right for the organization and reinforcing them with appropriate support strategies. Thus, the selection of commute options requires a good understanding of work site characteristics, organizational culture, and employee preferences. Employee preferences for commute options are generally influenced by commuting time, commuting cost, and convenience. Which commute options can compete with the SOV on these three attributes will be affected by work site characteristics and support strategies.

A chapter of the guidebook discusses the steps of selecting commute options and support strategies. The ETC is guided by questions reflecting the items discussed above. The guidebook contains the results of a study (*4*) of the effectiveness of various ECO programs in giving the ETC a sense of direction in choosing programs

PART II. Employee Attitude Survey

5. In order to design an employee commute program that will meet your needs and interests, we need to know your opinion of each commute option listed below. DO NOT LEAVE BLANK. This is not a commitment to use any option. Note: For options A-E, state your opinion of using that mode one or more days per week, not necessarily all five.
Answer this question even if you already use one of the commute options listed below.

	Very Appealing	Somewhat Appealing	Not at all Appealing
A. Train	❑	❑	❑
B. Bus	❑	❑	❑
C. Bike or Walk	❑	❑	❑
D. Vehiclepool (with 1 - 6 employees)	❑	❑	❑
E. Vehiclepool (with 7 or more employees)	❑	❑	❑
F. Compressed Work Week (work more hours per day, fewer days per week)	❑	❑	❑
G. Telecommuting (work at home)	❑	❑	❑

6. If you were to use any of the methods of commuting listed above, what concerns would you have? *Choose no more than* four *that are most important to you.*

❑ A. Longer commuting time	❑ E. Not having car with me	❑ J. Getting to work from station
❑ B. Need car for business appointments	❑ F. Getting home in an emergency	❑ K. Dropping off & picking up my child/dependent at day care
	❑ G. Cost	
❑ C. More dependent on others	❑ H. Parking at train station.	❑ L. Other (describe)
❑ D. Overcrowded buses or trains	❑ I. Personal safety at train station/park & ride lots	________________

FIGURE 5 Sample employee attitude survey.

(*continued on next page*)

7. If you now drive alone to work, would you consider changing to ridesharing, public transit, or other commuting alternative if any of the following services or incentives were available (CHECK ALL THAT APPLY)

	Yes	No	Maybe
A. Discount transit passes	☐	☐	☐
B. Cash subsidies for employees who do not drive alone	☐	☐	☐
C. Monthly travel allowances to be used for any commute mode	☐	☐	☐
D. Shuttle bus to transit station or park & ride lot	☐	☐	☐
E. Company cars or vans available for rideshare	☐	☐	☐
F. Preferential or reserved parking for ridesharing	☐	☐	☐
G. Guaranteed ride home in emergencies for ridesharers	☐	☐	☐
H. Help finding someone with whom to vehiclepool	☐	☐	☐
I. Information on transit routes and schedule	☐	☐	☐
J. Other (specify)	☐	☐	☐
K. Nothing. Would not consider alternatives to driving alone.	☐	☐	☐

8. Other issues/comments/ideas you have concerning NOT driving to work: ______________________

____

FIGURE 5 *(continued)*

appropriate for the organization, and in allowing the ETC to make an informed initial selection of site-specific commute options and support strategies.

The specific selection questions listed in the guidebook can be found in Figure 9. The list of questions is by no means an exhaustive one; its purpose is to guide the ETC in the right direction. Each question is followed by a detailed discussion related to that particular question. The selection procedure consists of the following six steps:

1. Analyze the characteristics of the work site.
2. Analyze the employees' preferences. The primary source of information will be the employee commute survey. Obviously, commute options that many employees have indicated as appealing should be high on the list to be considered.
3. Analyze the culture of the organization and how it affects the fit between commute options and the organization. If there is an ECO project team, the ETC can ask for its input. Also, a focus group of employees from different parts of the organization can be formed to assess preferences.
4. Make an initial selection for further consideration.
5. Select support strategies.
6. Refine the selected commute options and support strategies and combine them into an ECO program package.

DISCUSSIONS OF EACH EMPLOYEE COMMUTE OPTION

The most important part of the NY ECO guidebook is the chapter on commute options; its detailed discussion of individual employee commute options will give the ETC the whole picture of particular commute options that may be appropriate for the work site. Figure 2 lists the types of ECO discussed in the guidebook. A separate section is devoted to each commute option, containing in general the following topics: description or definition, candidates, employer benefits, employee benefits, employer's role, employer cost, employee cost, implementation steps, successful cases, additional resources, and sample program-implementation schedule.

These are essential pieces of information for the ETC to make an educated decision in the options-selection process. The candidates subsection helps the ETC to quickly group potential ECO participants into particular types of commute options. The subsection on employer and employee benefits provides types of benefits that they can expect from the program. The subsection on the employer's role indicates the level of effort required to make the option a success; it stresses the importance of management support for a successful program. Both employers and employees are cost conscious, and unless their choice is cost-effective, they will not be attracted to the program. The ETC can learn from this subsection the types of costs that will be incurred to operate a particular commute option.

The heart of each commute option subsection is the detailed list of steps needed to set up that particular option. Essential steps in implementing the commute option are discussed in order in plain English. The subsection on successful cases briefly presents one or two successful programs along with their backgrounds for the ETC to learn from them as well as to be encouraged by their successes. The subsection on additional resources gives titles of a few reports recommended for further information about the option. Finally, the sample program-implementation schedule subsection gives the ETC a time frame for implementing the option.

Sample Response Rate Calculation Worksheet

RESPONSE RATE:

A1	Total Number of affected* employees	A1	250
A2	Number of affected employees absent during the *entire* survey week	A2	13
A3	Number of affected employees to survey (target population): Subtract A2 from A1	A3 = A1 - A2	237
A4	Number of complete surveys returned by target survey population	A4	180
A5	**Response Rate:** Divide A4 by A3	**A5= (A4/A3)x100**	76%
A6	(Complete only if response rate is less than 80%) Number of incomplete surveys and non-respondents: Subtract A4 from A3	A6 = A3 - A4	57

* *affected employees are those employees that report to the worksite between 6:00 and 10:00 AM, Monday through Friday.*

FIGURE 6 Sample response rate calculation worksheet.

DISCUSSIONS OF EACH SUPPORT STRATEGY

Another chapter has similar detailed discussions of individual support strategies. Figure 2 lists the types of support strategies included in the guidebook. The subsections for support strategies follow a structure similar to the commute-options subsections: description, when it works, employer benefits, employee benefits, employer's role, employer cost, employee cost, implementation steps, sample (or successful) cases, additional resources, and sample program-implementation schedule when available.

The description subsection provides in detail kinds of approaches available for a particular type of support strategy. For instance, three approaches to parking management are discussed: charging for parking, creating preferential parking, and reducing parking supply. Some parking-management strategies are more applicable to certain work sites than others. Therefore, in the subsection on when it works, the appropriateness of various parking-management strategies to the employer's work site is addressed. The subsections on employer and employee benefits and costs present types of costs that may be incurred by the program. The role of an employer is crucial in parking management, because the employer can influence whether or not to provide free parking, and how much the employee has to pay. The subsection on implementation steps contains steps for successful implementation of parking management. This writing style avoids rhetorical arguments on the good and bad aspects of parking management.

IMPORTANCE OF MONITORING AND EVALUATION

Monitoring will tell the ETC whether the ECO program has achieved the organization's goal or not, and how the program can be improved. Monitoring also enables the ETC to maintain participation after initial enthusiasm has worn off and employees are returning to old habits. The four most common parameters used for monitoring the ECO program are APO, participation rates, employees' attitudes and concerns, and program costs. Evaluation means the interpretation of the records to determine what works and what does not work, identify where problems exist, and figure out how to improve the program. Monitoring and evaluation are essential to achieve the following goals:

- To prove the employer's compliance with the NY ECO regulations;
- To understand better the factors that impede or encourage the use of alternative employee commute options;
- To determine how to increase employee participation and APO;
- To increase the cost-effectiveness of the ECO program;
- To make effective progress reports to management, employees and other interested parties; and
- Ensure that only eligible employees receive participation incentives.

Sample Employee Trips and Vehicle Equivalents Calculation Worksheet

1) From the APO survey, count the total number of responses for each of the categories listed below and place the result in column 1.
2) Calculate the vehicle equivalents by following the directions in column 2, and place the result in column 3.
3) Sum column 1 to find the total employee trips and place the result in Box R1.
4) Sum column 3 to find the total vehicle equivalents and place the result in Box R2.

	Column 1 Number of weekly employee trips per category	Column 2 Conversion to vehicle equivalents	Column 3 Vehicle equivalent
Commute Options			
A Drive Alone	604	Divide by 1	604
B Drive Alone due to Disability	5	Multiply by zero	0
C Public Transit	60	Multiply by zero	0
D 2 Employee Vehiclepool	20	Divide by 2	10
E 3 Employee Vehiclepool	45	Divide by 3	15
F 4 Employee Vehiclepool	12	Divide by 4	3
G 5 Employee Vehiclepool	20	Divide by 5	4
H 6 Employee Vehiclepool	24	Divide by 10	2.5
I 7+ Employee Vehiclepool	28	Multiply by zero	0
J Taxi/Car Service	12	Divide by 1	12
K Motorcycle/Moped	15	Divide by 1	15
L Walk Only	20	Multiply by zero	0
M Bicycle	15	Multiply by zero	0
N Alternative Fuel Vehicle	-	Multiply by zero	0
O Dual Fuel Vehicle	5	Divide by 2	2.5
P Other:	-		-
Not Reporting To Work			
Q Telecommute Day (Work at Home)	5	Multiply by zero	0
R Reported to Another Location/Business Trip	-	Multiply by zero	0
S Compressed Work Week, Day Off.	10	Multiply by zero	0
R1 **Total Employee Trips** (sum row A through S)	900	**R2 Total Vehicle Equivalents**	667.9

FIGURE 7 Sample employee trips and vehicle equivalents calculation worksheet.

Sample APO Calculation Worksheet

APO Calculation:

Number of affected employees to be used in the worksite APO calculation			
B1	Number of employee trips to the worksite (transfer value R1 here)	B1 = R1	900
B2	If the response rate was less than 80%, multiply the number of non-respondents, value A6, by 5 (days)	B2 = A6 x 5	285
B3	Number of affected employee trips to be used for the APO calculation:	B3 = B1 + B2	1,185
Number of vehicle equivalents to be used in the worksite APO calculation			
B4	Total number of vehicle equivalents to the worksite (transfer value R2 here)	B4 = R2	667.9
B5	If the response rate was less than 80%, multiply the number of non-respondents, value A6, by 5 (days)	B5= A6 x 5	285
B6	Total number of vehicle equivalents to be used for the APO calculation:	B6 = B4 + B5	952.9
B7	**CURRENT WORKSITE APO** (divide B3 by B6)	**B7 = B3 / B6**	1.244
B8	Your target APO is (see regulations)	B8	1.56
B9	Maximum weekly vehicle equivalents allowed if target is to be achieved (divide B3 by B8)	B9= B3 / B8	760
B10	Number of weekly vehicle trips to be reduced to meet target APO	B10= B6 - B9	193

FIGURE 8 Sample APO calculation worksheet.

Monitoring and evaluation enable the ETC to answer in timely manner questions that may be posed by management, the union, and employees. The following are potential questions:

- What is happening to the worksite's APO?
- How much did the ECO program cost last year?
- How much did each employee commute option cost?
- How much did the support strategies and incentive programs cost?
- How are program costs related to changes in employee participation?
- Which support strategies or incentives and disincentives had the greatest impact on employees' decisions to use alternative modes?
- Did the number of participants increase after special marketing or promotional events? How much did these events cost last year?
- How successful have the selected commute options been in achieving the goals and objectives of the program?

Effective monitoring and evaluation are absolutely essential for the ETC to continue the ECO program and achieve the goals that were set forth in the beginning of the program.

SUMMARY

There have been several outstanding TDM or ECO guidebooks. The NY ECO guidebook builds on previously published ECO guidebooks and the results of many related studies. The NY ECO guidebook is the product of a literature search, an employer survey and the cooperation of the advisory committee.

A. Questions for Selecting Commute Options

Worksite Environment:

* Is your worksite adequately served by transit?
* Is your worksite located in a low density area?
* Do many of your employees live nearby and is your worksite in an area with good sidewalks?

Organization Characteristics:

* Does your organization have a motor pool?
* Is your organization having difficulty finding workers with some specific skill in the vicinity of the worksite?
* Does your organization operate extended hours or around the clock?

Employee Characteristics:

* Do many of the employees work on computers or spend a significant amount of time telephoning?
* Do one or several of your employees currently bicycle to work?

B. Questions for Selecting Support Strategies

* Is your worksite located in an industrial or office park or in an area with several other similar organizations?
* Does your organization provide free (or inexpensive) and convenient parking?

FIGURE 9 Questions asked in commute options and support strategies selection process.

This ECO guidebook can help employers educate new ETCs who are not familiar with transportation programs. This guidebook is comprehensive, definitive, and written in plain English. It describes the activities that the ETCs must carry out to develop and implement an ECO program.

Three support strategies were found to be especially important for making ECO programs work and last. They are the guaranteed ride home, parking management, and the commitment of upper management. Many successful programs had a combination of commute options and support strategies to meet the needs of participating employees. Guaranteed ride home programs are reported to be very low in cost because of the nature of such programs, that is, back-up transportation for emergencies.

Some specific references made in the Guidebook naturally pertain only to New York state; however, the majority of the discussions found in the guidebook are applicable to programs in other states and should be instructive to all employers interested in reducing the number of SOV commuters.

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Demographics of Carpooling

ERIK FERGUSON

Carpooling may be defined as shared ride trips via private automobiles for the journey to and from work. In the past, researchers argued that carpoolers could not be distinguished from other commuters based on demographic characteristics. Recently, some researchers have cited the influx of women in the work force and the continuing suburbanization of jobs and housing as reasons for the sharp decline in carpooling between 1980 and 1990. A review of significant research on carpooling over the past 20 years is presented with an in-depth analysis of 1990 Nationwide Personal Transportation Study data to identify the demographics of carpooling, then and now. Prior research suggests that family income, gender, distance to work, and residential location have the greatest effect on carpool formation. This study suggests that automobile availability within households and the level of education of individual commuters may be more significant factors in carpool formation. The research shows that (*a*) family income has little direct effect on carpool formation other than at the lowest income levels, (*b*) family income does affect automobile ownership, which partially determines auto availability, (*c*) gender has little direct effect on the formation of nonhousehold carpools, and (*d*) women are more likely to form household-based carpools in families with children, particularly very young children.

Researchers have argued that carpoolers are difficult to distinguish from drive-alone commuters based on demographics only (*1*). Carpooling preferences among groups with similar demographic characteristics were thought to vary more significantly as a function of underlying beliefs and attitudes. It has proven extremely difficult to get drive alone commuters to switch to carpooling based on sophisticated marketing techniques alone. Between 1980 and 1990 U.S. carpooling declined by 34 percent, even as regional ridesharing programs were becoming more common across the nation.

Researchers have attributed the decline of carpooling to the increased number of woman in the work force and the suburbanization of jobs (*2*). Working mothers often need to serve the transportation needs of children, discouraging carpooling with other adults. And as work and home trip destinations of suburban residents grow ever more distant, matching carpool partners based on the needs of individual commuters may become more difficult in future years.

DATA AND RESEARCH METHODOLOGY

A comprehensive national overview of the demographics of carpooling follows. The literature on carpooling is reviewed in conjunction with findings from the 1990 Nationwide Personal Transportation Study (NPTS). Most NPTS data are stored in six hierarchical files relating to relevant characteristics of sampled households, persons, vehicles, and trips. In all, 22,317 households, 48,385 people aged 5 or older, 41,178 vehicles, 94,383 vehicle trips and 149,546 person trips are described in the 1990 NPTS data base. This analysis is based on person trips only. After observations with missing data were removed, 123,270 person trips (82 percent) remained. Of these, 28,623 (23 percent) were work trips, which form the core data for most of this analysis.

Carpooling is defined as any home-based work trip in which the commuter is accompanied by at least one other person in a private motor vehicle. It does not matter if the accompanying person is a household member or not, nor does it matter what the other person's trip purpose might be. In the case of nonhousehold members, no information on trip purpose or anything else is available. It is likely that most are commuters, but this can only be surmised. In this analysis, carpooling is distinguished from driving alone, public transit, and nonmotorized transportation. Driving alone means operating a car, minivan, or pickup truck without any passengers. Public transit includes subways, elevated railways, light rail, trolleys, and buses. Nonmotorized transportation includes bicycling and walking.

URBAN FORM

Oppenheim stated that carpooling increases with trip distance, firm size, and population density, but offered scant supporting evidence for these assertions (*1*).

Trip Distance

Daniels, Richardson and Young, Teal, and Cervero and Griesenbeck each found that carpooling increases linearly with trip distance or time, or both (*3–6*). Ferguson showed that in Orange County, California, carpooling decreases with distance for trips of less than 10 mi (16.1 km), increases with distance for trips of 10 to 35 mi (16.1 to 56.4 km), and decreases with distance for trips longer than 35 mi (56.4 km) (*7*).

The 1990 NPTS data reveal that transit use increases and nonmotorized transportation decreases with distance, a similar relationship to that shown by Dasgupta et al. for the cities of Manchester and Sheffield in Great Britain (*8*). Nationwide, carpooling decreases with distance for work trips of less than 15 mi (24.2 km), and increases with distance for work trips of 16 mi (25.8 km) or more (Table 1). The percentage of carpools comprising nonhousehold members increases linearly with distance. The drive-alone mode split mirrors that of carpooling, first increasing with distance and then decreasing. Household-based carpools apparently compete most effectively with nonmotorized transportation as a substitute for driving alone in the short work trip market. Nonhousehold-based carpools compete most effectively with public transit in the long work trip market. Alternatives to driving alone appear to be less viable in the medium range of work trip lengths.

Travel Demand Management, 2419 Leisure Lake Drive, Dunwoody, Ga. 30338.

TABLE 1 Mode of Travel by Distance to Work (*16*)

Mode of Travel	Trip Distance (Miles) 1-5	6-10	11-15	16-20	21-30	31+	Total	Percent
Drive Alone	76.35%	81.85%	83.09%	81.31%	78.84%	71.80%	22,552	78.79
Carpool	17.80%	14.33%	13.92%	14.25%	16.47%	20.66%	4,664	16.29
Household-based	11.29%	8.63%	8.22%	6.18%	6.99%	7.02%	2,670	9.33
Non-household	6.51%	5.70%	5.71%	8.07%	9.48%	13.64%	1,994	6.97
Transit	3.10%	3.70%	2.99%	4.39%	4.69%	7.54%	1,057	3.69
Nonmotorized	2.75%	0.12%	0.00%	0.05%	0.00%	0.00%	350	1.22
Total	12,411	6,544	3,744	2,162	2,131	1,631	28,623	100.00
Percent	43.36	22.86	13.08	7.55	7.45	5.70	100.00	

Residential Location

Based on his analysis of 1977 NPTS data, Teal suggested that nonmetropolitan (rural) residents were more likely than urban residents to carpool (*5*). Hartgen and Bullard used 1980 and 1990 Census data to show that rural residents of North Carolina were more likely to carpool than urban residents of that state (*9*). Matthews also used Census data and found that the greatest decline in Georgia carpooling during the 1980s occurred in the rapidly growing suburban counties around Atlanta (*10*). Most other authors have been silent on the topic of geography and carpooling, perhaps because so much of this research has been of the case study variety, focusing on urban, suburban, or rural settings, but not all three together.

According to 1990 NPTS data, geographic location influences mode choice moderately to strongly, while affecting carpool composition only weakly, if at all (Table 2). Public transit and nonmotorized transportation are used most often in central cities, least often outside urban areas. Carpooling is most common outside urban areas, and least common inside urban areas, but outside the central city. Carpooling has been touted as the savior of the suburbs, at least in terms of alternative modes of travel, given that public transit and nonmotorized transportation are viewed as nonviable in those areas (*11,12*). These results suggest that public transit and nonmotorized transportation may be less nonviable in suburban communities than previously thought. In addition, carpooling may be in for a rough ride in Edge City.

Population Density

Oppenheim asserted that carpooling increases with population density (*1*). Most authors have been silent on this relationship, perhaps due to a lack of data. Ferguson included residential density terms in his 1977 and 1983 carpool regression equations, but neither was found to be statistically significant (*13*).

Using better or more accurate measures of population density, public transit and (to a lesser extent) nonmotorized transportation increase continuously with metropolitan statistical area (MSA) population density (Figure 1). Carpooling also increases with population density, but much more modestly and only at lower population densities. At more than 5,000 persons per square mile (1,929 persons per square kilometer), carpooling mode split begins to decline in absolute terms. Relative to driving alone, carpooling increases continuously, even at the highest population densities.

TABLE 2 Mode of Travel Residential Location (*16*)

Mode of Travel	Residential Location: Urban--Inside Central City	Urban--Outside Central City	Not Urban	Total	Percent
Drive Alone	74.36%	81.53%	80.82%	22,552	78.79
Carpool	16.51%	14.05%	17.99%	4,664	16.29
Household-based	9.24%	8.23%	10.35%	2,663	9.30
Non-household	7.27%	5.82%	7.64%	1,991	6.96
Transit	7.19%	3.40%	0.50%	1,057	3.69
Nonmotorized	1.94%	1.02%	0.68%	350	1.22
Total	9,929	8,590	10,104	28,623	100.00
Percent	34.69	30.01	35.30	100.00	

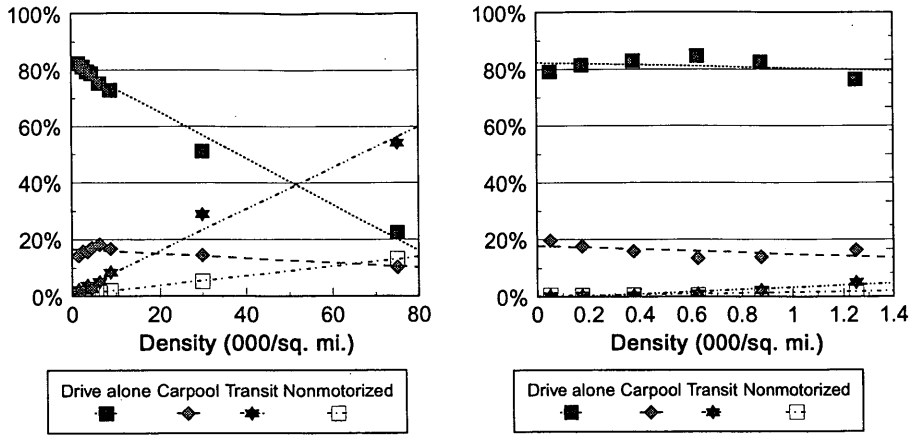

FIGURE 1 Mode of travel by residential population density: *left,* inside MSAs; *right,* outside MSAs (*16*).

MSA population density is measured categorically in the 1990 NPTS data, with much wider ranges used to describe the highest population densities. Treating these categorical range descriptions as actual point estimates located at the midpoint of each such range, all of the modal relationships are roughly linear in form. Elasticities of demand for particular modes can be measured as the slope of each line. It is clear that carpool mode split is less sensitive to population density than driving alone, public transit, nonmotorized transportation, or even carpool composition.

Outside MSAs, a different picture emerges. As non-MSA population density increases above about 500 persons per square mile (192.9 persons per square kilometer), a similar set of relations to those observed for MSAs appears, with driving alone decreasing and carpooling, public transit, and nonmotorized transportation increasing in terms of modal split (Figure 1). At less than 500 persons per square mile (192.9 persons per square kilometer), driving alone increases and carpooling decreases with increasing population density. Public transit and nonmotorized transportation are largely unaffected by population density in such sparsely settled regions. Compared to driving alone carpooling neither gains nor loses from changes in public transit and nonmotorized transportation outside MSAs, because these modes are relatively insignificant at all non-MSA population densities.

Neither mode split nor carpool composition are particularly sensitive to variations in population density outside MSAs. It appears that higher-than-average-density non-MSA regions emulate lower-than-average-density MSAs with reference to modal characteristics, and in fact these two types of regions often are contiguous in real terms.

DEMOGRAPHICS

Oppenheim reported that age, income, gender, and ethnicity were all unrelated to carpooling (*1*). In general, however, most published studies have ignored the effects of demographic variables on carpooling, either stating or implicitly assuming that earlier studies had demonstrated adequately that no such effects existed. This assumption is clearly mistaken, however, as will be shown using 1990 NPTS data.

Tischer and Dobson reported that commuters who drove alone to the Los Angeles central business district and who indicated having a higher-than-average propensity to switch to carpooling under appropriate conditions were more likely to be young, female, and black, with lower family incomes than those drive-alone commuters who showed little propensity to switch modes (*14*). Gensch reported that commuters who drove alone on the Santa Monica Freeway during the infamous Diamond Lane experiment and who indicated having a higher-than-average propensity to switch to public transit under appropriate conditions were more likely to be young, female, and Hispanic, with lower family incomes than those drive-alone commuters showing little desire to switch modes (*15*).

Age

Teal, in dismissing the effects of most demographic variables on carpooling, forgets to mention age among those variables that are not to be considered (*5*). In this Teal is far from alone, for most authors neither confirm nor deny they even looked at age as a determinant of or covariant with mode choice. An exception is Ferguson, whose research showed a statistical association between age and carpooling that is negative and significant, based on nonlinear regression analysis of 1977 and 1983 NPTS data (*13*).

Although statistically significant, the relationship between age and carpooling is far from powerful (Figure 2). Driving alone to work increases gradually while all major modal alternatives decrease gradually with age from about 16 to 25 up to 46 to 55. Beyond middle age, when the average worker typically reaches his or her peak performance and earning power, driving alone decreases, carpooling and public transit use increase, and nonmotorized transportation remains largely unaffected. Because there are fewer workers in the higher age groups, the effect of their changing modal preferences has less of an impact on linear regression estimates, which are dominated by more younger workers.

Education

Education has been all but ignored in the literature on carpooling, even more so than age. The only source this researcher found was

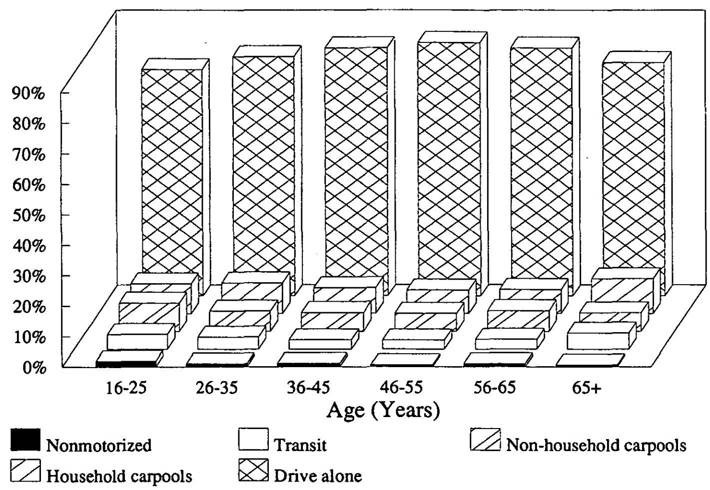

FIGURE 2 Mode of travel by age (*16*).

Teal, who states that no statistical relationship exists between carpooling and education, based on secondary sources (*5*). It has become an article of faith in the ridesharing community that carpoolers are virtually indistinguishable from those who drive alone, which is good in terms of aggregate market potential, but bad in terms of market segmentation, advertising campaign targeting, and the like. Ferguson showed that there is a statistical association between education and carpooling that is negative and significant, based on nonlinear regression analysis of 1977 and 1983 NPTS data (*13*). Ferguson found that auto commuters who had attended at least some college were more likely to carpool than those who had not (*13*).

An even more powerful relationship appears to exist between education and carpooling, based on 1990 NPTS data (Table 3). Commuters who have not completed high school behave differently than those who have high school diplomas or college educations. This relatively uneducated group is twice as likely to carpool, bicycle, or walk to work. Among commuters possessing at least a high school diploma, driving alone and the use of public transit and nonmotorized transportation increase with higher educational achievement. Only carpooling declines with education above the high school level. Whereas 17 percent of commuters with high school diplomas carpool, only 14 percent of commuters with some college and 11 percent of commuters with some graduate school carpool.

Gender

Oppenheim argued that gender was unrelated to carpooling (*1*). Subsequent researchers were far from silent on this demographic issue, agreeing that female and clerical workers were significantly more likely to carpool than male and professional and managerial workers (*5,6,8,14,15*).

Teal showed that married women were more likely to carpool than unmarried women, married men, or unmarried men (*5*). He argued that the relationship was statistically insignificant based on a chi-square test of a two-by-four outcome matrix. In 1977 Ferguson, using the same data structure but a different analysis method (multiple regression), showed that married women were significantly more likely to carpool than unmarried women, married men

TABLE 3 Mode of Travel by Education (*16*)

	Education					
Mode of Travel	**<High School**	**High School Graduate**	**Some College**	**Some Graduate School**	**Total**	**Percent**
Drive Alone	64.48%	79.51%	81.27%	82.24%	22,381	78.97
Carpool	28.58%	16.67%	13.90%	11.11%	4,579	16.16
Household-based	16.25%	8.89%	8.37%	7.02%	2,605	9.19
Non-household	12.33%	7.78%	5.53%	4.09%	1,974	6.96
Transit	4.32%	2.89%	3.84%	4.92%	1,035	3.65
Nonmotorized	2.62%	0.94%	0.99%	1.73%	347	1.22
Total	2,939	10,788	11,383	3,232	28,342	100.00
Percent	10.37	38.06	40.16	11.40	100.00	

or unmarried men (*13*). In 1983 Ferguson demonstrated that married men or women were significantly more likely to carpool than single men or women (*13*).

Cervero and Griesenbeck used multiple regression analysis to show that professional and managerial workers in suburban Pleasanton, California, making up about 25 percent of the total work force, were significantly less likely to carpool, significantly more likely to have flexible work hours, and significantly less likely to commute outside both the morning and afternoon peak periods than all other workers (*6*). Although women constituted more than 60 percent of the work force in Pleasanton during the mid-1980s, Cervero and Griesenbeck failed to address the role of gender in mode choice, although they do mention it explicitly as a factor in the location of corporate "back" offices, where administrative functions not requiring direct interaction with customers often are performed (*6*).

Rosenbloom and Burns found that middle-income women were more likely than middle-income men to drive alone in Tucson, Arizona (*2*). This is the only example known to this author of a study purporting to show that women are more likely to drive alone than men. Although Tucson women earned lower salaries and held lower-status jobs on average, they nonetheless were more likely to drive alone than men, and less likely to carpool, use public transit, or ride bicycles to get to work.

As Table 4 indicates, the 1990 NPTS data indicate that nationally, female workers are about 35 percent more likely than male workers to carpool. Male workers are almost 50 percent more likely than female workers to carpool with nonhousehold members. The use of public transit and nonmotorized transportation for the work trip varies little with gender in the NPTS data. Females are 5 percent more likely than males to use public transit. Males are 15 percent more likely than females to use nonmotorized transportation.

HOUSEHOLD LIFE CYCLE

The "life cycle" of a household traditionally is defined as a categorical variable based on the number of adults (1 or 2+), the age of the youngest child (none, under 6, 6 to 15, or 16 to 21) and whether a retired person is present in the household. Oppenheim argued that workers later in their life cycle (i.e., those whose children grew to adulthood) would become more amenable to carpooling (*1*). Although later authors discussed the effect of household characteristics such as number of persons, number of workers, and number of vehicles on carpooling, only Oppenheim referred explicitly to life cycle as a possible determinant of carpool formation (*1*).

Number of Adults

Ferguson showed that the likelihood of carpooling increased with the number of adults in the household (*13*). The number of working adults had a much greater positive impact than did the number of nonworking adults. Other authors have argued that the likelihood of carpooling increases with the total number of persons in the household (*1*) or with the number of workers only (*5,14*).

Figure 3 shows an interesting interaction between gender and the number of adults in the household. Men and women are remarkably similar to one another in terms of mode choices, once the number of adults in the household is controlled for. Workers in single adult households are more likely than those in multiple adult households to drive alone. Men are more likely than women to drive alone. However, men and women in single and multiple adult households are about equally likely to use nonmotorized transportation, public transit and to form non-household carpools.

The sole difference between men and women in either single- or multiple-adult households involves apparent trade-offs between driving alone and household-based carpools. Female workers in single-adult households are four times as likely as male workers in single-adult households to form household-based carpools. Female workers in multiple adult households are "only" twice as likely as male workers in multiple adult households to form household-based carpools. These results suggest that role differences may be more important than either psychological or economic differences in explaining gender variations in travel behavior.

Age of Youngest Child

Ferguson showed that the likelihood of carpooling decreased with the number of children in the household (*13*). No one else has modeled this relationship explicitly, though many have argued that child-care needs limit the ability of women to participate in formal carpool programs offered by employers (*2*).

TABLE 4 Mode of Travel by Gender (*16*)

	Gender			
Mode of Travel	**Male**	**Female**	**Total**	**Percent**
Drive Alone	81.09%	75.95%	22,548	78.79
Carpool	14.01%	19.11%	4,664	16.30
Household-based	6.92%	12.29%	2,670	9.33
Non-household	7.09%	6.81%	1,994	6.97
Transit	3.60%	3.81%	1,057	3.69
Nonmotorized	1.30%	1.12%	350	1.22
Total	15,790	12,829	28,619	100.00
Percent	55.17	44.83	100.00	

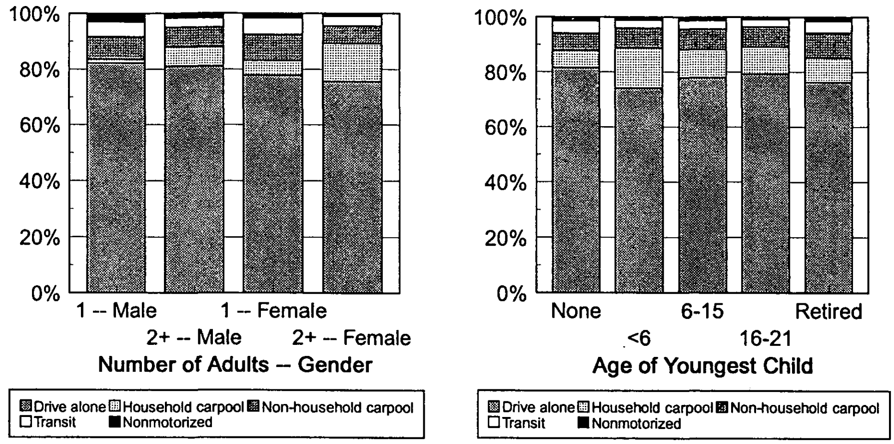

FIGURE 3 Mode of travel by life cycle characteristics: *left,* adults; *right,* children (*16*).

Figure 3 shows an interactive relationship between gender and the presence of children in the household. Men and women exhibit virtually identical travel behavior if there are no children or retirees in the household. Female workers with small children in the household are more than three times as likely as women with no children in the household to carpool with fellow household members; there is virtually no difference between these two groups of women in nonhousehold carpooling. Male workers with small children are 50 percent more likely than men with no children to carpool with other household members and 25 percent more likely to carpool with nonhousehold members.

Women are more likely than men to serve the travel needs of small children. However, men appear to be slightly more likely to travel with strangers (presumably in the stranger's car) so women will have an auto available to serve their children's needs. The presence of older children in the household has a similar effect, but is far less pronounced for either gender. Male and female workers respond similarly to the presence of children in the household, but females respond more. These results provide further evidence that gender differences in travel behavior are the result of differences in gender roles, not economics.

HOUSEHOLD SIZE

Oppenheim suggested that people living in larger households and those owning larger automobiles were more likely to carpool (*1*). Tischer and Dobson; Gensch; Teal; and Dasgupta et al. all found that as the number of vehicles per household increased, the likelihood of choosing alternatives to driving alone fell (*5,8,14,15*). Tischer and Dobson; and Teal found that carpooling increased with the number of workers in the household (*5,14*). Gensch found that public transit use fell with the number of workers in the household (*15*). The propensity to carpool should increase with the number of persons, adults, and workers, and fall with the number of vehicles, particularly as this relates to the number of drivers, licensed or unlicensed, within the household.

Ferguson found that carpooling positively correlated with the number of adults in the household and negatively correlated with the number of vehicles available to the household (*13*). Ferguson estimated that carpooling for the work trip was three times more sensitive to the presence of working adults than it was to the presence of nonworking adults (*13*). Ferguson estimated that carpooling was about twice as sensitive to the number of vehicles up to and including the number of working adults in the household as it was to the number of vehicles in the household that exceeded the number of working adults (*13*).

Number of Persons

As Figure 4 shows, carpooling is fairly sensitive to the number of persons in the household. Commuters living in households with five or more persons are two-and-one-half times more likely to carpool than those living in single-person households. The biggest leap in carpooling propensity occurs between one- and two-person households, however. Commuters in two-person households are 77 percent more likely than those in single-person households to carpool.

As household size increases, household-based carpools increase substantially while nonhousehold based carpools remain relatively unaffected. In fact, single-person household commuters are slightly more likely to carpool with nonhousehold members than commuters in households with more than one person. Much of the increase in carpooling that occurs with increasing household size appears to be drawn from alternatives to driving alone, such as public transit and nonmotorized transportation.

Number of Vehicles

As Figure 4 shows, carpool is also sensitive to the number of vehicles in the household. Commuters in households with no vehicles are almost twice as likely to carpool as those in households with four or more vehicles. Commuters living in households with one vehicle are in several ways more similar to those living in households with no vehicles than they are to those living in households with two or more vehicles. Commuters in households with either zero or one vehicle are more likely to carpool, use public transit and use nonmotorized transportation to get to work. One-vehicle household commuters nonetheless drive alone 67 percent of the time, while zero-vehicle household commuters drive alone a mere 11 percent of the time.

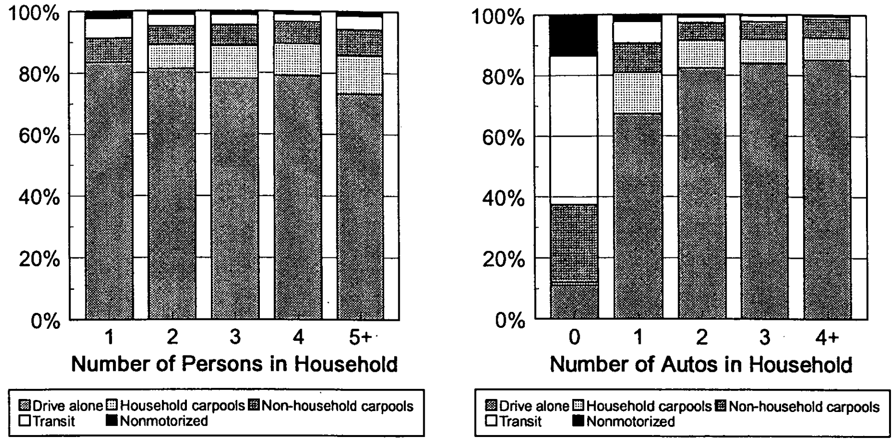

FIGURE 4 Mode of travel by automobile availability: *left,* demand; *right,* supply (*16*).

Zero- and one-vehicle households account for only 20 percent of the total commuters in the 1990 NPTS sample. For households with two or more vehicles, which account for more than four out of five sampled commuters, mode of travel to work is far less sensitive to the number of vehicles in the household. Household-based carpooling, public transit, and nonmotorized transportation use decline slightly with vehicle ownership in this range, while nonhousehold based carpools actually increase, if only slightly. These results suggest that households with two or more vehicles are more or less saturated, at least in terms of the marginal effect on mode choice for the journey to work of adding another vehicle to the household.

Family Income

Oppenheim argued that income had no effect on the propensity to carpool (*1*). Tischer and Dobson; and Gensch, both using disaggregate data, found that the propensity to switch from driving alone to carpooling or public transit under the influence of suitable modal incentives was higher for individuals with lower incomes (*14,15*). Teal found that carpooling was more prevalent among lower-income groups (*5*). In particular, Teal found that when the ratio of out-of-pocket drive-alone commuting costs exceeded 5 percent of average family income per worker, the propensity to carpool increased by a factor of two or three (*5*). Ferguson found that family income was unrelated to the likelihood of carpooling after controlling for other variables through multiple regression (*13*). Hartgen and Bullard; and Matthews, both using aggregate data, found that the percentage of commuters who carpooled decreased significantly with per capita income at the county level in the North Carolina and Georgia using 1990 Census data (*9,10*).

As Figure 5 shows, the 1990 NPTS data indicate that carpooling declines with income at lower-income levels, but is largely unrelated to income at higher-income levels. Workers living in households with family incomes of less than $30,000/year show large increases in driving alone and even larger relative decreases in carpooling, public transit, and nonmotorized transportation usage as income increases from $0 to $30,000. Workers living in households with family incomes of $30,000 or more show virtually no change in driving alone as income increases, although there is some slight substitution of public transit for carpooling at the very highest income levels. Workers living in households with family incomes

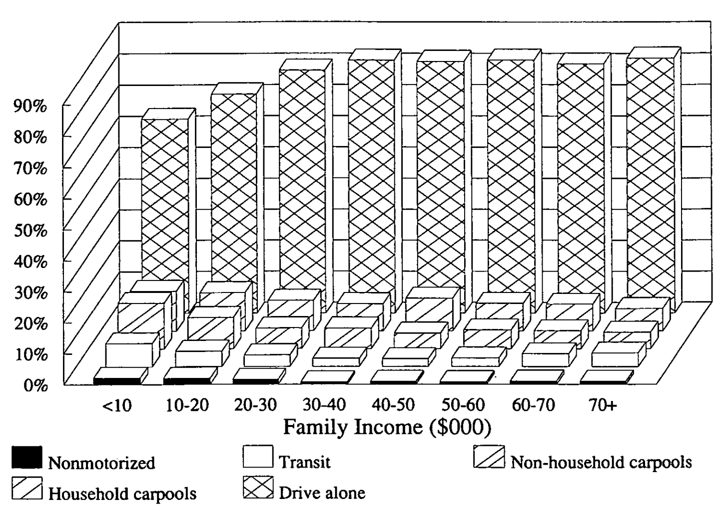

FIGURE 5 Mode of travel by family income (*16*).

of less than $20,000 are somewhat more likely than their higher-income brethren to carpool with nonhousehold members.

Ethnicity

Oppenheim asserted that ethnicity had no effect on carpooling (*1*). Most other authors have remained silent on this issue. Tischer and Dobson found that blacks had a higher propensity to switch to carpooling from driving alone (*14*). Gensch found that Hispanics had a higher propensity to switch to public transit from driving alone (*15*). Both of these studies deal with stated rather than revealed preferences, however.

As Table 5 shows, ethnicity and mode choice are indeed related. Whites are more likely than all other ethnic groups to drive alone to work. Blacks are more likely than all other ethnic groups to use public transit to get to work. Hispanics are more likely than all other ethnic groups to carpool to work. Members of other racial or ethnic groups are least likely overall to carpool with nonhousehold members.

It appears from a cursory examination of the data that the influence of ethnicity on mode choice can be explained almost entirely as a function of differences in family income or residential location, or both. Whites generally have the highest incomes and are most likely to live in suburban environments. The fact that whites are most likely to drive alone and least likely to use any of the alternatives should come as no surprise. Blacks generally have lower family incomes and are less likely to live in suburbs than whites. Blacks are least likely to drive alone, most likely to use public transit, second most likely to carpool, and third most likely to use nonmotorized transportation.

CONCLUSIONS

There are some interesting variations in carpooling by gender. Most such variations appear to be the result of role differences rather than being specific to the gender of commuters. There are also some interesting variations in carpooling with respect to urban form, but most of these effects were much smaller than expected.

The largest variations in carpooling appear to be related to household size, including both the number of persons and the number of vehicles, and the age and education of the respondent. Vehicle availability has long been known to influence transit versus highway mode choice decisions. The relatively large effect of vehicle availability on carpooling has not hitherto been emphasized much in the literature. The effects of age and education generally have been ignored in the literature on carpooling. In fact, age and education appear to be much more important in explaining recent declines in carpooling than urban form, female work force participation, or family income.

These results suggest that carpool marketing and research efforts may need to be better focused, if not entirely redirected. Suburbs may not be such a bad place for carpooling after all. Men and women are almost identical in terms of commuting behavior, once household-based carpools are controlled for. The transportation needs of small children may become more important in carpool formation in future years, but only if child-care facilities are provided closer to the workplace and are utilized by working women and men.

Given that most households are nearing saturation in terms of vehicle ownership, can carpools still be formed? This will depend largely on the extent to which carpools are made more attractive through preferential treatments and differential pricing. Vehicle availability might be reduced through policy measures, but this would require large-scale changes in land use or population density that probably would benefit public transit and nonmotorized transportation more than carpools.

The large negative effect of education and the smaller but still significant effect of increasing age on carpooling remain something of a mystery. It appears that these effects reflect increasing expectations or decreasing tolerance of others. If public relations has a role to play in modifying mode choice through marketing efforts in the future, it would appear to lie in this largely unexplored realm of commuters' attitudes.

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TABLE 5 Mode of Travel by Ethnicity (*16*)

	Ethnicity					
Mode of Travel	**White**	**Black**	**Hispanic**	**Other**	**Total**	**Percent**
Drive Alone	81.02%	64.33%	66.12%	72.58%	22,449	78.77
Carpool	15.31%	22.22%	23.25%	18.95%	4,655	16.33
Household-based	8.88%	9.95%	14.92%	12.23%	2,665	9.35
Non-household	6.43%	12.27%	8.33%	6.72%	1,990	6.98
Transit	2.52%	12.04%	8.58%	6.85%	1,045	3.67
Nonmotorized	1.15%	1.41%	2.06%	1.61%	350	1.23
Total	24,143	2,201	1,411	744	28,499	100.00
Percent	84.72	7.72	4.95	2.61	100.00	

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Carpooling with Co-workers in Los Angeles: Employer Involvement Does Make a Difference

ROY YOUNG

Carpool rates in Los Angeles are the highest of all metropolitan areas in the United States. But the carpool rate has not changed here since 1991, even with a mandatory employer-based vehicle trip reduction regulation involving over 6,000 employers and nearly 2 million commuters. Carpooling with co-workers has been increasing while carpooling with friends and family has been decreasing. Therefore, employer-based efforts have been responsible for maintaining regional rideshare rates. An analysis was conducted comparing co-worker carpoolers and carpoolers who ride with friends and family based on commute behavior, employment characteristics, attitudes toward the commute, and demographics. Carpooling with co-workers has produced greater reduction in vehicle trips and vehicle miles traveled than carpooling with family and friends. Those riding with co-workers are far more likely to consider commuting costs, comfort, and stress—perhaps a function of relatively long commute distances. More men, more commuters in the 30- to 39-year age group, more whites and blacks, and more commuters with household incomes of $50,000 or greater are now carpooling regularly as a result of employer efforts.

Convincing commuters to use alternatives to driving alone to work has been difficult. Nationwide, the percentage of commuters driving alone to work has increased significantly, from 64 percent in 1980 to 73 percent in 1990. One of the few urban areas found to buck this trend is Los Angeles, where the incidence of drive-alone commuting has increased only slightly, from 69 percent in 1980 to 70 percent in 1990 (*1*).

Of the commuting alternatives available in Los Angeles, carpooling is the most widely used. In fact, of the 10 largest urban areas, Los Angeles has the highest carpool rate (*2*). But, despite significant efforts to change commuter behavior over the last 3 years, there has been no change in drive-alone and carpool commute shares in the area (Figure 1).

The explanation most widely offered is that no alternative can compete with the freedom and convenience of drive-alone commuting. Increasingly people's lives are so fast-paced and complicated that one must drive alone to work to "chain" different work and nonwork trips, and time is becoming more precious.

Nevertheless, federal and state legislation, with the aim of reducing air pollution from mobile sources and increasing the capacity of our highways, has pointed to a role and responsibility of employers to help reduce vehicle trips and miles traveled by encouraging their employees to use alternatives to driving alone to work. Accordingly, in Los Angeles, Rule 1501 was phased in by the South Coast Air Quality Management District beginning in 1988, which mandates large employers to plan and implement vehicle trip reduction programs. Since the launch of the regulation, virtually all progress among affected employers to date has been the result of increases in carpooling (*3*).

Commuter Transportation Services, Inc., 3550 Wilshire Boulevard, Suite 300, Los Angeles, Calif. 90010.

These factors in combination—lifestyles with increasing need for unrestricted auto travel and increasing employer responsibility for encouraging employees to use alternatives to driving alone to work—have produced a somewhat predictable result in Los Angeles: a growth in carpooling with people from work (from the same company or another company close by) and a decline in carpooling with friends and family (Figure 2). The percentage of carpoolers riding with "co-workers" has increased from 34 percent in 1991 to 42 percent in 1993; conversely, the percentage of carpoolers riding with friends or family members has declined from 66 percent in 1991 to 58 percent in 1993. It is apparent that without employer initiatives, regulated or voluntary, the carpool rate would have decreased dramatically during this period. While "convenient" carpooling (with friends or family) is no longer reliable as a source of increases in vehicle trip reduction, "active" carpooling (with co-workers) has made important gains through employer-based efforts.

PURPOSE

The purpose of this analysis is to learn about the commute behavior and attitudes of carpoolers who ride with co-workers. Past efforts to identify key variables that explain whether a commuter will choose to carpool have found that many factors play a role, and none alone has a high level of predictive power. But now that the segment of carpoolers whose partners are co-workers is growing, a look at the characteristics of this segment compared to those who carpool with friends and family may prove enlightening. If the co-workers carpool group is different in significant ways, the analysis will help employers identify new prospects and motivate employees to switch from driving alone to forming carpools with co-workers. In addition, the analysis will help policy makers understand and realize the potential of employer-based regulations.

METHOD

The analysis is based on a comparison of the two carpool groups' commute behavior, employment characteristics, attitudes toward the commute, and demographic characteristics.

The data are from the 1993 State of the Commute survey conducted by Commuter Transportation Services (CTS). Since 1989,

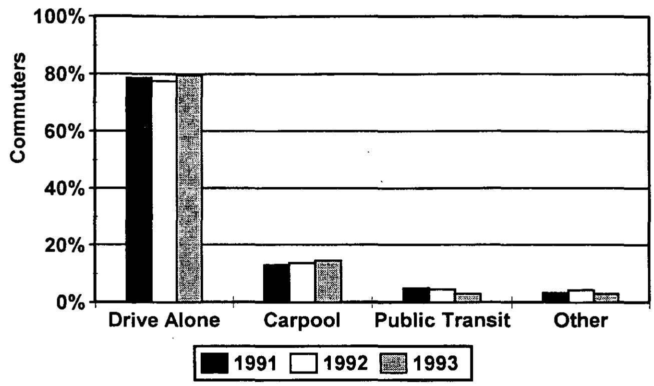


FIGURE 1 Commuter mode shares—greater Los Angeles, 1991 to 1993 (*4–6*).

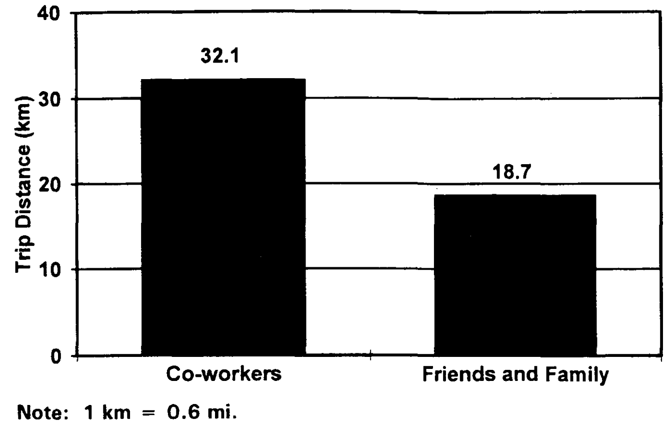


FIGURE 3 One-way trip distance by carpool group.

CTS has conducted an annual survey of commuters who work full time away from the home in the five-county southcoast region. For each of the last three surveys—1991, 1992, and 1993 (*4–6*)—a total of 2,500 interviews were conducted by telephone among a randomly selected sample, with 500 each in Los Angeles, Orange, Riverside, San Bernardino, and Ventura counties. When combining the data for all counties, the sample was weighted for the number of workers in the county and the number of full-time workers in the household.

Respondents are asked how they usually travel to work. Those who report that they carpool are then asked who they carpool with on an open-ended basis. Responses are then coded into the following categories: (*a*) household members; (*b*) nonhousehold relatives; (*c*) co-workers; (*d*) friends, acquaintances, neighbors; and (*e*) someone from a matchlist.

Thus, those who have co-workers as partners may be carpooling with someone who works for the same company or someone who works for another company located nearby. At some point in the carpool arrangement, presumably either of these may be referred to by respondents as a "friend." So, in part, the response may depend on how the relationship is viewed, and partnerships of co-workers that have been maintained for some time are likely to be referred to as carpooling with friends.

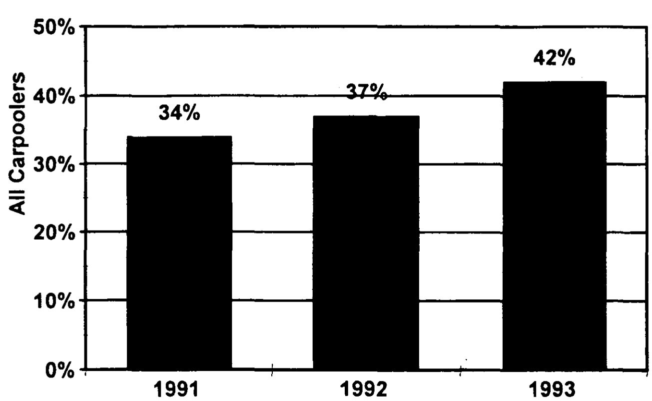


FIGURE 2 Carpooling with co-workers, 1991 to 1993 (*4–6*).

COMPARISON OF TWO CARPOOL GROUPS

Commute Behavior

Distance

Co-worker carpools have nearly twice the one-way commute distance of friends and family carpools, 32.2 km (20.0 mi.) versus 18.7 km (11.6 mi.) (Figure 3). There are several possible explanations for this phenomenon. First, in finding the optimal household location, a family will not usually locate such that several family members have a long commute to the same general destination. This means that carpools of family members are located closer to their destination, thereby decreasing the average commute distance for the family and friend carpool group.

Second, at long commute distances, there is a greater probability of finding a suitable carpool partner among co-workers than among family and friends. This is because co-workers are usually more plentiful than friends and family members, have the same commute destination, and probably have a similar work schedule.

Third, carpoolers with longer trip distances receive greater financial and emotional benefit than carpoolers with shorter trip distances. Employer-based carpool matching efforts, which advertise cost and savings through carpooling and offer financial subsidies to carpoolers, will be more effective with long-distance commuters than short-distance commuters, thereby increasing the number of long-distance carpools among co-workers, and increasing the average commute distance for all co-worker carpools.

Use of Freeways, High-Occupancy Vehicle Lanes, and Park-and-Ride Lots

Because of the difference in average commute distances, it is not surprising that freeway use is far more prevalent among co-worker carpools (64 percent) than among friend and family carpools (51 percent). The usage of high-occupancy vehicle (HOV) lanes among those freeway users with access is higher among co-worker carpools than among family and friend carpools (80 versus 68 percent). Therefore, the success of future marketing of new HOV facilities will depend, at least in part, on employer-based efforts to

encourage carpooling. Similarly, park-and-ride lots are used more frequently by co-worker carpools than by family and friend carpools, which suggests that employer-based carpool matching efforts should consider using park-and-ride lots as connecting points.

Length of Time in Current Carpool Arrangement

Family and friend carpools have greater longevity on average than do co-worker carpools (Figure 4).

There are several factors contributing to this disparity. First, as previously suggested, after a length of time a co-worker carpool partner would be considered (and in response to a survey question be referred to as) a "friend." Second, there is a higher level of social compatibility and stability for the group of family and friend carpools, since the members probably knew each other prior to the inception of the carpool. The members of the co-worker carpool may or may not have known each other before they began carpooling. This unfamiliarity leads to a number of carpool arrangements that are terminated quickly because the members were not socially compatible. This group of failed carpools brings down the average longevity for the co-worker group as a whole. Third, work arrangements and schedules change more frequently than friend and family relationships, which create a number of carpools with a short duration because of schedule or even employment changes. Finally, employer-based encouragement is relatively new, largely a function of new regulations.

Previous Commute Mode

More than 8 in 10 of those who now carpool with co-workers previously drove alone to work, compared with only over 5 in 10 of those who now carpool with family and friends (Figure 5). Consequently, the formation of carpools among co-workers actually reduces more vehicle trips than the formation of carpools among family members and friends.

Employment Characteristics

Company Size

Carpoolers who have co-workers as partners are more likely to work for large companies than carpoolers who have family members or friends as partners. Not only are large companies mandated to encourage carpooling at their work sites, but by virtue of their large size (100 or more employees at a work site), they have a better chance of creating practical carpool arrangements than do smaller employers. Not surprisingly, carpoolers riding with co-workers are more likely to report being offered incentives to rideshare than carpoolers who ride with family and friends (Figure 6).

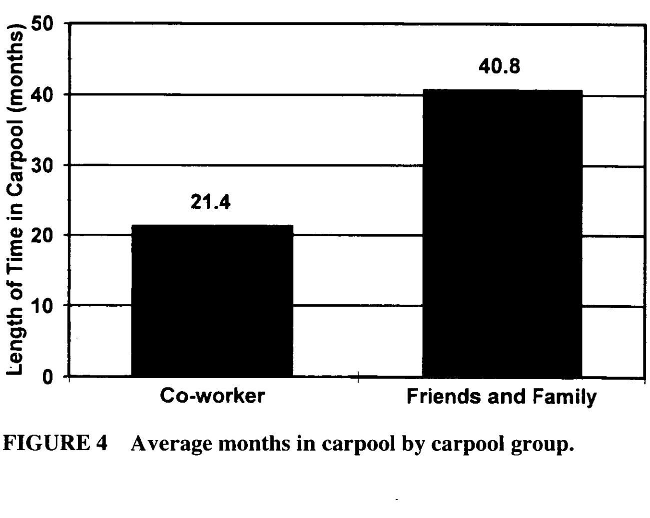


FIGURE 4 Average months in carpool by carpool group.

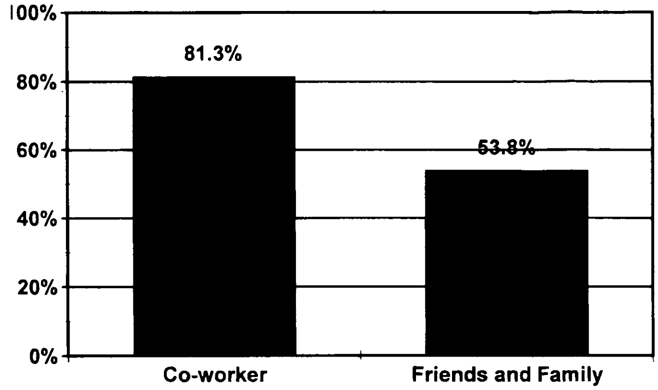


FIGURE 5 Percentage of carpoolers converting from driving alone by carpool group.

Industry and Occupation

Members of the different carpool groups are employed in different industries. Commuters who carpool with co-workers are much more likely to be employed by finance, insurance, and real estate companies than are those who carpool with family members and friends. This also holds true to a lesser extent in the construction and service industries. Conversely, commuters who carpool with family and friends are more likely to be employed in the manufacturing, transportation, or wholesale trade industries than are those who carpool with co-workers. The carpool groups are represented more or less equally in other industries.

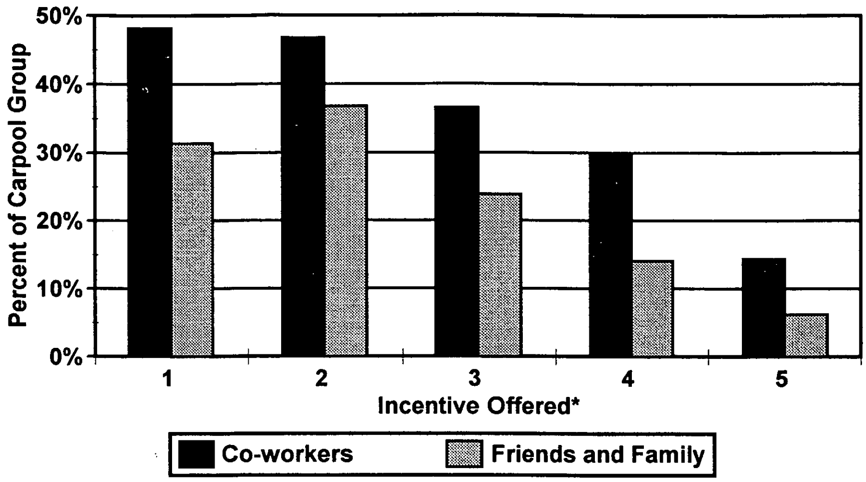
Both groups of carpoolers—those who have co-workers as partners and those who have family and friends as partners—are likely to classify their jobs as "production/crafts" or "maintenance." Carpoolers with co-workers are more frequently employed in "secretarial/clerical" or "middle management" positions than those in the family and friends carpool group, whereas those in the friends and family group are more often employed in the "sales" and "professional" occupations (Figure 7).

Attitudes Toward Commute

Mode Choice Factors

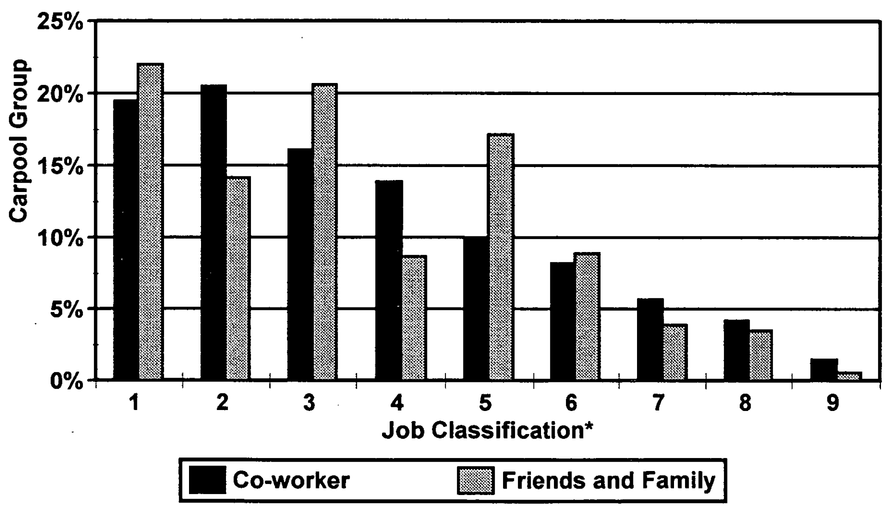
The survey asks commuters to cite the factors they consider when choosing their commute mode on an open-ended basis. Responses have been coded and collapsed into the groups shown in Figure 8.

The most frequently stated mode choice factors for both carpool groups fall into the convenience and flexibility group, but these factors are considerably more important to the friends and family group than to the co-worker carpool group. Employers can facilitate



* Incentive Codes: 1. Ridesharing information. 2. A custom carpool matching service. 3. Preferential parking for ridesharers. 4. Monetary subsidies for ridesharers. 5. Employer sells a bus or rail pass.

FIGURE 6 Perceived availability of ridesharing incentives by carpool group.

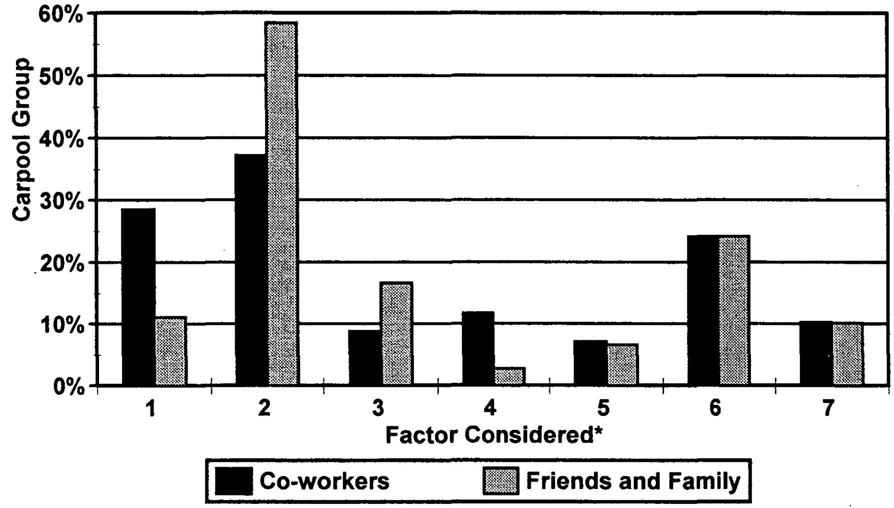


* Job Classification Codes: 1. Production/Crafts. 2. Secretarial/Clerical. 3. Professional. 4. Middle management. 5. Sales. 6. Maintenance. 7. Senior management. 8. Construction. 9. Other.

FIGURE 7 Job classification by carpool group.

ridesharing by allowing employees some flexibility in the starting and ending times of the workday, and by matching the commuter with truly appropriate ridesharing arrangements. However, only by overcoming the perception that ridesharing is inconvenient will employers make progress in achieving their ridesharing goals.

Commute cost is far more likely to be considered by co-worker carpoolers. In fact, co-worker carpoolers are more likely to cite cost than travel time. This suggests employers can convert some drive-alone commuters to ridesharing by offering monetary subsidies to ridesharers, or by charging for parking for employees who commute by driving alone. Monetary subsidies and free parking are easily understood by the commuters as direct cost saving measures, and therefore are appealing to a broader range of employees than are many other ridesharing incentives.



* Mode Choice Factors (Collapsed): 1. Cost. 2. Flexibility and Convenience. 3. Practicality. 4. Comfort and stress. 5. Privacy and safety. 6. Travel time to work. 7. Other factors.

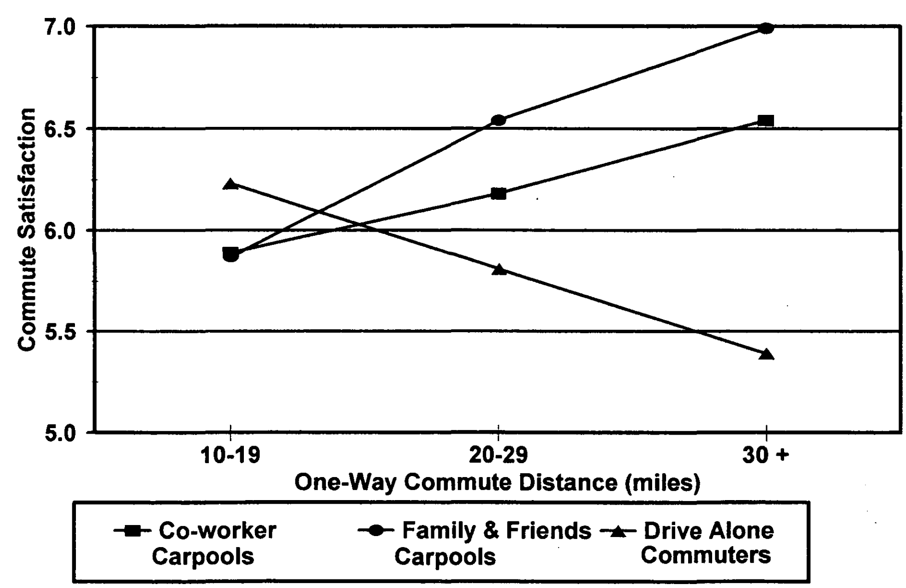
FIGURE 8 Mode choice factors considered by carpool group.

Commute Satisfaction Rating

One would expect commute satisfaction to have a strong inverse relationship to commute distance. While this holds true for drive-alone commuters, both carpool groups show a positive relationship between commute satisfaction rating and distance (Figure 9). This demonstrates an increase in benefits, both tangible and intangible, realized by carpoolers as travel distance increases. A "share the cost: share the driving" message should be integral to all employer-based ridesharing promotions.

Because commute satisfaction increases with distance for commuters carpooling with co-workers, employers can expect success in rideshare conversion among those employees with the most to gain, those with the greatest commute distances. Identifying acceptable ridesharing partners, however, becomes more difficult as commute distance increases, largely because of lower residential densities. Consequently, the development and growth of an extensive regional commuter database for rideshare matching is critical.

Another factor that helps explain the surprising relationship between commute satisfaction and distance is expectations. As



(Overall commute satisfaction: "1" least satisfactory and "9" most satisfactory

FIGURE 9 Commute satisfaction by distance by commuter group.

commute distance increases, one would expect to be increasingly less pleased with the commute: note the satisfaction for commuters driving alone (Figure 9). However, for commuters carpooling with family and friends, the long commute may serve a social function. For commuters carpooling with co-workers, the social aspect may be superseded by substantial financial savings resulting from shared driving costs, although the social benefits may not be lost completely.

Demographic Characteristics

Gender

Women are more likely to carpool than men in general. However, co-worker carpools are more gender-balanced than are family and friend carpools (Figure 10).

Age

For persons under age 30, a carpool partner is far more likely to be a friend or relative. For persons in the 30- to 39-year age group, a carpool arrangement is far more likely to be with a co-worker than a friend or family member (Figure 11). Perhaps a certain level of maturity may be necessary for co-workers to form and maintain a carpool.

This phenomenon is also a function of travel distance, as commuters age 30 to 39 have a longer average one-way commute distance than other age groups. Among carpoolers, the difference is even more pronounced (Tables 1 and 2).

TABLE 1 Average One-Way Commute, All Commuters

Age Group	Mean Commute Distance [km (mi)]
<20	16.9 (10.5)
20–29	22.5 (14.0)
30–39	26.2 (16.3)
40–49	25.6 (15.9)
50–59	19.6 (12.2)
>60	22.7 (14.1)

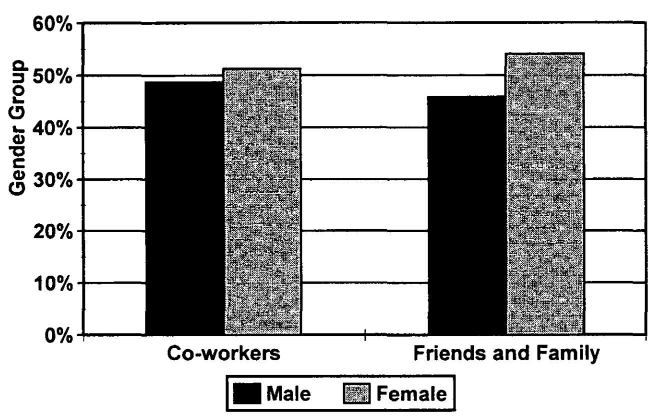


FIGURE 10 Gender by carpool group.

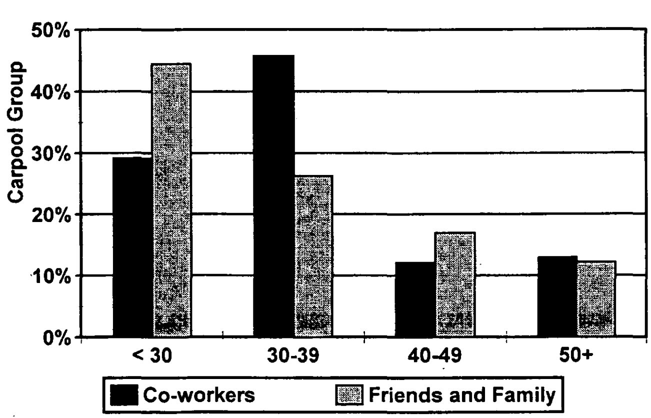


FIGURE 11 Age distribution by carpool group.

Ethnicity

Whites and blacks are overrepresented in the co-worker carpool group. Hispanics and Asians are overrepresented in the family and friends carpool group (Figure 12).

Income

There is also disparity between the levels of household income for the two groups. Only 35 percent of the commuters in the family and friends carpool group have an annual household income of $50,000 and over, as compared with 46 percent of the co-worker carpool group (Figure 13). This indicates that employer-based efforts to increase carpooling are expanding the income profile of carpoolers upward. The greater concern about commute costs among co-worker carpoolers, therefore, is more likely a function of commute distance than income.

CONCLUSIONS

While regional work trip carpool rates in Greater Los Angeles have not changed over the past 3 years, carpooling with co-workers has accounted for an increasing share of all carpooling. Therefore, without employer-based efforts, carpooling rates would surely have decreased.

Carpooling with co-workers has produced greater reductions in vehicle trips and vehicle miles traveled than carpooling with family and friends.

Not surprisingly, carpool incentives offered by employers have induced more carpooling with co-workers. In addition to employer incentives, co-worker carpools are more likely than family and friend carpools to be facilitated by publicly provided facilities, including HOV lanes and park-and-ride lots.

TABLE 2 Average One-Way Commute, Carpoolers

Age Group*	Mean Commute Distance [km (mi)]
<30	22.7 (14.1)
30–39	29.6 (18.4)
40–49	22.2 (13.8)
>50	26.1 (16.2)

* Groups collapsed due to small sample sizes.

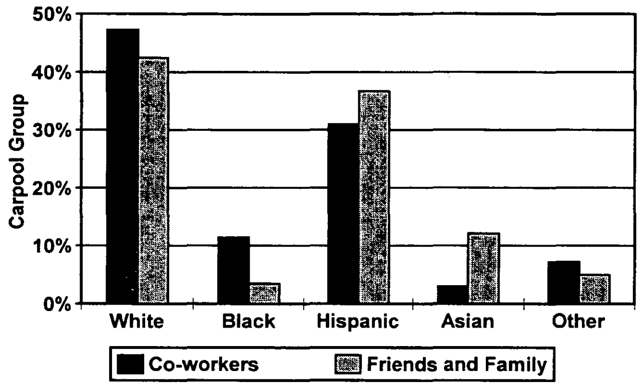


FIGURE 12 Ethnicity by carpool group.

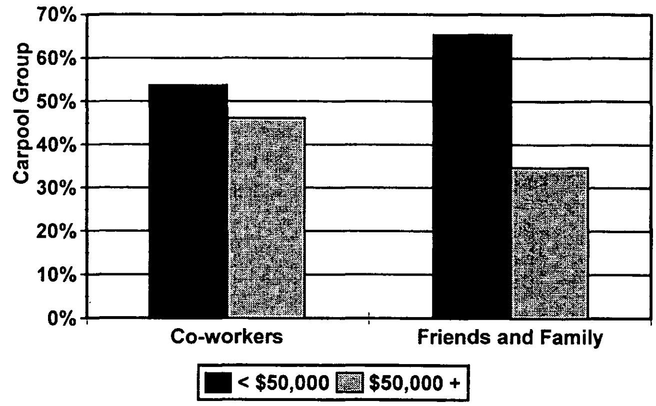


FIGURE 13 Annual household income by carpool group.

Because of their long commute distance, carpoolers who ride with co-workers are more likely to use a freeway during their commute. Usage of available HOV lanes is higher for this group than the group of family and friends carpoolers. Thus, successful implementation of future HOV lane projects rely heavily on employer-based efforts to encourage carpooling.

Compared to carpoolers who ride with family and friends, carpoolers who ride with co-workers are twice as likely to consider commuting costs when making their commute mode choice, and are twice as likely to consider comfort and stress. Thus, drive-alone commuters who cite these considerations are prime targets for conversion to co-worker carpools.

Commute satisfaction is a positive function of distance for carpoolers, and a negative function of distance for drive-alone commuters. This means employers can expect some success in carpool formation for employees with longer commute distances, provided there are suitable carpool partners. To maximize the likelihood of finding a suitable carpool partner, an extensive regional database for rideshare matching employers is essential.

Employer-based rideshare marketing efforts have broadened the demographic profile of carpoolers. More men, more commuters in the 30 to 39 age group, more whites, more blacks, and more people with household incomes of $50,000 or greater are now carpooling.

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Lake-Cook Corridor Suburb-to-Suburb Commuter Demonstration Project

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As employment at suburban activity centers has increased, congestion at these centers has also grown. Fewer options are available for suburb-to-suburb or city-to-suburb commuters than for the typical suburb-to-city commuter. However, in some cases, these employment centers are located near, but not within walking distance of, commuter rail stations that serve the traditional suburb-to-central city trips. The development of the Lake-Cook Road Corridor is consistent with the development of other major suburban activity centers across the country. Construction of a new commuter rail station on the Metra North Line at Lake-Cook Road is scheduled for completion in mid-1995. A Congestion Mitigation/Air Quality demonstration project is described that examined three shuttle-feeder transit alternatives for application within the corridor that would be anchored at the new rail station. The alternatives examined were fixed-route service, van shuttle service, and demand-responsive/taxi service. A two-stage sample plan was used to survey potential demand among approximately 30,000 employees in the corridor. A combination of an analogue model and a modal split model was used to estimate potential transit demand within the corridor. A comparable route performance analysis from major metropolitan areas with significant amounts of suburban employment was used to calibrate these two models. On the basis of this evaluation, a preferred alternative for van shuttle service was recommended and a detailed service plan developed. A joint public-private funding package was developed to provide for implementation of the service.

Commuter rail stations are usually considered to be origin points for work trips to the Chicago central business district (CBD), but they increasingly serve as destination points for reverse commuters (city-to-suburb) and suburb-to-suburb commuters (*1*). Pedestrian access from such stations to close-in employment locations is an important factor in encouraging trips into these stations by commuter rail. Connector bus service to link commuter rail with suburban employment centers is one transit option available to decrease vehicle trips and overall vehicular emissions (*2*). The use of shuttle feeder service that operates from rail stations to employment centers has also been gaining popularity in recent years.

The construction of a new Lake-Cook commuter rail station on the Metra Milwaukee District North Line (Metra) is scheduled for completion in mid-1995. Almost 30,000 employees work within a corridor 0.8 km (0.5 mi) deep along Lake-Cook Road in the villages of Deerfield and Northbrook, Ill. The corridor runs in an east-west direction and is approximately 9 km (5.5 mi), long. The commuter rail line roughly bisects the corridor. Construction of this station near such a large employee population provides an opportunity to establish an employee base of public transportation users in the corridor. However, because of the distances involved, access to and from the station and employee worksites is required. Under a demonstration grant from Congestion Mitigation/Air Quality (CMAQ) funds that were administered jointly by two municipalities, their chambers of commerce, and a transportation management association, three alternative methods of providing shuttle-feeder transit were examined for application within the corridor (*3*). A systematic surveying approach was used to determine employment size and concentrations and to identify employee commute patterns and willingness to change modes. Potential transit demand was determined through the use of two ridership estimation models and was used to evaluate and compare applicable service and delivery characteristics of shuttle-feeder concepts applicable to the corridor. Based on this evaluation, a preferred alternative was recommended and a detailed service plan developed that successfully competed for a subsequent 2-year CMAQ demonstration grant under which the service will be operated. The processes employed and the findings obtained in the initial study are included in this paper.

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SURVEYS

Two sets of surveys were conducted to identify the employment characteristics of the corridor. One focused on developing a data base of employers; the other on employee commute habits.

Employer Survey

The Transportation Management Association (TMA) of Lake-Cook, in cooperation with the Villages of Deerfield and Northbrook, Ill. and their chambers of commerce, developed, distributed, collected, and tabulated an employer data base. The data base verified current employer information such as contact person(s), number of employees, and location and residential ZIP codes of employees. Data from over 440 employers, representing 31,700 employees, were compiled into a data base.

A survey instrument was also developed and sent to the employers to verify employer size and type, working hours, existing modes of transportation that employees take to work, employee characteristics, and, most importantly, employer attitudes toward financial support of a shuttle service.

More than 150 surveys were returned. These surveys represented firms with a total of more than 18,300 employees, or 58 percent of the entire employee population of the corridor. The survey results indicated that 19.8 percent of the employees resided in ZIP code areas located along the Metra. The corridor had a large number of service and office workers. There was also a concentration of employees working in light industry in the Sky Harbor industrial area in Northbrook. Although there was some current support for employee transportation programs such as transit subsidies, prefer-

ential parking, or support for a carpool/vanpool program, most employers were not involved in such programs for their employees. Employers perceived that a shuttle service would improve their employee recruitment and retainment, help reduce employee stress, and improve air quality.

Employee Survey

An employee survey was conducted to develop an information base on the employees in the Lake-Cook area and to determine the market potential for a feeder-shuttle service. Less than two and one-half percent of the total number of businesses in the area have more than 250 employees, but these 29 largest firms employ well over a third of all of the employees in the area. Accordingly, these large employers represent the greatest concentration of employees and would be the greatest beneficiaries of such a service.

Sample Design

The universe list of firms was reviewed and a sample design was developed to achieve a sample size for estimates with 90 percent confidence and an error of ± 0.10 within size class. The strategy was a classic two-stage sample plan of employers and employees for inclusion in the survey. Stage 1 was a sample of employers within the Lake Cook area; Stage 2 was a sample of the employees of those businesses. The employees were surveyed at their place of work in sampled buildings within the TMA area. The sample plan included businesses with 10 or more employees clustered into size classes, with a sample of establishments by size class and a sample of the employees of that establishment.

Sample of Employers

The universe for the survey was determined to be 378 businesses, which represented 27,550 employees. Businesses with between 10 and 25 employees were not initially included in the sample but were added to ensure that the travel behavior characteristics of small firms were addressed in the service planning task.

Sample of Employees

For small employers, those with under 50 employees, a mail-out/mail-back field procedure was developed. Because mail-out/mail back procedures typically result in more attrition than field visits, the effort to ensure adequate response from the smaller businesses was a crucial part of the survey execution.

For large employers (those with 50 or more employees) only a sample of the employees was necessary. The percentage of employees surveyed depended on the size class of the firm. The method used to create the sample of employees was an employer-procured sample.

The employer-procured sample method required the employer to draw a list of all employees whose Social Security numbers or employee numbers (if sequentially assigned) end in random digits specified by the consultant. If a 50 percent sample was required (as was the case for businesses with 50 to 99 employees), the consultant generated five random digits. The employees whose Social Security numbers or employee numbers ended in those specified digits became the sample of employees surveyed. This method has the advantage of ensuring against sample bias (by occupational status, for example), but has the disadvantage of placing a burden of effort on the office manager or contact person at each business.

A presurvey meeting was held with the major employers to ensure their participation in the survey. As a result of this meeting, the major employers agreed to draw the sample using random digits supplied by the consultant. The employers used either employee numbers or Social Security numbers.

Linking the employer sample to the employee sample was necessary to ensure sample integrity for both phases of the survey. The unique number assigned to each employer by the TMA was carried on for the sample firms for the employee survey to link the two data sets. This allowed analysis to be performed on the employee data within the context of the establishment responses within that size-class.

Once the universe of 378 businesses was available with the unique number assigned by the TMA, a sample and a replicate were prepared for use in the field. The sample included the unique number of that establishment; the survey day-of-the-week; the name of the contact person; position, company name, address, and phone number of part-time and full-time employees; and type of business of the firms sampled. The replicate provided alternates to the main sample for cases in which an employer was no longer in business, moved out of the area, or refused to participate. In these cases, the first listing in the size class from the replicate was used in the place of the original sampled firm.

Level of Confidence

The sample size for the survey was determined using Equation 1 for a level of confidence of 90 percent. The 90 percent confidence level is equal to 1.64 standard errors. The sample sizing equation used is:

$$n = \frac{Z^2 * C.V.^2}{E^2} \tag{1}$$

where

n = number of samples required for each size class;
Z = number of standard errors for specified level of confidence;
$C.V.$ = coefficient of variation or ratio of standard error to mean, and
E = relative error.

Given this equation, to decide how many samples would be required, one would need to know the *C.V.* of the variable mean and specify the level of confidence and the relative error of the mean desired or required. Unfortunately, the *C.V.* is not typically known until the survey has been analyzed. However, enough workplace surveys have been conducted to know that the *C.V.* is close to 1.0 overall for estimates of simple variables. Stratification of the sample by size class can reduce that figure significantly. Research in California (Barton-Aschman, unpublished data) has shown it can be as low as 0.5 for work trips. A value of 0.75 was used for sample sizing purposes.

The sample design allowed for just under one-fifth of all establishments to be sampled and 9 percent of all employees, which required that about 3,000 completed employee surveys be obtained.

The precision of the sample design was estimated at ±10 percent at the 90 percent confidence level within size class.

Survey Design

The survey form, shown reduced in Figure 1, was printed front and back on standard letter-sized sheets of lightweight colored stock. Each printed questionnaire was imprinted with a unique serial number, starting with 10,000 and ending with *n*, printed on the top right-hand side. During the pretest of the survey, it was determined that a significant number of the employees of the smaller firms would need to see the survey instrument in Spanish rather than English. Accordingly, a Spanish translation was made of the survey instrument.

A survey date was preassigned to each sampled firm. Within size category, an effort was made to collect an equal number of employee responses for each day of the work week. This was an iterative process in which a day of the week was randomly assigned to each firm and then checked to ensure that no particular day of the week was skewed with too many or too few employees. The sample was sorted by day of the week for use in the field.

Data Expansion

The questionnaires returned in this survey represented a sample of all workers (regular and temporary) who work in the study area on a typical weekday. To accurately interpret the responses, it was necessary to factor the completed returns to represent both individual establishments as well as the entire universe of Lake-Cook commuters.

Data expansion was the process by which the sample of returned questionnaires was expanded to represent all employees in the study area. The factoring process was completed in two stages. First, returned questionnaires were expanded to represent all employees of the firm from which they were gathered; next, the sampled firms were expanded to represent all firms in the study area. This factoring process was stratified by firm size to account for the behavior differences of employees from different-sized companies.

Expansion to Individual Establishments Returned questionnaires from a particular establishment represent travel by all employees at that establishment; therefore, each returned questionnaire was factored to the total employment and to the attendance employment at that establishment. This factor was calculated simply by dividing the number of returned questionnaires for that establishment into the number of employees who were in attendance on survey day to get the attendance factor, and the number of returns into the number of total employees at the establishment to get the employment factor. This resulted in two factors for each establishment, and two new fields were then created on the data base, one for the attendance factor and one for the employment factor. These factors were then posted to the data base for that employer. The sum of employment factor equaled the total employment of the sampled businesses in that stratum or size class. In some cases, attendance was not reported and was estimated from other establishments in the same size category. The average attendance for the similar firms was calculated and applied to those firms missing attendance reports.

Expansion to the Universe To expand the returns to the universe of all employees in the Lake-Cook study area, expansion factors were calculated for each employment size class. As with the expansion to individual establishments, two universe expansion factors were calculated for each size class, one for total employees and one for average weekday attendance.

The total employment for each stratum (from the universe of businesses) becomes the numerator and the total employment of the sampled firms, by class size, becomes the denominator for the total employment factor. The attendance factor was also developed by class size. The average observed attendance by size class was applied to the total employment to estimate the overall attendance in the study area. Then, the sum of observed attendance by size class was divided into the estimated total attendance to determine the universe attendance factor.

These two factors, the universe employment and the attendance employment factors were posted to the data base for all establishments within a size category. When frequencies on the data were run concerning profile questions (the number of males and females, income, occupational status), the employment factors were used to represent the universe of employment in the study area. On the other hand, when statements were made about the amount of activity on a typical day (the number of people arriving by mode, the number of midday trips, etc.), the attendance factors were used to represent the amount of employees on an average weekday.

Returns

The employee return rate overall was extremely good: 62 percent of the employees surveyed returned a usable response. Only one of the targeted firms in the classes with 250 or more employees declined to participate and most of the participating firms involved themselves in the employee subsampling procedures with exemplary commitment. As the size class became smaller, the firm refusals and attrition increased, as was expected, although the employees surveyed still showed a remarkably high response rate.

SERVICE DELIVERY CONCEPT

Information was collected from the employer survey to determine the location of major employment concentrations within the corridor. Additionally, information was collected on the type of business (retail, office, service, etc.), the total number of full-time and part-time employees, and standard work hours. The purpose of identifying employment size and concentrations was to develop an initial grouping of employer clusters. These clusters were refined throughout the service planning process to estimate ridership and to generate route schedules.

The second step in developing potential service concepts was to identify employees' home ZIP codes and the closest intersection to their homes. The purpose of this step was to determine the number and percent of employees who live within a reasonable distance of the Metra. Information on home ZIP code locations was collected in both the employer and employee surveys. The intersection closest to the employee's home was collected in the employee survey. A ZIP code map was used to identify those ZIP codes zones within a reasonable travel time from the Metra line.

Using the results from the above steps and the findings of a search of current practice, three types of service delivery options were

DEERFIELD AND NORTHBROOK

Lake-Cook Transportation Survey

Employee

Thank you in advance for your time and participation in this important survey. The purpose of this survey is to better understand the transportation needs of employees in the Lake-Cook Corridor and in the Deerfield and Northbrook area. Please answer each of the questions below and return this to the person who gave it to you. Your answers will be kept confidential and will only be used to produce statistical data needed to improve transportation services in the area.

1. What is your zip code at *home*?

   ___ ___ ___ ___ ___

2. What is the nearest *major* intersection to your home?

   ________ and ________

3. Do you usually work in the Lake-Cook Road area?

   ☐₁ Yes ☐₂ No

4. Do you work full-time or part-time? (Less than 30 hours each week.)

   ☐₁ Full-time ☐₂ Part-time

5. Did you work in the Lake-Cook Road area yesterday? (or your last regular work day.)

   ☐₁ Yes ☐₂ No

6. What day of the week was that?

   ☐₁ Monday ☐₃ Wednesday ☐₅ Friday
   ☐₂ Tuesday ☐₄ Thursday

7. At what time did you arrive *to* work yesterday?

   ____ : ____ (hour) (minutes) ☐₁ A.M. ☐₂ P.M.

8. How many *minutes* did it take you to get from home to work yesterday?

   ________ (minutes)

9. Approximately how many *miles* do you live from your work place in the Lake-Cook Road area?

   ________ (miles)

10. How did you arrive at your work site yesterday?

    ☐₁ Driver of auto, truck, or van (including carpool)
    ☐₂ Passenger of auto, truck, or van (including carpool)
    ☐₃ Public bus (Route No. ________)
    ☐₄ Metra
    ☐₅ Other ________

11. If you arrived at your work site by auto, truck, or van, how many people were in the vehicle *(including yourself)*? No. of people ________

12. If you did *not* drive to work, was an auto available for this trip?

    ☐₁ Yes ☐₂ No

13. If you came by Metra, how did you get *to* the station?

    ☐₁ Drove auto ☐₃ Walked ____ (minutes)
    ☐₂ Dropped off ☐₄ Bus (Route No. ____)
    ☐₅ Other ________

14. If you came by Metra to the Lake-Cook Road area, how did you get *from* the station?

    ☐₁ Drove auto ☐₃ Walked ____ (minutes)
    ☐₂ Dropped off ☐₄ Bus (Route No. ____)
    ☐₅ Other ________

15. At what time did you leave work yesterday?

    ____ : ____ (hour) (minutes) ☐₁ A.M. ☐₂ P.M.

16. If a midday shuttle were available to and from Northbrook Court or Deerbrook Mall, would you use it?

    ☐₁ Yes ☐₂ No

    If "yes," how many times per week? ____

17. Do you usually use your own car for trips during work hours?

    ☐₁ Yes ☐₂ No ☐₃ Not applicable

The following questions relate to your travel to work.

18. In your commute to and from work, do you make stops on the way?

	Yes	No	If "yes," how many stops per week
1. To Work	☐₁	☐₂	____
2. From Work	☐₁	☐₂	____

19. What factors do you consider when choosing your means of transportation to work? (Check up to three.)

    ☐₁ Travel time
    ☐₂ Cost
    ☐₃ Convenience
    ☐₄ Flexibility
    ☐₅ Comfort and safety
    ☐₆ Reducing pollution/conserving energy
    ☐₇ Ability to make stops enroute

20. What kinds of things do you think would make shuttle bus service attractive in the Lake-Cook Road area?

    ☐₁ Bus shelters
    ☐₂ Crosswalks
    ☐₃ Placement of bus stops close to my building
    ☐₄ Sidewalks
    ☐₅ Other ________

21. If you drive alone to work, what are the *three* most important reasons why you don't regularly use public transportation to commute to the Lake-Cook area?

    ☐₁ Public transportation is not convenient to my home
    ☐₂ Public transportation is not convenient to my work site
    ☐₃ Work late/irregular hours
    ☐₄ Public transportation is too time-consuming
    ☐₅ Cannot get home in an emergency
    ☐₆ Public transportation is too costly
    ☐₇ Other ________

Now we would like to ask you a few questions for statistical purposes only. This information will be grouped for sample verification and travel demand estimation and is completely confidential.

22. What is your age? ________

23. Are you male or female?

    ☐₁ Male ☐₂ Female

24. Which of the following best describes your current job classification?

    ☐₁ Professional/Technical/Clerical
    ☐₂ Managerial/Administrative/Sales
    ☐₃ Skilled Craft
    ☐₄ Laborer
    ☐₅ Service Worker
    ☐₆ Equipment Operator/Trucker
    ☐₇ Other ________

25. What is your annual income?

    ☐₁ Less than $10,000
    ☐₂ $10,000-19,999
    ☐₃ $20,000-29,999
    ☐₄ $30,000-39,999
    ☐₅ $40,000-49,999
    ☐₆ $50,000-59,999
    ☐₇ $60,000 or more

Do you have any comments about transportation in the Lake-Cook Road area?

____
____
____
____
____
____
____
____
____

Thank you for your assistance!

FIGURE 1 Employee survey instrument.

selected for further analysis. The selected options were labeled the fixed-route option, the van option, and the demand-responsive option.

The fixed-route option consisted of three routes (labeled A, B, and C) that would operate on a fixed schedule and routing and would serve three sets of employment clusters located west of the new Metra station. For employment clusters east of the new Metra station, instead of creating a new route, improvements to existing Pace (the bus transit agency for the suburban Chicago area) fixed-Route 626 were proposed. Vehicles for Routes A, B, and C would range from 25- to 40-passenger vehicles.

The van option consisted of seven van routes serving employment clusters along the corridor. The routing of each van would be flexible in transporting employees to their worksites. For example, if Van Route 1, which serves Employer A, did not have any passengers on the van traveling to Employer A in the morning, it would not be required to make a stop but would continue to the next destination. In the p.m. peak period, however, the van would be required to stop at every worksite along the route. Van sizes would range from 6-passenger to 16-passenger vehicles, depending on the ridership estimates.

The demand-responsive option consisted of taxicabs operating as feeders to and from the Metra station. Taxis would be available at the Metra station each morning to provide service to individual worksites. For service back to the Metra station in the afternoon, each employee would be required to make an advance reservation. Depending on how the carrier operates the reservation system, reservations could be required a day in advance, or by a set time each day (e.g., 2:00 p.m.)

TRANSIT RIDERSHIP ESTIMATION

A combination of two models was used to estimate potential transit demand within the corridor. The models used were an analogue model and a modal split model. The models provide estimates of potential patronage based on transit service levels and travel volumes within a corridor. The use of two models provides a range of possible ridership levels and thus affords a more reasonable estimate of patronage. A comparable route performance analysis from major metropolitan areas with significant amounts of suburban employment was used to calibrate these two models.

The analogue model estimates transit demand using productivity factors derived from comparable transit services in the Chicago area, as well as from other large metropolitan areas. For the fixed routes, a factor of 23 passengers per revenue hour was employed. This model is highly sensitive to service levels on a route. Ridership is determined by multiplying estimated revenue hours by the productivity factor. The estimate reflects patronage at about 24 months after implementation. Data for route productivity for selected bus routes in the Lake-Cook corridor and for selected bus rail-feeder routes were obtained from Pace, the bus transit agency serving the suburban area. The number of passengers per revenue hour ranges from just under 26 for routes in the Lake-Cook corridor to just under 18 for a sample of Pace rail feeder/reverse commute routes (*4*).

The modal split model estimates transit demand based on transit trip "capture" rates for the total travel volume within a corridor. The modal split model is also calibrated using experience from Chicago and comparable metropolitan areas. Two levels of modal split were used in this analysis: conservative and optimistic. The conservative estimate is based on experience with similar services in other areas and on average travel patterns. The optimistic estimate is based on ridership expectations for a high level of bus service. For trips operating between suburbs, a transit modal split of 3.4 percent for the conservative level and 5 percent for the optimistic level was assumed. For reverse commute trips—that is, trips with the residential end in the city of Chicago—a modal split of 5.0 was assumed for the conservative level, 7.5 percent for the optimistic level. As with the analogue model, these estimates reflect patronage after about 24 months of operation.

The passenger demand growth curve is shown in Figure 2. The demand curve is based on ridership growth patterns for comparable routes in large metropolitan areas in the United States. Indications are that the Chicago suburban area follows similar patterns. The 100 percent ridership level shown on the curve at 24 months reflects the calibration values for the two models discussed above. At the end of 24 months, a route's ridership is likely to rise about 5 percent beyond the 12-month baseline estimate with the same level of service. Since these employment areas continue to grow, there is also

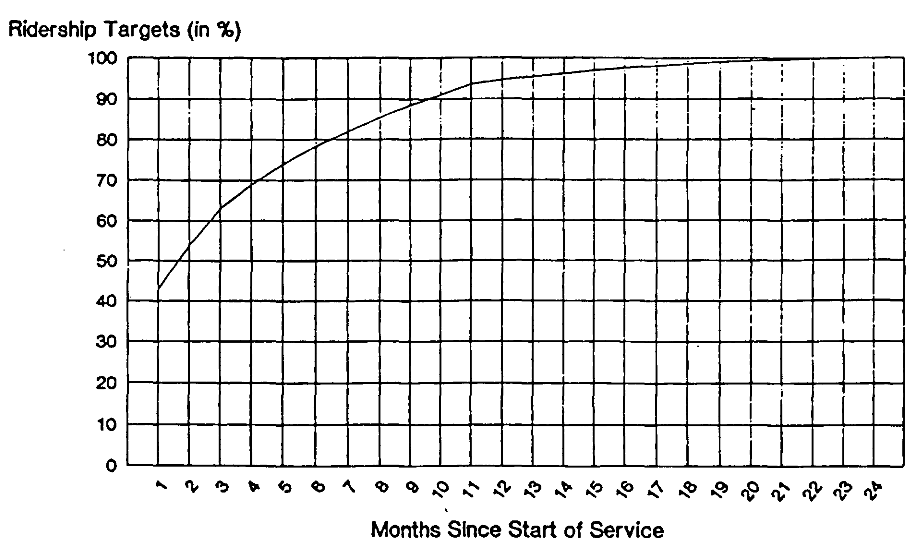

FIGURE 2 Ridership targets for new routes and suburban express routes.

a good potential for additional ridership during the first 2 years attributable to new employees.

The employee survey results provided a base number of employees who may use the shuttle service. From the total number of employees, only 25 percent live within ZIP codes with convenient access to the Metra line. Of that 25 percent, those who typically work in the Lake-Cook corridor, those working full-time, and those starting to work between 6:00 and 9:00 a.m. were accounted for, as shown in Table 1. The mode split rates developed in the ridership estimation methodology were then applied to the employee base, which resulted in 268 to 400 daily employees. Ridership estimates were generated for each of the service delivery options, both for the start-up of service and at the end of the 24-month period based on the ridership growth curve. The derived ridership estimates for the three service delivery options are shown in Tables 2, 3, and 4.

ANALYSIS OF SERVICE DELIVERY OPTIONS

Operational Components

Once the ridership estimates were prepared, each of the service delivery options was analyzed for application in the Lake-Cook corridor based on its operational components. It was determined from the existing Metra schedule that each route should maintain an approximate 20-min round trip travel time to meet the most train times (in both directions). If not, then a second vehicle would be required.

The analysis determined that Fixed-Route A would not maintain a 20-min round trip travel time and would require two vehicles. Fixed-Routes A and B were found to not have adequate ridership to warrant fixed-route service. Fixed-Route C ridership was found to be very close to warranting fixed-route service. Additionally it was determined that, routes and schedules would not have flexibility as each vehicle would have to maintain the routing and schedule published. Under the van option, the analysis determined that all employment clusters would generate adequate ridership to warrant van service, except for one route whose employment cluster is a regional shopping center about 1.6 km (1 mi) east of the Metra station location. All van routes would be able to maintain a 20-min round trip travel time with the exception of Van Route 1, which serves the western end of the corridor. This van route would require two vehicles to maintain the 20-min travel time because of the distance involved and the congestion-induced delay encountered at the west end of the corridor. The analysis showed that vans would have flexibility in morning routes from the station to the worksites and that van service would be easily phased in or removed without adversely affecting many employers or employees.

TABLE 1 Shuttle Service Preliminary Ridership Estimates, Lake-Cook Road Corridor

Employee Base			
Total Corridor Employees			28,800
% of employees living in Metra corridor		25.0%	7,200
% usually work in Lake Cook corridor		95.7%	6,890
% work full-time		98.5%	6,787
% starting work between 6-9 am		90.6%	6,150
% Suburb to Suburb Commuters		40.0%	2,460
% Reverse Commuters		60.0%	3,690
Ridership Estimates			
Mode Split		Conservative	Optimistic
Suburb to Suburb		3.4%	5.0%
Reverse Commute		5.0%	7.5%
Mode Split applied to Employee Base:			
Suburb to Suburb		84	123
Reverse Commute		185	277
	total	268	400
2 Year Ridership Growth Curve:			
Initial	40.0%	107	160
6 mo.	75.0%	201	300
12 mo.	90.0%	241	360
18 mo.	95.0%	255	380
24 mo.	100.0%	268	400

TABLE 2 Preliminary Ridership Estimates, Lake-Cook Road Corridor, Fixed Route Option

Ridership Scenario	Ridership Conservative	Ridership Optimistic
Initial (First 6 mo.) - 40%	107	160

Group	Employees	% of Employees	Fixed Route	AM Peak Ridership (a) Conservative	AM Peak Ridership (a) Optimistic	Passengers per Trip Conservative	Passengers per Trip Optimistic
1	3,208	11.8%	Rt. A	21	32	4	5
2	2,203	8.1%	Rt. A				
3	2,426	8.9%	Rt.B	19	29	3	5
4	2,495	9.2%	Rt.B				
5	7,420	27.3%	Rt.C	29	44	5	7
6	3,687	13.5%	walk				
7	1,270	4.7%	walk				
8	670	2.5%	Pace				
9	3,836	14.1%	Pace				
	27,215	100.0%		70	104		

Ridership Scenario	Ridership Conservative	Ridership Optimistic
Maximum (24 mo.)	268	400

Group	Employees	% of Employees	Fixed Route	AM Peak Ridership (a) Conservative	AM Peak Ridership (a) Optimistic	Passengers per Trip Conservative	Passengers per Trip Optimistic
1	3,208	11.8%	Rt. A	53	80	9	13
2	2,203	8.1%	Rt. A				
3	2,426	8.9%	Rt.B	48	72	8	12
4	2,495	9.2%	Rt.B				
5	7,420	27.3%	Rt.C	73	109	12	18
6	3,687	13.5%	walk				
7	1,270	4.7%	walk				
8	670	2.5%	Pace				
9	3,836	14.1%	Pace				
	27,215	100.0%		175	261		

(a) Schedule Assumptions:
30 min. frequency
6:30-8:30 AM
3:30-6:30 PM
Trips in AM=6
Trips in PM=7

Ridership estimates under the demand-responsive option would be much lower than the fixed-route or van option. This is primarily because of the requirement that employees make reservations for return trips in the afternoon. The analysis showed that the demand-responsive option has the most flexible vehicle requirements.

Cost Estimates

An estimate of annual cost for each of the service delivery options was prepared for each time period (start-up and after 24 months), and for conservative and optimistic ridership levels. The cost estimates also were calculated as annual cost per passenger. Two cost estimates were prepared for the fixed-route option, one using Pace as the service provider and one using a private contractor as the service provider.

The fixed-route option would cost between $287,500 and $362,000 per year, with annual cost per passenger of between $1,110 and $1,650. The van option would cost between $250,000 and $300,000 per year, with a lower annual per passenger costs of $750 to $1,120. The demand-responsive option would have costs ranging from $232,500 to $342,500 per year. The annual costs per passenger would be $2,500 for both the conservative and optimistic ridership levels for the demand-responsive service option.

Recommended Option

Based on the above analyses, the recommended service delivery option was the van option. The van option consists of seven van routes serving employment clusters distributed along the length of the corridor. Preliminary schedules were developed for the van routes for both a.m. and p.m. peak periods. To coordinate with both northbound and southbound Metra train schedules, each van is scheduled to be at the station at approximately 20- to 30-min intervals. All van routes will be operated with one vehicle except for Route 1, which will require two vehicles.

FARE SENSITIVITY ANALYSIS

Although the service will be provided under a demonstration grant for the first 2 years, it was necessary to evaluate the effect that fares

TABLE 3 Preliminary Ridership Estimates, Lake-Cook Road Corridor, Van Option

Ridership Scenario	Ridership Conservative	Ridership Optimistic
Initial (First 6 mo.) - 40%	107	160

Group	Employees	% of Employees	Van Route	AM Peak Ridership (a) Conservative	AM Peak Ridership (a) Optimistic	Passengers per Trip Conservative	Passengers per Trip Optimistic
1	3,208	11.8%	1	13	19	2	3
2	2,203	8.1%	2	9	13	1	2
3	2,426	8.9%	3	10	14	2	2
4	2,495	9.2%	4	10	15	2	2
5	7,420	27.3%	5	29	44	5	7
6	3,687	13.5%	6	14	22	2	4
7	1,270	4.7%	6	5	7	1	1
8	670	2.5%	7	3	4	0	1
9	3,836	14.1%	8	15	23	3	4
	27,215	100.0%		107	160		

Ridership Scenario	Ridership Conservative	Ridership Optimistic
Maximum (24 mo.)	268	400

Group	Employees	% of Employees	Van Route	AM Peak Ridership (a) Conservative	AM Peak Ridership (a) Optimistic	Passengers per Trip Conservative	Passengers per Trip Optimistic
1A	3,208	11.8%	1	32	47	5	8
1B	2,203	8.1%	2	22	32	4	5
2	2,426	8.9%	3	24	36	4	6
3	2,495	9.2%	4	25	37	4	6
4	7,420	27.3%	5	73	109	12	18
5	3,687	13.5%	6	36	54	6	9
6	1,270	4.7%	6	13	19	2	3
7	670	2.5%	7	7	10	1	2
8	3,836	14.1%	8	38	56	6	9
	27,215	100.0%		268	400		

(a) Schedule Assumptions:
30 min. frequency
6:30-8:30 AM
3:30-6:30 PM
Trips in AM=6
Trips in PM=7

would have on the estimated ridership levels because the service will need to be either self-supporting or employer subsidized if it is to continue beyond the initial period. A fare sensitivity analysis was conducted to determine the expected impact on ridership of particular fare levels. This change in ridership levels was calculated using a fare elasticity measure that was determined to have a value of −0.26. This level of elasticity was based on a composite of the following elasticities:

1. Local bus operations in Illinois: −0.28.
2. Households with one to two cars: −0.22.
3. Households with typical suburban incomes: −0.18.
4. Choice riders of transit: −0.31.
5. Standard Simpson-Curtain average: −0.33.

The resulting impact on ridership was calculated for fares of \$0.50, \$0.85, \$1.00, and \$2.00 (fare in addition to the Metra rail fare, which ranged from \$1.75 to \$3.70 each way). A \$0.50 fare would cause a ridership decline of about 5 percent; an \$0.85 fare would cause a ridership decline of about 9 percent; and a \$1.00 fare would cause a ridership decline of about 10 percent. If fares were to cover all of the cost of the service, the fare would range from \$1.80 under the low-cost, low-ridership scenario to \$1.50 under the high-cost, high-ridership scenario. Using the fare elasticity model, a fare of \$1.50 would cause a decline in ridership of about 15 percent, or about 60 daily riders.

EMPLOYER FINANCIAL PARTICIPATION

The TMA conducted follow-up focus groups with major employers to discuss the shuttle service and their willingness to support the service financially. On the basis of the estimated cost and level of service and the initial willingness of the employers to participate financially, the TMA proposed that the major corporations in the Lake-Cook Road corridor provide the initial financial support to cover the 20 percent cost of the local share of the proposed CMAQ grant, or \$60,000. Fourteen firms, representing 11,400 employees, agreed to participate financially in the project at an annual estimated cost of \$6.00 per employee.

TABLE 4 Preliminary Ridership Estimates, Lake-Cook Road Corridor, Demand Responsive Option

Ridership Scenario	Ridership Conservative	Ridership Optimistic
Initial (First 6 mo.) - 40%	37	56

Group	Employees	% of Employees	DR Vehicle	AM Peak Ridership (a) Conservative	AM Peak Ridership (a) Optimistic	Passengers per Trip Conservative	Passengers per Trip Optimistic
1	3,208	11.8%	1	4	7	na	na
2	2,203	8.1%	2	3	5	na	na
3	2,426	8.9%	3	3	5	na	na
4	2,495	9.2%	4	3	5	na	na
5	7,420	27.3%	5/6	10	15	na	na
6	3,687	13.5%	7	5	8	na	na
7	1,270	4.7%	8	2	3	na	na
8	670	2.5%	9	1	1	na	na
9	3,836	14.1%	10	5	8	na	na
	27,215	100.0%		37	56		

Ridership Scenario	Ridership Conservative	Ridership Optimistic
Maximum (24 mo.)	93	137

Group	Employees	% of Employees	DR Vehicle	AM Peak Ridership (a) Conservative	AM Peak Ridership (a) Optimistic	Passengers per Trip Conservative	Passengers per Trip Optimistic
1	3,208	11.8%	1	11	16	na	na
2	2,203	8.1%	2	8	11	na	na
3	2,426	8.9%	3	8	12	na	na
4	2,495	9.2%	4	9	13	na	na
5	7,420	27.3%	5/6	25	37	na	na
6	3,687	13.5%	7	13	19	na	na
7	1,270	4.7%	8	4	6	na	na
8	670	2.5%	9	2	3	na	na
9	3,836	14.1%	10	13	19	na	na
	27,215	100.0%		93	137		

(a) Schedule Assumptions:
3.4 to 5.0 passengers per vehicle hour
6:30-8:30 AM
3:30-6:30 PM
Vehicles in AM=10
Vehicles in PM=10
Vehicle Hours in AM=20
Vehicle Hours in PM=30

CMAQ FUNDING

After completion of the study, the TMA of Lake-Cook, the Village of Deerfield, and the Northbrook Chamber of Commerce presented the findings to the CMAQ Project Selection Subcommittee. A request was made for $830,280 in FY 94 and FY 95 CMAQ funds for the implementation of the van service and construction of pedestrian improvements to serve an employment cluster in the vicinity of the new rail station. The selection committee approved this request.

IMPLEMENTATION

Implementation of this demonstration project is just under way. The major implementation components include finalizing the service plan and selecting a service provider, monitoring the service, developing a marketing plan, constructing the pedestrian improvement, and evaluating the effectiveness and air quality benefits of the shuttle service and pedestrian improvements.

The development of the marketing plan has been initiated. The TMA is working with Metra Commuter Rail to coordinate a marketing plan to include such elements as

- Developing schedules, timetables, and brochures targeted for shuttle service users;
- Meeting with employers and employees to market the service;
- Developing and implementing a guaranteed ride to the station for employees who miss the van service;
- Providing free passenger tickets to encourage employee use of the shuttle; and
- Conducting on-board survey evaluations of employee usage and satisfaction with the shuttle service.

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Stated Choice–Based Performance Evaluation of Selected Transportation Control Measures and Their Transfer Across Sites

W. PATRICK BEATON, HAMOU MEGHDIR, AND QIUZI (CYNTHIA) CHEN

The stated-preference approach to demand forecasting is gradually coming of age. Despite inherent problems with scaling factors, dynamics and IIA, data-generation approaches relying on hypothetical-choice set experiments continue to grow in use. Previous models have demonstrated construct validity and reproducibility over time. The current research examines the transferability of stated-preference models across target populations residing within the same transportation network. Two employment sites in northeastern New Jersey provide the setting. The stated-choice approach is tested for consistency when applied to different sites. The sites are not identical, nor are the instruments. These differences become the basis for developing a set of alternative hypotheses that test for structural differences between the two models. The strategies of transportation-demand management proposed for implementation at both sites are essentially the same. The differences arise for the most part from the availability of off-site transportation resources to each site's employees. One site is in a relatively isolated suburban setting that has little public mass transportation and no off-site parking. The other site is an urban facility with access to public mass transportation and off-site parking. The stated-choice models estimated at the two sites have essentially the same structure. Where site-specific conditions are comparable, the logit coefficients are statistically identical; where the site-specific conditions differ, the coefficients differ in the direction predicted by theory.

The Clean Air Act Amendments (CAAA) of 1990 require the preparation of employee trip reduction compliance plans. The plans must commit an affected employer to a set of employee commute option (ECO) strategies. The plans must demonstrate convincingly the effectiveness of the strategies (Section 108f, CAAA). Most often, the evidence for their effectiveness comes from case histories without controls (*1*). Efforts such as these provide overall guidance by describing the outcomes of the application of groups of strategies. Issues of research design, validity, reliability, and transferability tests are rarely addressed. Efforts to transfer the quantitative performance estimates from such studies have been known for their lack of success (*2*). This study explores an alternative approach to performance evaluation. It is one of a series of studies extending the use of stated-choice techniques to transportation-demand modeling and mode-choice forecasting.

Stated-choice models are based upon the mode-choice decisions of individual commuters. The models are estimated based on the real commutes employees make in real transportation corridors. They differ from traditional demand-forecasting models in that hypothetical ECO strategies are overlaid on the existing transportation network. Survey research techniques are used to extract from individual commuters their choice of commuting mode given hypothetical but realistic values for the time, comfort, cost, and convenience of each proposed commuting alternative.

Validity and transferability issues have been addressed in stated-choice models. Stated-choice forecasts have been favorably compared with revealed choices under several travel conditions in England (*3*). Comparison of stated-choice with revealed-preference commuting choices awaits the arrival of appropriate data. The reliability of stated-choice results when repeated studies are performed at the same site has been affirmed (*4*). However, the issue of transferability has yet to be addressed. The report that follows examines two stated-choice models designed to forecast the impact of ECO strategies on mode-choice decisions.

EXPERIMENTS

Commuting-choice experiments were performed at two employment sites in the New York metropolitan area. The first experiment occurred at the Matsushita Electric Corporation of America's (MECA's) headquarters facility at Secaucus, New Jersey, during the spring of 1992. The MECA study has been reported in detail in (*4*). The second experiment occurred at the Port Authority of New York and New Jersey Technical Center (PATC) in Jersey City.

The methods used to design, test, administer, and analyze the results were identical. The initial stated-choice questionnaires were created in the laboratory of the New Jersey Institute for Transportation (NJIT). The data to be generated through each survey instrument were tested for applicability to the multinominal logit model using simulation techniques (*5*). Focus-group meetings were held to explore the relevance and appropriateness of the draft instruments. Revisions were made and the new instrument was pilot-tested on 15 to 24 employees at each site. The final instrument was administered using each site's mail system to distribute the instrument to a randomly-selected sample of commuters.

The response rates obtained for the MECA and the PATC surveys differ from each other, reflecting the different conditions under which they were administered. A randomly selected sample of 133 drive-alone PATC employees were sent stated-choice surveys on May 26, 1993. Within 1 month, 62 were returned completed. Two

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response-enhancement letters were sent to the employees included in the sample. After 2 weeks, an additional 17 surveys were returned. The total response rate for PATC was 59.4 percent. The MECA response rate for surveys administered under the same conditions as the PATC survey was 44.6 percent; however, 38 surveys were rejected due to noncompensatory responses on the part of the respondents (*4*). The effective response rate for MECA was 32 percent. The different response rates reflect the authoritative intervention by top management into the survey-administration process at PACT. The MECA survey received written support from a top member of the management team; however, completion of the survey was not made an important objective as it was with PATC management.

While the underlying methods were the same, specific elements of the two experiments were not identical. The MECA experiments provided commuters with two commuting alternatives: single-occupant vehicles (SOVs) and rideshare. The rideshare alternatives were defined in the experiment as either carpool or vanpool. The PATC experiment presented commuters with three alternatives: SOV, carpool, and vanpool. Another difference is found in the attribute representing benefits given to rideshare commuters. The MECA experiment presented commuters with a subsidized meal in the corporate cafeteria valued up to $3.00 per day, while the PATC study offered commuters up to a $3.00 per day tax-free transportation benefit to vanpool users. The availability of alternative parking identifies a third difference between the two sites and studies. The MECA location has an abundance of free on-site parking but essentially no off-site parking; on the other hand, the PATC site has an effective constraint on on-site parking, but has access to local on-street parking. Most PATC employees report that they have experienced the need to park on the street or in private lots found within a 15-min walk of the work site. (*6*).

The employee characteristics of the two employment sites differ as well. The MECA-headquarters site has approximately 2000 employees. The PATC site has 566 employees. Approximately 80 percent of the employees of each site are male. Roughly 89 percent of MECA employees commute using an SOV. Its average passenger occupancy (APO) is estimated to be 1.08; in contrast, 51 percent of the PATC employees use SOV, yielding an APO of 1.36.

Transportation Control Measures

The transportation control measures (TCMs) examined in this study consist of parking-management policies such as parking charges and parking space availability, rideshare incentives such as transportation benefit payments or subsidized meals, guaranteed ride home programs rated at several levels of convenience, and the implicit effectiveness of the employee transportation coordinator. The stated-choice method generates performance data by asking employees a complex set of hypothetical commuting-choice questions. In the case of the PATC study, a sample of employees was shown a set of three commuting options: SOV, carpool, and vanpool. Parking-management policies, subsidies (when available and at a specific value), guaranteed ride home, and similar factors characterizing each commuting option were shown to the respondent. After reading these descriptions, the employee was asked to choose the commuting alternative he or she would use under actual commuting conditions. An example of one choice task is shown in Figure 1; the full survey instrument is available from the authors. Employees were given 16 choice tasks; each choice task was prepared using fractional factorial design tables where interaction effects among the design variables are assumed to be negligible and the values of the characteristics form orthogonal independent variables (*7*). The data base from the completed surveys was constructed and the conditional logit program ALOGIT 3.2 was used to compute the importance of each TCM toward the choice of a commuting alternative (*8*).

Analytical Model

The commuting decision is modeled as a rational process. Each employee-commuter chooses one alternative among those presented in each choice task. The selection process is based on the explicitly or implicitly stated costs and benefits shown in each choice task. Tests for lexicographic decision processes are used to detect non-rational or noncompensatory decision-making processes (*9*); when a noncompensatory process is found, it is removed from the data base. The costs and benefits shown in each choice task form the design attribute subset of independent variables. The second subset of independent variables consists of socioeconomic, demographic, and attitudinal indicators. In the case of the PATC study, each stated choice made by an employee is combined with a comparable set from the other employees in the sample to form a multinomial dependent variable. The MECA model has a binomial dependent variable.

The underlying analytical model describing the outcomes of PATC employees' commuting decision-making process is the multinomial logit. The model combines the discrete decisions of individual commuters into a choice probability for each alternative. The fundamental assumption underlying the use of this model is the Luce axiom regarding the independence of irrelevant alternatives. For the conditional logit to be the basis of unbiased estimators, it is assumed that the ratio of the probability of choice for any two alternatives is independent of all other alternatives.

The conditional logit model is

$$P_i = \frac{eV_i}{e_i^V + e_j^V + e_k^V} \tag{1}$$

where P_i is the probability that an individual n in the target population will choose one alternative from a choice set containing alternatives $\{i, j, k\}$, and V_i, V_j, and V_k represent, in linear parameters, indirect utility functions for each alternative. The indirect utility functions are shown in Equation 2:

$$\begin{aligned} V_i &= \alpha_0 + \alpha_1 X_1 + \cdots + \alpha_m X_m + \varepsilon_{i,n} \\ V_j &= \beta_0 + \beta_1 W_1 + \cdots + \beta_m W_m + \varepsilon_{j,n} \\ V_k &= \gamma_0 + \gamma_1 Z_1 + \cdots + \gamma_m Z_m + \varepsilon_{k,n} \end{aligned} \tag{2}$$

The set of coefficients $\{\alpha, \beta, \gamma\}$ represents the alternative specific constants, the marginal utilities assigned by commuters to each design attribute, and the shifts in the alternative specific constants generated by individuals through their socioeconomic and attitudinal indicators. The coefficients $\{\alpha_m, \beta_m, \gamma_m\}$ are interpreted as marginal utilities linking a change in one unit of an attribute $\{X_m, W_m, Z_m\}$ to the change in utility experienced by individual n holding income constant.

Test for IIA Assumption

The Hausman specification test is used to test for the IIA assumption (*10*). The test involves the preparation of two logit equations.

Experiment Code SOVCPVP

If you were presented with the following three alternative ways to commute to the Port Authority Technical Center beginning in June 1993, which one would you choose to use?

Alternative 1. Drive alone	Value of Characteristic
Parking space fee per day at PATC	You pay nothing
Parking space availability	first come first serve in Lot 2

Alternative 2. Carpool (Pickup and drop off at your home)	
Vehicle leaves PATC for home at	5:04 p.m. sharp
Parking space charge at PATC	You pay nothing
Extra time for ridesharing	5 min for each one way trip
Guaranteed ride home	None offered
Carpool subsidy	None offered
Guaranteed parking spot in lot:	Lot 1

Alternative 3. Vanpool (Pickup and drop off at your home)	
Van leaves PATC for home at	5:04 p.m. sharp
Parking space change at PATC	You pay nothing
Extra time for ridesharing	5 minutes for each one-way trip
Guaranteed ride home	None offered
Vanpool subsidy	You are paid $3.00 per day
Guaranteed parking spot in :	Lot 1

After comparing the characteristics of the three alternatives shown above, I choose:

****Please check one and only one alternative****

Drive alone	( )
Carpool with other PATC employees	( )
Vanpool with other PATC employees	( )

FIGURE 1 One of 16 choice tasks presented in stated-choice experiment.

The first is the unrestricted model containing all of the choice alternatives; the second model is restricted in that one of the alternatives is removed.

The null and alternative hypotheses are

$$H_0: \beta = \gamma$$
$$H_a: \beta \neq \gamma \quad (3)$$

where β represents the logit coefficients taken from the unrestricted model, and γ represents those taken from the restricted model.

The Hausman test permits the rejection of the null hypothesis when

$$[\gamma - \beta]'[V_\gamma - V_\beta]^{-1}[\gamma - \beta] \geq \chi^2_{1-\alpha,r} \quad (4)$$

where

$[V_\gamma - V_\beta]^{-1}$ = inverse of difference between variance covariance matrix for restricted and nonrestricted models, respectively;

α = significance level, and

r = number of parameters in restricted model.

Specification of Logit Models

The logit model requires that variables representing attributes of the TCM programs and the socioeconomic characteristics be assigned to each alternative's utility function. From the point of view of the choice experiment, the attributes and their values provide the information for the respondent to distinguish one alternative from another. From the point of view of the logit model, the attributes are the independent variables used to specify the utility functions.

Both the PATC and MECA studies provided employees with a set of design variables representing ECO programs and at the same time elicited from their respective employees a set of socioeconomic and available transportation resources. The MECA model has been presented in a previous paper (*4*); therefore, only the PATC model will be described in detail.

Four socioeconomic-regional transportation variables were used to provide the conditions underlying the PATC's employees'

decision-making process regarding their commutes. At the final estimation of the model, all of these variables were entered into the SOV utility function. Household income was entered in order to account for the positive income elasticity of demand for driving alone. Perceived availability of parking spaces was included to reflect the supply of parking at the PACT site. This characteristic was specified by asking employees if they felt they had an assigned parking space. Approximately 40 percent of the employees returned a positive perception. Discussions with PATC's facility manager revealed that no formal parking assignment policy exists for the site. Accurate or not, the perception of a right to an on-site parking space must be considered the basis for the initial commuting decision. Therefore, the perception of an assigned parking space should result in a positive marginal utility for the SOV mode.

Two additional variables specify the employees' perception of the utility and convenience of public mass transit. When employees use public mass transit on a usual or an occasional basis, knowledge of the commuting alternative will lessen the sense of being captive to the SOV. Therefore, it is assumed that occasional use of the transit alternative will reduce the marginal utility of the SOV mode. Alternatively, for employees who never use public mass transit, the SOV mode will have a positive marginal utility. The use of public mass transit is conditioned on its cost. The final background variable retained for the model is the number of transfers employees must make when using public mass transit. The greater the number of transfers needed for the commute to work, the higher the cost of transit in terms of time, comfort, convenience, and fare; therefore, the higher the positive utility attached to the SOV mode.

Stated-Choice Equation

Table 1 displays the conditional logit equation for the PATC model. Assuming that the error covariance for the responses to the stated-choice tasks both for individual respondents and across respondents is zero, the coefficients reported in the table are statistically significant at the 0.05 level and have signs that are considered theoretically correct. The equation obtains a $\bar{\rho}^2$ statistic of 0.23, well within the desired range of 0.2 to 0.3. The IIA assumption was tested with the Hausman test. The χ^2 value of 5.36 was not in the critical region of the χ^2 statistic given 9 degrees of freedom; therefore, IIA is not rejected. Thus, the use of a nonnested logit model is assumed appropriate for examining the logit choice process for SOV, carpool, and vanpool alternatives.

The logit equation is partitioned into its three commuting equations: SOV, carpool, and vanpool. The design variables are reported at the beginning of each partition and are highlighted. The variables used to specify the socioeconomic segments of the model are placed at the end of the SOV partition. Each of the socioeconomic variables generates utility coefficients with signs predicted by theory. Household income, having an assigned parking spot, and never using public transit have a positive stimulus on the use of SOV. Similarly, the need to transfer when using public transit also has a positive influence on the utility of the SOV mode. All of the socioeconomic variables tested and used in the final model influence the level of SOV use.

Seven TCM design variables are included among the three modal equations. The SOV component of the logit equation has two design variables: parking charges and the nominal variable, defined as availability of parking spaces in the PATC lots when the employee arrives at work. Parking charges reduce the utility found in the SOV mode, while parking space availability increases utility.

TABLE 1 Conditional Logit Equation for Commuting-Choice Decisions Made by PATC Employees Who Currently Drive Alone to Work, Spring 1993

Attribute	Logit Coefficient	t score
Single Occupant Vehicle		
Parking Charges at PATC	-0.16	3.9
Parking spaces available	0.54	4.3
Household Income	0.000017	6.7
Employee has assigned Parking Space	0.47	3.5
When taking transit, employee uses Park and Ride lot	-1.37	8.5
When taking transit, employee is dropped off at stop	-0.85	4.5
Number of transfers employee must use when taking transit	0.34	7.2
Carpool Equation		
Extra time consumed carpooling in comparison to SOV	-0.037	3.0
Guaranteed Ride Home Program at PATC	1.13	5.6
Extra time spent using GRH service over SOV	-0.016	2.1
Vanpool Equation		
Guaranteed Ride Home Program at PATC	1.13	5.6
Extra time spent using GRH service over SOV	-0.016	2.1
Extra time spent consumed vanpooling in comparison to SOV	-0.048	4.7
Vanpool subsidy ($)	0.29	5.3

Equation Statistics

Initial Likelihood	-1342
Final Likelihood	-1037
Rho bar squared	.23
Chi square (IIA test)	5.36
Chi square , df=9, significance level=0.05,	16.9

The carpool equation contains three design variables. First, the existence of a guaranteed ride home program increases the utility of the carpool option, while time spent waiting either for the carpool or for the guaranteed ride home acts as a negative weight for carpooling. The vanpool equation has four design variables. By design, the coefficients for the guaranteed ride home program are the same for both rideshare options. Similar to the carpool model, extra time

spent in the vanpool over that spent driving alone has a strong negative influence on the vanpool option. The final policy variable relates to the qualified transportation benefit program. The coefficient is strongly positive, indicating the price-sensitive nature of the vanpool option.

Forecasting Effectiveness of TCM

The logit model derived from the PATC employees' stated choices is used to construct a series of modal split forecasts. The percentage of employees choosing to commute by SOV, carpool, and vanpool is computed for various ECO policies. Seven scenarios are constructed and shown in Table 2. The first scenario represents the current situation, in which essentially all employees in the model commute using the SOV. That is, no parking charges, vanpool fringe benefits, or guaranteed ride home programs exist, parking spaces are available, and employees perceive that an extra hour of time is wasted using either the carpool or vanpool option. The APO derived from the first scenario is 1.0 persons per vehicle. This is appropriate in that the actual APO for the employees in this sample is 1.0.

Scenario 2 identifies one of a set of commuting-management strategies that will result in the PATC meeting the trip-reduction requirements of the Clean Air Act. The set of strategies includes a $2.00 per day parking charge, a guaranteed ride home rated at 15 min lost time over a personal vehicle being available, an average of 15 min additional time spent commuting for carpoolers and 30 min for vanpoolers. Lastly, there is a $3.00 transportation benefit payment given to those employees who join a qualified vanpool. Scenario 2 is forecast to raise the site's APO from 1.00 to 1.62.

Parking charges are known to be difficult to implement. Scenario 3 allows employees to retain their free parking while leaving all other variables at the levels shown in Scenario 2. The percentage of employees who use SOV rises to 54 percent from its target level of 46.8 percent and the projected APO declines from 1.62 to 1.49. Scenario 4 returns to the $2.00 parking charge but removes the guaranteed ride home from Scenario 2. This scenario increases the use of the SOV to 66.2 percent while dropping the APO to 1.32. Scenario 5 explores the impact of ineffective rideshare matching at the site. Ineffective rideshare matching means that the employee transportation coordinator has not succeeded in finding rideshare matches that will reduce the average effective time lost ridesharing (compared to SOV) to less than 1 hr. As a result, the projected APO declines to 1.30. Scenario 6 removes the transportation subsidy from vanpooling. The result is a drop in the percent vanpooling from the target level of 26.3 percent to 13.3 percent, and a drop in APO from 1.62 to 1.42.

Tests for Transferability of TCM Coefficients

Transferability of the logit model's utility coefficients is a relative property. Where validity and reliability reflect the properties of a target population and its sample, the property of transferability reflects a model's ability to be applied to other populations. The question is not so much whether a model is transferable but rather under what conditions it can be transferred.

The conditions surrounding the administration of the stated-choice instruments differ across the two sites reported in the study. Consequently, the structure of the logit models for PATC and

TABLE 2 Projected Modal Split for Employees Who Currently Drive Alone to PATC

Scenario Subsidy	Parking $	Parking Charge Available	Guaranteed Space Home	Time lost Ride GRH	Time lost Using the Carpools	Time lost Using Vanpools	Vanpool Using $
1	0	1	0	0	60	60	0
2	2	1	1	15	15	30	3
3	0	1	1	15	15	30	3
4	2	1	0	0	15	30	3
5	2	1	1	15	60	60	3
6	2	1	1	15	15	30	0

Scenario	% SOV	% Carpool	% Vanpool	APO	Comments
1	100.0 %			1.00	Current
2	46.8%	26.9%	26.3%	1.62	ETR Goal*
3	54.3	23.1	22.6	1.49	No Parking Chg.
4	66.2	17.1	16.7	1.32	No GRH
5	58.6	6.6	34.7	1.30	Poor matching
6	54.3	32.3	13.3	1.42	No Subsidy

*Employee Trip Reduction goal is expressed as the increment to APO obtained from single occupant vehicle drivers. It is assumed that the PATC employees who currently use bus and rideshare continue that pattern. The combined APO for the site is therefore 1.97.

MECA will differ. It will be more appropriate to determine whether the coefficients differ in theoretically predictable directions.

In comparing the two studies, the null hypothesis asserts that the marginal utility estimates for TCMs will be identical across the two models. Two alternative hypotheses control the tests for transferability.

- Hypothesis 1: Given the existence of alternative parking at the PATC site and little or no parking at the MECA facility, parking management programs such as parking charges will have a higher disutility at MECA than at PATC.
- Hypothesis 2: A rideshare incentive that requires the commuter to consume an assigned good or service not directly related to transportation services will have a lower marginal utility than a monetary incentive directly tied to the consumption of transportation services. Consequently, the subsidized lunch for ridesharers at MECA will have a lower marginal utility than an equivalent payment for rideshare services at PATC.

The remaining TCMs such as the guaranteed ride home and the marginal disutility of time lost ridesharing are hypothesized to hold constant across the two models.

Individual TCM coefficients across the two models are tested using an asymptotic *t*-test (*10*). The test is

$$t = \frac{\beta_k^1 - \beta_k^2}{[\text{var}(\beta_k^1) + \text{var}(\beta_k^2)]^{1/2}} \qquad (5)$$

where

β = parameter estimate for TCM k,
(var) = variance operator, and
superscripts = MECA and PATC models.

Table 3 presents the coefficients for comparable TCMs across the two models. Alternative hypothesis 1 is accepted. Parking charges have a much greater impact on the utility of driving alone at MECA than they do at PATC. However, given the quadratic form of the MECA parking-charge term, its marginal impact on driving alone diminishes with increases in the parking charge. This may suggest the existence of subsets of employees who respond differently to parking charges.

Figure 2 graphically displays the role of off-site parking availability in the performance of parking charges. The design variables for both the PATC and the MECA models were set to a roughly equivalent baseline value. Rideshare incentives were set at zero a guaranteed ride home program rated at a 25-min wait time, and time lost ridesharing set at 22 min. The base case has no parking charge. In this case MECA has 80 percent of its employees commuting by SOV, and PATC has approximately 58 percent. Next, let on-site parking charges be instituted. At a charge of $2.30 per day, both sites have the same percentage of commuters arriving at work by SOV. The $2.30 charge has reduced the MECA drive-alone levels by 30 percent. PATC, on the other hand, has had its drive-alone levels reduced by 6 percent. Where off-site parking exists such as that surrounding PATC, the parking charge appears to do little to affect

TABLE 3 Logit Coefficients Derived for TCMs Given to Employees of PATC and MECA in Separate Stated-Choice Exercises

Transportation Control Measure	PATC Coefficients	MECA Coefficients
SOV Alternative		
Parking Charge	-0.16	-0.81*
Parking Charge Squared	0	0.047*
Carpool-rideshare		
Extra time consumed ridesharing over SOV alternative	-0.037	-0.041
Guaranteed Ride Home with a 25 minute wait time	1.13	0.99
Vanpool-rideshare		
Extra time consumed ridesharing over SOV alternative	-0.048	-0.041
Transportation Benefit subsidy	0.29	0.29
Transportation Benefit subsidy squared	0	-0.018*

*t score obtained from the difference of estimators is significant at the 0.05 level.

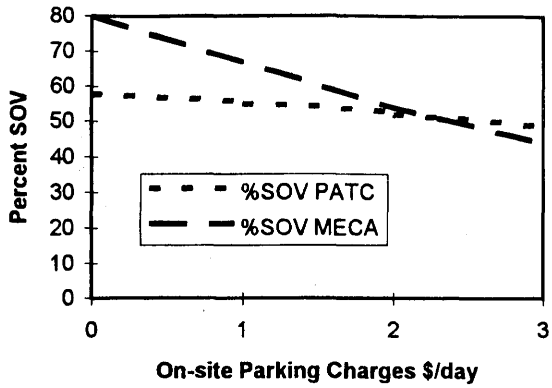

FIGURE 2 Off-site parking effects on performance of on-site parking charges.

the percentage of employees using the SOV mode for their commute. On the other hand, where off-site parking is not a feasible alternative, the imposition of parking charges such as those tested at MECA will have a strong impact on commuting behavior.

Alternative hypothesis 2 is also accepted. The impact of the rideshare subsidy on commuting-mode choice depends on the form of the incentive. The subsidized lunch in MECA's cafeteria has a diminishing marginal utility over the range of cash values used in the study. On the other hand, PATC's dedicated cash payment for transit and qualified vanpools does not diminish in its effectiveness in increasing vanpool use over the range of payments studied. The remaining coefficient comparisons confirm the null hypothesis. Delay time brought about by either form of rideshare has the same disutility with time lost across both sites. Similarly, the marginal utility of a guaranteed ride home program is essentially the same across both sites.

CONCLUSIONS

Two employment sites in northeastern New Jersey provided the setting for an experiment in transportation-demand measurement. The stated-choice approach to the measurement of discrete choice is tested for consistency when applied to different sites. The sites are not identical, nor are the instruments. These differences become the basis for developing a set of alternative hypotheses that will test for structural differences between the two models. The transportation-demand management strategies proposed for implementation at both sites are essentially the same. The differences arise for the most part from the availability of off-site transportation resources to each site's employees. One site (MECA) is in a relatively isolated suburban setting that has little public mass transportation and no off-site parking. The other site (PATC) is an urban facility with access to public mass transportation and off-site parking. The stated-choice models estimated through a standard logit process have essentially the same structure. The coefficients of transportation-control measures presented to each site are for the most part identical. The marginal utilities estimated for a rideshare matching program and a guaranteed ride home program are essentially the same. The rideshare incentive program that was implemented as a subsidized lunch at the MECA cafeteria has a lower marginal utility with respect to the face value of the subsidy than does the direct subsidy payment for transportation services. However, this difference is slight. The major difference between the two models comes from their parking charge coefficients. The site with no off-site parking available to employees is much more sensitive to parking charges than the site with off-site parking on the street.

In the evaluation of any new analytical technique, reliability and consistency are essential properties. With the completion of this study, stated choice has been shown to possess in two paired studies the properties of reliability and transferability. This is an important beginning; however, additional studies by other researchers in different parts of the country are needed to further test the conceptual soundness and empirical stability of stated choice. Clearly an essential step will be to perform validity tests using revealed-preference techniques simultaneously with stated-choice tests.

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Employee and Student Trip Reduction: First-Year Results from Metropolitan Phoenix

ELIZABETH K. BURNS

Initial trip reduction achievement by three commuter groups in the Maricopa County Regional Travel Reduction Program for metropolitan Phoenix, Arizona, is reported. Although students had the most success in changing their behavior, non-school employees, by far the largest commuter group, and school employees also reduced their percentages of single occupant vehicle trips. Total reductions in single occupant vehicle miles traveled were small but measurable. Although economic subsidies as well as less expensive measures were linked with trip reduction at non-school work sites, education measures were linked with trip reduction at school sites. These findings confirm that early progress can be expected from regional employer-based trip reduction programs, indicate the need to consider different commuter groups, and affirm the value of diverse trip reduction measures.

Trip reduction programs are now conducted at a wide range of locations from individual work sites to individual communities and metropolitan regions (*1*). Across the country regional ordinances have been enacted to address both the vehicle emissions portion of the urban air pollution problem and increasing traffic congestion. However, between 1980 and 1990, the national population growth rate was exceeded by drive alone trip growth and by growth in the number of vehicles (*2*). Mandatory trip reduction programs focused on commuting behavior may contribute to slowing these growth trends.

The experience of these programs must be examined to identify whether or not travel behavior can be changed and, if so, how much change occurs. Although researchers have not agreed on a single evaluation research design, every new trip reduction program should be evaluated for its initial efforts and later progress (*3*). Although these new public programs can be expected to take several years to become fully effective, especially the large regional programs (*4*), early results are useful as indicators of future program progress, as comparisons with other programs, and as predictions for newer programs.

This paper describes the first-year program impact of the Maricopa County, Arizona, regional program and examines three key commuter groups at single work sites where employers adopted trip reduction plans with multiple trip reduction measures: students, school employees, and non-school employees. Initial program impact is indicated by comparing commuting travel before the regional program was implemented with travel characteristics 1 year later.

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MARICOPA COUNTY REGIONAL TRAVEL REDUCTION PROGRAM

Vehicle emissions are a major source of regional air pollution in metropolitan Phoenix (urban Maricopa County). The Arizona State Legislature established the Maricopa County Regional Travel Reduction Program (MCRTRP) in 1988 under pressure from the Environmental Protection Agency after a suit by an advocacy group, the Center for Law in the Public Interest. Attainment of a 22.3 percent reduction in regional carbon monoxide emissions by 1991 was to be achieved by four sets of activities: existing programs in the 1987 Carbon Monoxide Plan, a mandatory oxygenated vehicle fuels program, a loaded mode test for the vehicle inspection maintenance program, and this mandatory travel reduction program.

This program's small (1.8 percent) expected contribution to emission reduction understates its role in educating local employers and commuters to the need to reduce drive alone trips.

Employers with 100 or more workers at a site must participate and make a "good faith" effort to achieve trip reduction goals. Specific requirements are (*a*) to survey employees, (*b*) to appoint a transportation coordinator, (*c*) prepare a trip reduction plan, and (*d*) to disseminate alternate mode information (*5*).

Trip reduction goals were set as a 5 percent reduction each year in either the percentage of single-occupant vehicle (SOV) trips or the percentage of SOV miles traveled. This standard was set for the program's first 2 years and later mandated by the legislature for the third year. Employers have surveyed their employees' travel using a single survey instrument designed by the county program; students have been surveyed using a separate survey instrument.

The Maricopa County Trip Reduction Ordinance, effective July 1, 1994, expanded the program to include small employers with 50 or more employees at a single work site. New trip reduction goals were set to reach and maintain a 60 percent rate of SOV trips or miles traveled.

STUDY DATA SETS

This study follows the approach and methods of Giuliano et al. (*6*) in their evaluation of the South Coast Air Quality Management District's Regulation XV in Los Angeles, a more stringent regional trip reduction program also initiated in 1988.

This metropolitan Phoenix study includes the 384 employers in the program on April 31, 1992, that had completed minimum requirements for the first 2 years: a baseline year employee and student survey, an approved trip reduction plan, and the first program year employee and student survey.

Baseline year data describe employee commutes before the trip reduction program went into effect. Additional employers were in the program on this date but, whereas some had completed baseline year requirements, none had completed their first-year plan and surveys. The first-year completion qualifier ensures that the measures in each employer's plan were available and changes in employee travel behavior from the baseline year to the first year were known.

The MCRTRP's approach of phasing large employers into the program before smaller employers biases results in favor of the larger companies. Smaller employers are likely to have entered the program later and not to have completed first-year requirements in spite of possible progress toward reduction goals. A maximum period of 17 months could occur between the baseline and the second year survey because the program's baseline period began in July 1988 and ended in December 1990.

The basic unit of analysis in this study is the work site with no examination of the combined effect of several work sites operated by one employer. Two types of work sites are included in the study: employer (525) and school (53). Travel behavior is reported for 332,980 commuters: 245,421 employees at 525 non-school sites; 13,451 employees at 50 school sites; and 74,108 students at 53 school sites.

Standard industrial classification codes at the four-digit level were available from the MCRTRP files and were summarized at the one-digit level to indicate the economic profile of participating employers. This profile indicates the importance of manufacturing (34.5 percent of non-school sites); services (50.5 percent of non-school sites and 100.0 percent of school sites); and state and local government (13.5 percent of non-school sites).

The 578 sites also vary by size and by type of commuters. Non-school employees are concentrated at small sites with over 40 percent of non-school employees at sites with 100 to 199 employees; over 60 percent at sites with less than 299 employees; and 77.6 percent at sites with less than 500 employees. School employment, however, is concentrated at large sites with only 24.5 percent at sites with below 500 employees. Sites with over 1,000 commuters account for 54.7 percent of all school sites, but only 6.9 percent of non-school sites. The main campus of Arizona State University is the largest single site in the program: 3,825 students and 9,349 employees participated in the baseline year survey (*7*).

Study data differ from the Giuliano et al. study of the initial Los Angles program. Although average vehicle ridership change was mandated for three Los Angeles regions, the metropolitan Phoenix program mandated the same SOV trip reduction measures throughout the region. The Phoenix program had a smaller total number of work sites (578) than the Los Angeles program even when 53 school sites were included. The Los Angeles study developed a 1,100 site sample from 4,032 non-school work sites. The Phoenix program also had fewer large work sites with 500–999 employees (15.6 percent), compared to 22 percent in the Los Angeles study, and fewer sites with over 1,000 employees (6.9 percent) compared to 15 percent in the Los Angeles study.

CHANGE IN DRIVE-ALONE COMMUTING

Total Change

The single most important indicator of the effectiveness of the trip reduction program is the change in drive alone commuting between surveys for each work site. This change is reported by the MCRTRP staff in two ways: change in the percentage of SOV commute trips per week and change in the SOV one-way commute miles per week.

Table 1 compares baseline year and first-year averages for both measures. Employees had similar high levels of drive alone commutes at non-school (81.7 percent) and school (82.8 percent) sites. Their drive-alone commutes were reduced during the study period at similar rates: 3.9 percent for non-school employees and 3.6 percent for school employees. Students not only had a lower baseline SOV travel rate (42.5 percent), but indicated the greatest percentage decline in SOV commutes (13.4 percent).

Change in drive-alone commute miles indicates a different trend. Average SOV miles traveled per week declined for all three groups (Table 2). Although school employees traveled fewer miles (46.3) than employees at other sites (53.5), they reduced their miles traveled by only 0.8 percent compared to a reduction of 1.3 percent for non-school employees. Students had a low initial level of miles traveled (31.2), but were able to reduce their travel by 5.7 percent, a rate higher than either school or non-school employees.

Change by Number of Commuters

Detailed findings indicate trip reduction behavior. Bar charts show the frequency distributions of the average percentage of SOV trips and the average SOV miles during the baseline year and first year for non-school employees, school employees, and students at each work site. On Figures 1 through 6, an overall shift to the right in column heights from the baseline year to the first year shows that trip reduction occurred. Distinctive Arizona State University results are shown and discussed separately.

TABLE 1 SOV Trips

Categories	Mean Baseline SOV %	Mean SOV % after 1 year	Change in SOV %	N
Employees at non-school sites	81.7	78.5	3.9%	525
School employees	82.8	79.8	3.6	50
Students	42.5	36.8	13.4	53

TABLE 2 SOV Miles

Categories	Mean Baseline SOV Miles	Mean SOV miles after 1 year	Change in miles	N
Employees at non-school sites	53.5	52.8	1.3%	525
School employees	46.3	45.9	0.8	50
Students	31.2	29.4	5.7	53

Shifts toward trip reduction are clear for non-school employees. Their travel in the baseline year, grouped by the percentage of SOV trips reported for each non-school employee work site (Figure 1), peaked in the category of 89–85 percent, with a rapid decline in numbers of employees at sites with lower rates. This peak shifted downward to the 79–75 percent category a year later. The number of commuters in all higher percentage categories declined. The number of commuters in all lower percentage categories increased except for the 64–60 percent category, suggesting a minimum trip level that may be difficult to reduce.

The SOV miles per week for sites with non-school employees are shown on Figure 2. The numbers of commuters are distributed symmetrically around a peak in the 59–55-mi range in both years. After 1 year of the program's operation, however, this peak is lower, the number of employees in all lower mile ranges increases, and most higher mile categories show decreases.

School employees similarly shifted their trips, but their percentage of SOV commutes clustered in both years in a single peak category, 89–85 percent (Figure 3). Few sites had an average employee SOV commute below 64–60 percent, reinforcing the previous finding that 60 percent is a minimum level of drive-alone trips that may be difficult to reduce. First year travel, however, declined in the category above 89–85 percent (94–90 percent) and increased in all but one of the lower categories.

The school employees' pattern of SOV miles traveled shows a baseline year peak in the 44–40-mi range that shifted to the lower 39–35-mi range after 1 year (Figure 4). Fewer employees traveled in all but two of the eight categories above 39–35 mi.

These general patterns of school employee travel differ for the main campus of Arizona State University. The percentage of baseline year SOV trips, 71.5 percent, was reduced to 71.2 percent (Figure 3), whereas the average SOV miles (41) increased slightly to 41.57 mi (Figure 4). These results may have been influenced by the fact that fewer employees replied to the survey taken after 1 year of program operation (3,295) than completed the baseline survey (3,825).

All student travel contrasts strongly with employee commuting patterns, whether at school or non-school sites. Two different student groups appear to create these trends. Alternate mode use is likely to be higher for high school students who are primarily dependent on household members for use of a car than for university students, many of whom support themselves. Separating Arizona State University students from all other students clarifies this pattern on Figures 5 and 6.

The student baseline year percentage of SOV commutes had one cluster at a high peak of 79–75 percent and a second, lower peak at 25–30 percent (Figure 5). In the first year, the number of students declined in all percentage categories higher than 79–75 percent and increased overall in the lower than 79–75 percent categories. For

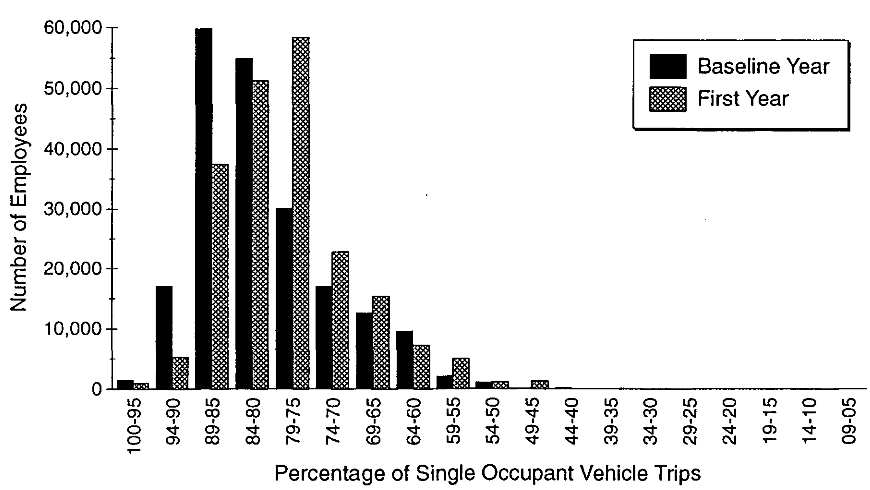

FIGURE 1 SOV trips by employees at non-school sites.

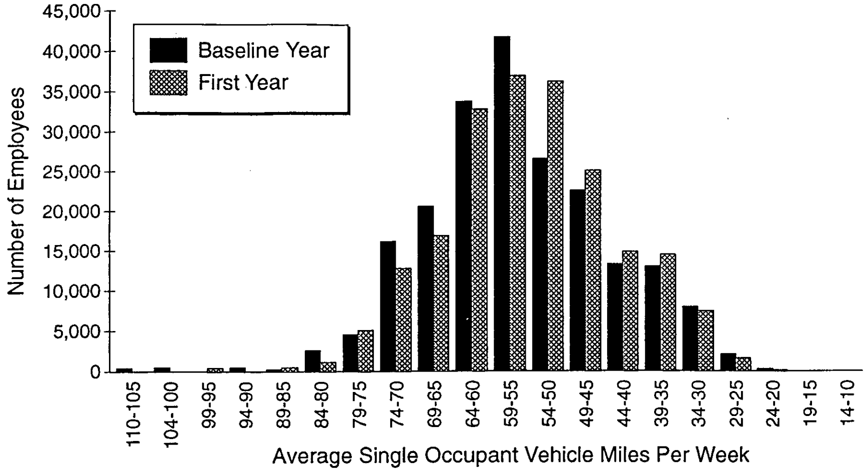

FIGURE 2 SOV miles by employees at non-school sites.

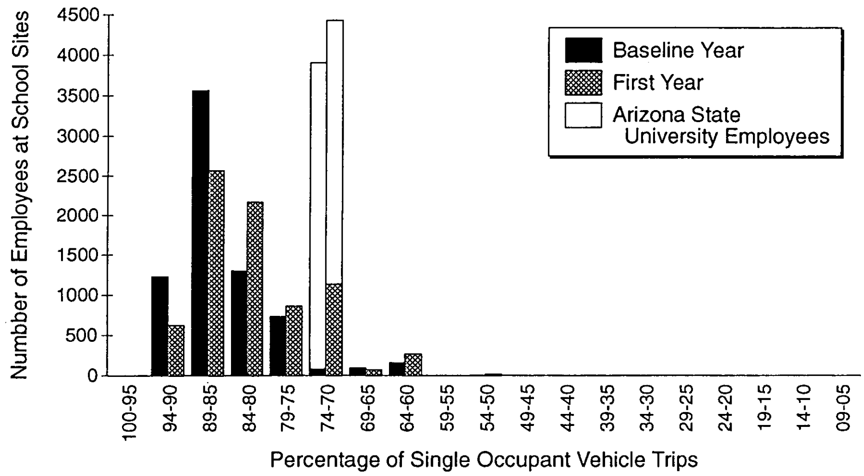

FIGURE 3 SOV trips by employees at school sites.

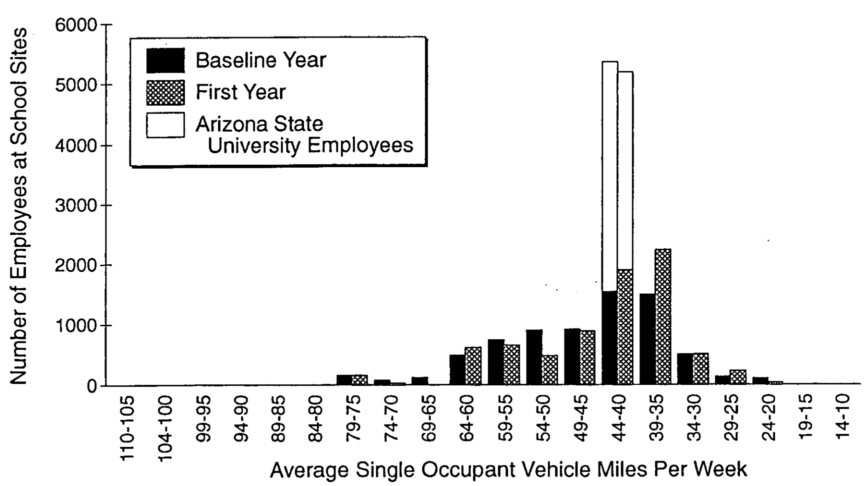

FIGURE 4 SOV miles by employees at school sites.

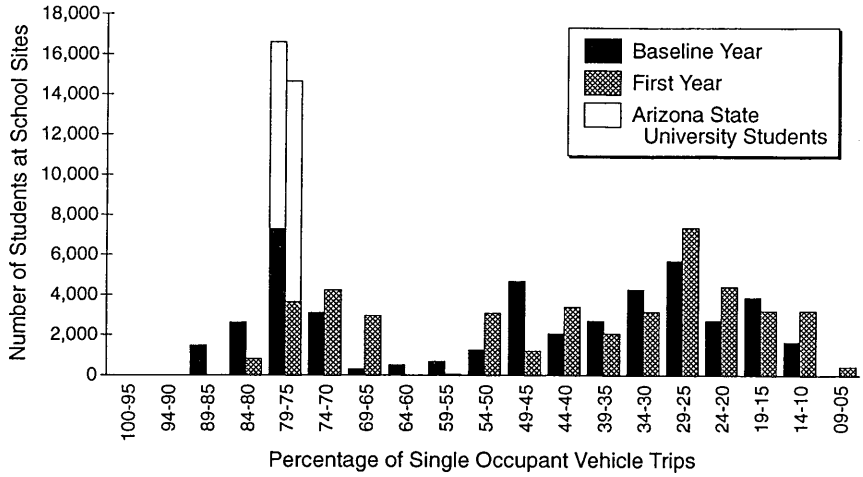

FIGURE 5 SOV trips by students.

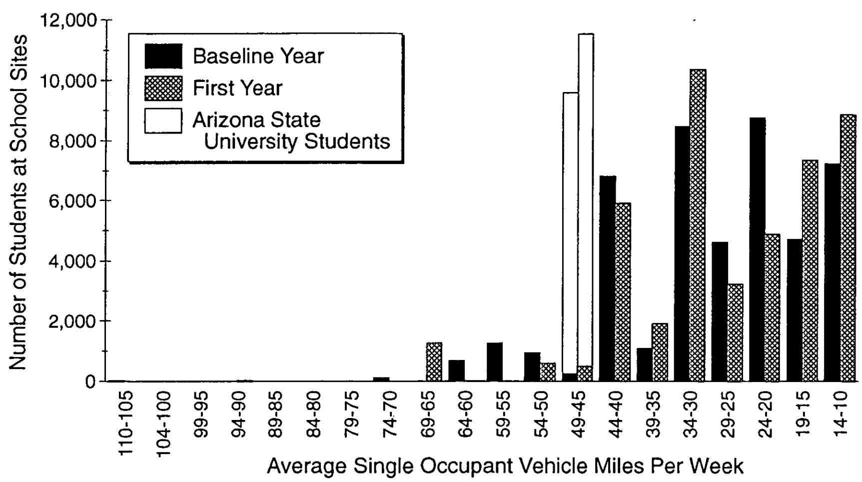

FIGURE 6 SOV miles by students.

SOV miles traveled (Figure 6), student commutes were concentrated in several categories with peaks at 44–40, 34–30, 24–20, and 14–10 mi. A clear peak emerged, however, at 34–30 mi in the first year.

Arizona State University students were two-thirds of all students in the category of 79–75 percent SOV trips. They achieved a 1 percent reduction based on a reported 77.5 percent baseline year percentage and a 76.7 percent first year percentage (Figure 5). These university students increased their SOV mile commutes by 3 percent, however, based on their reported 45-mi baseline year average and 46.4-mi average in the first program year (Figure 6). The varying number of student survey respondents at the Arizona State University main campus may have influenced these results. More students (11,036) completed surveys in the first program year than in the baseline year survey (9,344).

Trip Reduction Achievement

Overall, these findings indicate that (a) fewer employee and student commuters drove alone and (b) a small reduction in miles driven occurred. Aggregate figures show the approximate air quality impact of the first year's program, calculated by using 25 mi as a measure for 1 pound of pollution and multiplying the midpoint value for SOV miles by the number of employees in each category. Non-school employees reduced pollution by 5.8 tons/week, based on a decrease of 290,737 mi from a baseline year total of 11,527,841 mi/week.

Net student and school employee emission amounts indicate the impact of the program's largest employer and site. Arizona State University's atypical findings were, in part, due to large differences in the large numbers of employees and students surveyed. School employees, including Arizona State University employees, decreased pollution by 0.24 ton/week from their baseline year level of 490,846 mi/week. The net student impact including Arizona State University students, however, was an emissions increase equal to 0.58 ton/week from an initial level of 1,705,720 mi/week.

Trip reduction achievement, defined as meeting one or both of the 5 percent trip reduction goals during the first program year, occurred at different levels for these employee and student groups. Non-school employees met the trip reduction goal on 39 percent of

their sites; school employees met the goal on 50 percent of their school sites; and students met the goal on 71 percent of the school sites (Arizona State University is considered as one site).

These differences are important considerations when trip reduction plans must be developed for distinct groups who commute to a single work site. Chi-square analyses confirmed that non-school employees, school employees, and students were distinct populations. Employee groups differed significantly when compared for progress or lack of progress toward trip reduction and when compared for achievement or lack of achievement of trip reduction goals. School employees and students were similarly compared and were separate populations.

USE OF INCENTIVES

Frequency of Measures by Mode

Each employer's plan is a mix of incentives to encourage ride sharing or other alternate modes and discourage use of drive alone commutes. The set of incentives for each site was identified for all 578 sites from each original plan document.

The quality of the incentive data is limited. Employers with multiple work sites routinely applied a single plan to all sites. Although 51 incentives are identified, plan descriptions are brief. There is no information on when an incentive is phased in during a year, so an incentive's impact could be limited by when it is initiated. Without direct monitoring of companies, a suggested measure may not be actually in place.

Initial trip reduction plans had an emphasis on education measures (publications/newsletters, new hire orientation) and carpool incentives (preferred parking spaces, guaranteed ride home, prizes). Incentives are grouped in the program's classification system by modes (Table 3).

Over half the non-school plans contained the following measures: preferred parking spaces for carpools (77.9 percent), guaranteed ride home for carpools (69.5 percent), publications and newsletters about the trip reduction program (68.6 percent), prize drawings for carpools (67.0 percent), new hire orientation (58.7 percent), Zip code matching for carpools (57.7 percent), and bike racks for bicycle riders (61.3 percent).

School sites had more uniform plans that focused on a few of the same measures most included in the non-school plans. The most common measures were: preferred parking spaces for carpools (84.9 percent), publications/newsletters about the trip reduction program (73.6 percent), bicycle racks for bicycle riders (67.9 percent), new hire orientation (64.2 percent). A guaranteed ride home for carpools, which can be expected to serve adult employees more than students, was included in only 17.0 percent of the school plans. Similarly, few school plans include ZIP code matching (3.8 percent) for carpools. Prize drawings for carpools were included in 45.3 percent of the school site plans.

Measures that shift or eliminate trips are not a large component of the initial plans. Flexible work hours (22.1 percent), compressed work week (15.6 percent), telecommuting/work at home (11.2 percent) were included in non-school plans. Interestingly, 26.4 percent of the school sites included the option of a compressed work week. This option could be easier to implement at elementary and high school sites than at employer sites where employees have diverse schedules and activities. Only 15.6 percent of the employer sites had a similar option. A shuttle between work sites, a measure that can shorten the SOV portion of a commute or eliminate SOV trips during the work day, was adopted for employee work sites (10.3 percent), but seldom mentioned in school plans (1.9 percent) where fewer sites require daily connection.

Parking fees, coupled with alternate mode incentives, are widely discussed nationally as an economic disincentive to drive alone commutes. Most Arizona employers provide free parking, however. Only 1.9 percent of the ten non-school plans and one school plan proposed a parking fee increase. Arizona State University, where parking fees are charged for students and employees, recommended a parking fee increase that was not adopted.

Baseline Year Values and Number of Measures

Using a large number of measures is one reasonable strategy for an employer's first trip reduction plan. In such a plan each employee has more chances to respond to at least one incentive. In addition, employers with high baseline year levels of drive alone commuting may respond by offering a large number of plan measures in an effort to increase their chances of influencing more employees. There is little difference, however, in the average number of measures for non-school (13) and school plans (11).

Statistical correlations of the data indicate there is no statistically significant relationship for non-school sites between the level of baseline year SOV percent trips and SOV miles, the number of plan measures, and SOV percent trips and SOV miles reduced. For school sites, student trip reduction indicated no association between each measure of trip reduction and either the number of school plan measures or baseline year values and no relationship with SOV miles reduced for school employees. There is a low positive correlation ($r = +0.26$), however, between the percent of SOV trips reduced and the number of plan measures.

Individual Measures

Aggregate analyses of trip reduction plans offer little insight into initial trip reduction progress in metropolitan Phoenix as each plan is a set of separate measures designed to respond to the specific concerns of employees or students. However, individual measures can be linked to changed commuter behavior.

The 51 measures were separately examined to determine whether a measure's presence in the employer plan was associated with a statistically significant decrease in the percentage of SOV trips or SOV miles. Significant relationships are reported for non-school and school plans (Table 3) from one-way analysis of means tests. This test compared the average change between the group of employer plans offering the incentive and the group of employer plans not offering the incentive. Similar tests compared each measure offered at sites where the regional program's goal of a 5 percent or greater reduction was and was not achieved.

Reduction in SOV trip percentage at non-school sites was associated with measures for four modes: carpool, vanpool, bus, and walking. Two vanpool measures—prizes and guaranteed ride home—plus a carpool measure, the local "Don't Drive One-in-Five" campaign have the strongest individual statistical association. Vanpool prizes and guaranteed ride home were associated with sites that achieved the 5 percent reduction goal.

For reduction in SOV miles, measures for carpool, vanpool, and bicycle modes are significant. Two vanpool measures—prizes and

TABLE 3 Frequency of Measures by Mode

MEASURES	Non-School Sites (N = 525) Number	Percent	School Sites (N = 53) Number	Percent
Carpooling-related Incentives				
preferred parking spaces	409	77.9%	45	84.9%
guaranteed ride home	365 b	69.5	26	49.1
prize drawings	352 c	67.0	24	45.3
zip-code matching	303	57.7	26	49.1
subsidize carpool drivers	89	17.0	6	11.3
"Don't Drive One-in-Five"	23 b	4.4	6	11.3
free/discount parking for carpoolers	21	4.0	2	3.8
Vanpooling-related Incentives				
preferred parking spaces	190 c	36.2	19	35.8
guaranteed ride home	161 bc	30.7	9	17.0
prize drawings	121 bd	23.0	6	11.3
zip-code matching	73 d	13.9	2	3.8
subsidize vanpool drivers	42 c	8.0	0	0.0
Bus-riding Incentives				
bus-route/schedule books supplied on site	255	48.6	11 ac	20.8
guaranteed ride home	236 b	45.0	16	30.2
subsidize bus tickets/passes	229	43.6	20	37.7
prize drawings	208 a	39.6	9	17.0
work with local transits to extend service	152	29.0	7	13.2
bus ticket/pass on site	131	25.0	13	24.5
flexible work hours for riders	79	15.0	9	17.0
Bicycle-riding Incentives				
bike racks	322	61.3	36	67.9
prize drawings	195	37.1	10	18.9
guaranteed ride home	195	37.1	9	17.0
showers and/or lockers	118	22.5	23	43.4
bike-lane maps supplied	99	18.9	17	32.1
bike safety workshops/printed materials	78	14.9	6	11.3
"Bike-to-Work Day"	83 c	15.8	0	0.0
subsidize bike buyers	57 c	10.9	15	28.3
"Bike One-out-of-Five"	0	0.0	0	0.0
Walk-related Incentives				
prize drawings	74 a	14.1	5	9.4
guaranteed ride home	12	2.3	0	0.0
"Walk-to-Lunch" program	1	0.2	0	0.0
Education and Communication on TRP				
cafeteria/breakroom information center	382	72.8	44	83.0
publication/newsletters on TRP	360	68.6	39	73.6
new hire orientation	308	58.7	34	64.2
Clean Air Campaign	158	30.1	8 ac	15.1
TRP information through pay stuffers	137	26.1	1	1.9
recognition in newsletters	109	20.8	10	18.9
Transportation Fair	104	19.8	7	13.2
TRP coordinator(s)	79	15.0	11	20.8
TRP committee	59	11.2	14	26.4
other kinds of TRP fairs	50 d	9.5	1	1.9
Others				
flexible work hours	116	22.1	9	17.0
compressed work week	82	15.6	14	26.4
telecommuting/work at home	59	11.2	1	1.9
shuttle service between work sites	54	10.3	1	1.9
award	41	7.8	3	5.7
on-site services	26	5.0	1	1.9
capital improvements	12	2.3	8	15.1
increased parking fees	10	1.9	1	1.9
subsidize apartment close to work	8	1.5	1	1.9
miscellaneous	3	0.6	0	0.0

a: Presence of incentive significantly related to decline in SOV percent, at $p < .05$
b: Presence of incentive significantly related to decline in SOV percent, at $p < .01$
c: Presence of incentive significantly related to decline in SOV miles, at $p < .05$
d: Presence of incentive significantly related to decline in SOV miles, at $p < .01$

ZIP code matching—and an education category of specific trip reduction events other than an employer's general fair have the strongest statistical association. Vanpool preferred parking and a guaranteed ride home for vanpool and bicycle commuters were associated with work sites that achieved a 5 percent reduction as was the shuttle service between work sites.

School sites, where the trip reduction plans serve both employees and students, present a less complex pattern. Two education measures are strongly linked to reduction in SOV trips and miles—the availability of bus books on site and the local "Clean Air Campaign." School sites are effective settings for these measures; students reduced their SOV trips more than either school or non-school employees. Both measures were linked to achievement of a 5 percent reduction in SOV percent, whereas a guaranteed ride home and bicycle racks were linked to achieving a 5 percent reduction in SOV miles traveled.

The number and set of measures associated with progress in trip reduction varies by mode. The strong association of vanpool measures with a reduction in the percentage of SOV trips and SOV miles supports multiple efforts to serve this group of commuters who often travel long distances. Both direct economic rewards, in the form of prizes and subsidies, and assistance, as trip reduction events, ZIP code matching, and guaranteed rides home, matter to vanpool users. Carpool users are influenced by direct incentives—prizes—but also by assistance, a guaranteed ride home option, and education campaigns. Bus riders were similarly influenced by prizes and a guaranteed ride home. The combination of economic subsidy and education measures influenced bicycle riders, whereas walkers responded only to prizes.

Interestingly, individual measures with potentially high direct employer costs were identified only for two vanpool measures, subsidy and preferred parking spaces, and the "subsidize bicycle buyers" measure. Tests were conducted for the measures of prizes, subsidies, and guaranteed ride home combined for all modes. When these measures are considered across modes, the two economic incentives are strongly associated with reduced SOV miles traveled, whereas the guaranteed ride home is linked to a reduction in SOV trips.

It is important that at least two of these measures, prizes and guaranteed ride home, need not be extremely expensive for employers. Prize drawings may be effective because they maintain awareness of the trip reduction program, offer an immediate reward, and provide an incentive for continued participation. The frequency of prize drawings, employee eligibility requirements, and prize dollar values are not known, however, during this initial program year.

Assistance with emergencies outside the work site is essential for carpool, vanpool, and bus users, who, unlike bicycle and walking commuters, can find themselves stranded at work. These infrequent emergencies can be handled in a number of ways: loan of a company car, release time for a co-worker to drive an employee home, or payment of a taxi ride. In this trip reduction program and its Tucson, Arizona, counterpart, working women, especially mothers with young children, were more likely to drive to work alone than men (*8*). Their domestic and family responsibilities must be addressed so that women can participate in trip reduction efforts (*9–11*).

CONCLUSIONS

The key finding of this study is the positive direction of trip reduction that occurred at metropolitan Phoenix work sites in the initial program year. Although non-school employees, by far the largest commuter group, and school employees had some success in reducing their percentage of SOV trips, students, the commuters with the lowest levels of drive alone use, were most successful in changing their behavior. Adult workers, even those with regular schedules provided by school employment, were least likely to change their commute trip behavior.

This study found a non-school employee pattern of initial progress toward meeting trip reduction achievement goals similar to that identified for metropolitan Los Angeles (*7*). Progress was greatest in Los Angeles for work sites with low baseline year average vehicle ridership where trip reduction measures apparently made a strong impact. The Los Angeles study, however, found positive relationships between trip reduction and the number of plan measures and between the number of measures offered and high levels of baseline year drive-alone commutes. Neither relationship was supported for metropolitan Phoenix in this program analysis.

The Phoenix results indicate limited positive findings for regional air quality improvement. Reductions in the number of SOV miles traveled per week were greatest for students and, again, smallest for school and non-school employees. The small reduction by large numbers of non-school employees with longer commutes than school employees and students produces the largest aggregate contribution to improved air quality.

Economic incentives were linked to trip reduction in metropolitan Phoenix, especially for carpool and vanpool users reducing the number of SOV miles traveled. Inexpensive measures such as participant prizes and a guaranteed ride home were also statistically significant. The Los Angeles study similarly found that these measures as well as financial incentives for specific mode users, other employee benefits, and time off with pay were significantly related to trip reduction.

Economic incentives alone, however, will not address the full range of family and household responsibilities that provide the context for individual commute mode decisions. For any given employer, the number of commuters who can easily shift modes can be expected to decline after the early program years. Retaining early program participants and expanding participation remain critical employer issues. Multiple measures that address the concerns of commuters who have no alternative to driving alone, disproportionately women, should be increasingly important in employer trip reduction efforts.

After 1 year the initial trip reduction program experience of metropolitan Phoenix indicates the promising result that employee and student commuters, at least initially, do respond to trip reduction measures. These findings also suggest that trip reduction measures have a limited, but measurable impact on regional air quality improvement. Together with other studies of trip reduction program efforts, this study contributes knowledge about larger issues of how travel demand can be managed both at the scale of individual employers and for metropolitan regions.

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Role of Site Amenities as Transportation Demand Management Measures

DIANE DAVIDSON

Employee use of corporate services related to trip-making and the reduction of vehicle miles of travel (VMT) were observed. An activity diary was distributed at two major suburban worksites during the summer of 1993. The participants provided 5-day records of the activities they performed on the work site and related the impact of their site activity to their trip-making behavior. The total sample traveled 24 408 km (15,255 mi) during their respective survey weeks but recorded a total reduction of 1 008 km (630 mi) and elimination of 4 020 km (2,513 mi) for a total of 5 014 avoided km (3,134 mi) as a result of on-site amenity use. Had the amenities not been available, the total VMT would have been 20 percent higher. The study concludes that microlevel land use changes, in the form of amenities, offer transportation planners an effective transportation management tool. Amenity enrichment can contribute significant reductions in VMT, air pollution, and energy consumption that are not predicated on changing travel mode choice. The results add to the understanding of suburban travel behavior and provide insight regarding the mix of on-site services that will be required to reduce employee dependence on a private vehicle during the work day.

This study examined the impact of corporate amenities on transportation demand management. Amenity use at two corporate work sites was evaluated for its impact on the reduction of vehicle miles traveled (VMT), ability to rideshare, employee productivity, and employee job satisfaction. The data presented in this paper are part of a larger study for FTA on trip chaining and on-site amenities.

TRIP CHAINING

Before a description of the study findings, the relationship of trip chaining and corporate amenities is briefly discussed to put the study into context. The complex relationship between land use and employee travel behavior creates obstacles for successfully changing employee commuting behavior. Commuters drive alone to work because access to a vehicle before, during, and after work is necessary to perform basic activities. When workers are dependent on their cars to fulfill their basic need for everyday services, they can be expected to be reluctant to make commuting arrangements that limit their freedom of mobility. Trip chaining occurs during the process of filling the need for services. It is the act of linking one or more trips onto the morning or evening commute trip.

Trip Chain Trends

Trip chaining data collected as part of larger studies of employee commuting habits in Brentwood, Tennessee; Orlando, Florida; and Overland Park, Kansas, were compared for trends and relationships. Travel pattern data from these communities revealed that employees relied heavily on their vehicles to gain access to everyday services. The data defined a full work trip as including stops for meals, shopping, and daycare. To commuters with these essential needs, the idea of ridesharing and giving up one's vehicle will appear irrational. The studies showed that employees were twice as likely to make stops on their way home from work as on the way to work with stops for purposes such as going to the bank and the dry cleaners and to eat and to shop.

The review revealed a great consistency between suburban data sets as well as urban and suburban data sets so that certain trip chaining characteristics, such as gender and occupation, appear to be homogeneous across geographical locations. For instance, clerical workers in suburban Brentwood, Tennessee, and urban Orlando, Florida, were more likely that any other occupational group to stop for general shopping and did so at identical frequencies (32 percent).

Working women made more frequent stops than men in both the morning and evening periods for a variety of purposes. Women were significantly more involved with child-related transportation than their male co-workers. They made more frequent stops than men in both the morning and evening periods for every purpose, with the exception of entertainment. Significantly, the data showed women to be more likely than men to trip chain, regardless of their income or occupational group. This implies that ridesharing may be more difficult to implement for working women, particularly for those with young children. The overall significance of trip chaining is the strong and rational deterrent that it poses to rideshare and transit arrangements.

Corporate Amenities

There are two methods for addressing the trip chain problem. One is to deliver services to the site, and the other is to enrich the site or adjacent land use with a mixture of amenities, services, and facilities. Corporately provided amenities are one way to substitute land use for transportation. On-site amenities are defined as support services, facilities, or incentives that employers make available to employees either immediately at the work site or within walking distance to the site. They encompass a broad range of options including cafeterias, day care, sport facilities, banking, and dry cleaning, etc. Although site services have the potential to balance the inconvenience of ridesharing/transit by making it more competitive with driving alone, transportation planners need a better understanding of their effectiveness in reducing single occupant trips to have confidence in them as transportation measures.

To a developer, amenities are the features that "go beyond" building basics and design. They are the aspects that respond to the marketing of comfort, aesthetics, and convenience. Comfort is provided

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through zoned heating, temperature control, lighting, and furnishings. Aesthetics are cosmetic enhancements like artwork, atriums, landscaping, expensive exterior treatments, unique design, and other features. Convenience relates to the proximity of shops, restaurants, and services within the building. Fitness facilities, child care, and shuttle services are usually listed as "other" amenities. A fourth group of amenities is rapidly developing that are "technologically" oriented, such as electronic message centers, advanced telecommunications, video conferencing, and smart buildings.

STUDY METHODOLOGY

The on-site amenity study consisted of site interviews with senior management knowledgeable about the employees and the on-site services, distribution of an activity diary to collect employee data, and, data analysis.

Activity Diary

Attitudinal data regarding the relationship of amenities to workplace factors and actual activity were collected using an activity-based diary. Researchers developed a diary booklet that would collect activities for a 1-week period in a conveniently sized (5- by 7-in.) format. The diary booklet provided spaces for the recording of on-site activities for a 5-day period. A 2-page section was provided for each day of the week. Respondents were asked to identify all of their daily on-site activities, the mode of travel that would have been used to access each service had it not been available on-site, and their estimated miles of travel to perform each activity off-site. In addition, the booklet contained socioeconomic questions, which were to be completed only once, and a cover page, which presented easy-to-follow instructions.

Two difficulties can arise out of using the diary method. One is that diary keepers may complete an unequal number of diary days for the analysis. For example, some respondents completed the full 5 diary days, but others completed only 3 or 4 days, yet standard regression applications assume an equal number of "trials." Also the response rate was low, although researchers attempted to increase the participation rate by holding drawings, and top management encouraged participation. Fifty completed diaries were returned by Comdata Corporation employees in July 1993 for a 5 percent return rate. Service Merchandise Company (SMC) employees returned 127 diaries for a 15 percent response rate in August, 1993. On the other hand, the combined sets of employee diaries represented 885 work days. Employees at both these companies are asked to participate in many surveys, and the length of the survey time period may have discouraged participation. Future researchers may want to limit the study to a 1-day period, randomly selecting which day of the week each participant is to complete.

Management Interviews

The influence of a corporate culture on the organizational behavior of the workforce can be assessed through focus groups, interviews with selected informants, a review of corporate literature, and corporate language. The purpose of the management interview was to identify the type of amenities located on the site and to get an understanding of the corporate philosophy concerning their installation of the amenities and the role that amenities played on the life of the business. In addition to the corporate interview, company publications such as newsletters, annual reports, and advertising were also reviewed to identify the corporate culture. Senior management who had been involved in the selection of the various amenities during the relocation or expansion phase were interviewed. During the interviews, the values, corporate objectives, strategies, type of workforce, and the reasons for incorporating various facilities or amenities were explored. The descriptions of the study sites incorporate the results of the management interviews.

Comdata Corporation

Comdata is a 20-year-old company with headquarters in the city of Brentwood in northern Williamson County. It is a leading supplier of funds transfer, cash advances, permits, and telecommunications services to the transportation, leisure, and retail industries. A primary program is the provision of transactions for fuel, phone, and cash services for an estimated 7,000 trucking companies. The multisite company constructed an 11 970-m^2 (133,000-ft^2) headquarters building on 9 acres in 1989 on land zoned for office uses. Adjacent land uses include other corporate offices and a Kindercare child care center. Comdata operates 24 hr a day with three shifts. Amenities have been installed to create a comfortable site for all workers. Flexible work hours are available for Voice Center employees, and telework policies are being implemented. The city of Brentwood allowed Comdata to install 156 parking spaces over the code in return for commitments to implement transportation demand management (TDM) programs. Management perceives the site amenities to be part of their commitment to promote TDM. Comdata is also an active TMA member through which ridematching assistance and guaranteed ride home services are provided. Amenities available on the premises include a 150-seat, full service cafeteria, which is open from 7:00 a.m. to 3:30 p.m.; a break room with microwave, icemaker, and vending machine; an automated teller machine (ATM); a fitness center open 24 hr a day; direct payroll deposit; college-level classes; a company store with logo merchandise; and dry cleaning pick-up.

Service Merchandise Company

SMC is a multisite corporation with 400 showrooms across the country. The national headquarters is located on 32 acres on the northwest quadrant of a major Interstate interchange. SMC consolidated offices from three buildings in Nashville to the Brentwood office building in 1989 by conducting a major renovation to add 21 600 m^2 (240,000 ft^2) of gross floor area to the existing 9 180-m^2 (102,000-ft^2) building while increasing the number of employees from 600 to 1,400. The company operates on a 24-hr basis with 1,200 people on an 8 a.m. to 5 p.m. schedule. As part of SMC's application to expand, the Brentwood Planning Commission required SMC to appoint an employee transportation coordinator, promote ridesharing, and report annually on progress by conducting vehicle occupancy counts. By 1994, SMC had assigned over 75 priority parking spaces for carpools and registered 250 employees in the TMA's guaranteed ride home program. The annual reports show an overall 14 percent decrease in single occupant vehicles from 94 percent in 1991 to 80 percent in 1993.

The following amenities are found at SMC: a full service cafeteria, break room with vending machines, company store that offers company logo items, automated order center for SMC catalogue

items, ATM, direct deposit, travel agency for personal use, newsstand, dry cleaning pick-up stall, post office area, and a first aid clinic.

AMENITIES FINDINGS

On-site amenity use and travel behavior revealed in the diaries are described following brief demographic profile of respondents.

Demographic Profile

Employee profiles at the two firms were homogeneous. About three-fourths of the total respondents were women; 58 percent were married; almost one-fourth of the households had preschool or elementary age children; two vehicles were available per household; and, the mean educational level was "some college." Respondents were most likely to be clerical workers (37 percent) or managers (21 percent). The majority of the respondents had 1 hr for lunch (57 percent). Men were likely to have 1-hr lunch periods (83 percent) than were women (48 percent). Managers were twice as likely (89 percent) to take an hour than were non-managers (44 percent). More than half of the total respondents drove alone to work every day of the week, whereas 80 percent used an HOV mode 1 day a week, 11 percent were HOV users 2 days a week, 5 percent rode a carpool or vanpool 3 days a week; 2 percent pooled 4 days a week; and 8 percent never drove alone.

User Attitudes Toward Amenities

On-site amenities perceived to be important to the general ability to ridesharing by the employees were direct deposit, child care, and the cafeteria. Car repair, stamps, and midday shuttles were moderate in importance, and educational classes, dry cleaning, and grocery pick-up were ranked low. Although the aggregate results identified educational classes as being among the least important amenities to ridesharing, two-thirds of the Comdata employees, who were heavy ridesharers and who had access to classes, cited it as being important.

Importance of On-Site Amenities to Productivity

The amenities that employees perceive as most contributing to productivity were direct deposit and a cafeteria. On-site child care ranked third compared with near-site child care ranking in eighth place. Fitness facilities consistently ranked high as contributing to productivity. The amenities least likely to be perceived to contribute to productivity were the company store, grocery delivery, and shuttle services.

The availability of a cafeteria was perceived as boosting a productivity factor of all commuters, regardless of their pool status, although it appeared to be of greatest importance to non-poolers and heavy poolers. Women were more likely to perceive a cafeteria as being very important to their productivity (47 percent) than men (37 percent).

Perceived Importance of Amenities to Satisfaction

Employees indicated the importance of amenities on their job satisfaction. Direct deposit was very important to more than three-fourths of the sample. A cafeteria was very important to 61 percent of all respondents. Child care facilities were perceived as being very important to work satisfaction by 41 percent of the total respondents. This compares with only 23 percent of the total respondents who perceived a closely sited child-care facility as being very important to job satisfaction, indicating that on-site access is a salient factor. Having access to an ATM and a fitness center and the opportunity to purchase of stamps were very important to about half of the respondents. Table 1 shows that direct deposit, a cafeteria, and fitness facilities were perceived as the amenities most important to worker satisfaction. Stamp purchase, an ATM, and car repair also influence employee satisfaction. The amenities that were perceived as contributing least to satisfaction were the company store, grocery delivery and a shuttle.

Predictors of Attitudes Toward Amenities

In examining the existence of significant predictors of the importance of the amenities, multiple regression analysis revealed no clear trends with one exception: the number of children in the household was a marginal predictor of attitude toward childcare. Also not surprising, lower educational level proved to be a significant, but weak predictor of the perceived importance of on-site education. Both educational attainment and occupation were related to the importance of a cafeteria, with those in higher categories (college, post grad/managers, execs) regarding the cafeteria as a bit less important. Number of children was weakly related to the importance of a company store and direct deposit.

Relationship Among Factors

Overall, employees perceived the importance of amenities to worker satisfaction as being somewhat greater than their impor-

TABLE 1 Most Important Amenities

PRODUCTIVITY	SATISFACTION	RIDESHARE
1st Direct Deposit	Direct Deposit	Direct Deposit
2nd Cafeteria	Child Care	Cafeteria
3rd ChildCare	Cafeteria	Fitness
4th Fitness	Classes	ATM
5th Car Repair	Stamps	Stamps

tance to productivity. The perceived importance of amenities to worker satisfaction was far greater than any perceived relationship to ridesharing. A perceived relationship between amenities and job satisfaction emerged at both firms. The importance of financial services provided on-site was particularly evident with 80 percent of the total respondents rating direct deposit as important to job satisfaction and 54 percent likewise rating access to an ATM. While the relative degree of percentages differed, there was agreement in the rank order of the perceived importance of the various amenities. Direct deposit was the highest ranked amenity in all categories, followed by the cafeteria. Table 1 presents the importance of amenities to productivity, ability to rideshare, and satisfaction.

Relationship of Amenities to Vehicle Need

Respondents were asked to agree or disagree with a series of statements about the impact of having access to a variety of amenities on needing to have a car available at work. The questions elicited the workers' perception of the impact of services on behavior. The workers strongly agreed that an ATM, a cafeteria, and a stamp machine make it less necessary to have a personal car at work. There was strong agreement that the on-site amenities make it less necessary to have access to a car during the day. Overall, the ATM, cafeteria, and stamp machine were the top three amenities that respondents strongly agreed would lessen dependence on a car. For all amenities, non-poolers were less likely to agree that amenity availability would reduce the necessity for a car. Heavy poolers were in strongest agreement that a gym (60 percent), stamps (50 percent), and ATM (33 percent) make a car unnecessary.

On-Site Amenity Use

For the total respondents, direct deposit, company cafeterias and ATMs were the most frequently used amenities, followed by college classes and near-site childcare. Non-poolers were slightly more likely than poolers, particularly light poolers, to use on-site services. Non-poolers had a total weekly mean use of five, compared with four uses for heavy poolers and three for light poolers.

Relationship of Amenities to VMT

Two mutually exclusive categories resulted from employee use of amenities on the site in that vehicle miles of travel were reduced and eliminated. Respondents were first asked if they used a particular amenity and if they asked yes, were asked how they would have performed that activity if it had not been present and available on the site. If they would have used a single occupant vehicle to perform the activity, then they were asked to estimate the number of miles that the availability on site reduced or eliminated. None of the answers were doublecounted in the analysis.

Total Miles Reduced

The total respondents reduced 1 008 km (630 mi) of travel for an overall weekly VMT reduction of 5.12 km (3.2 mi). Comdata employees reduced 2 096 km (131 mi) and SMC workers reduced 798.4 km (499 mi). Men were more likely to reduce VMT than women. Comdata men had a mean weekly reduction of 5.92 km (3.7 mi) compared to 3.68 km (2.3 mi) for women, although the sum reductions for women (87) were twice those of the men (44). SMC men had a mean of 5.34 compared to that of women with 5.44 km (3.4 mi).

Managers tended to reduce VMT as a result of amenity use to a greater degree than non-managers. Comdata mangers reduced twice as many mean miles (3.4), as non-managers (1.2).

Heavy poolers at Comdata were much more likely to have a higher mean of miles reduced (6.7) than light poolers (0) or non-poolers (2.3). SMC non-poolers (4.5) had a much higher mean than heavy poolers (1.6), quite the reverse of the case at Comdata.

Total Miles Eliminated

More importantly, the total survey participants eliminated or totally avoided a sum total of 4 044.8 km (2,528 mi) of travel. The total mean miles eliminated by all survey participants was 14.3. Table 2 presents the data by company and amenity. The significance of the data is that vehicle mile eliminations were much higher at both Comdata (1,124) and Service Merchandise (1,404) than were the mere reduction of vehicle miles off an existing trip. Non-work trips were eliminated as a result of the on-site services.

The mean weekly miles eliminated per Comdata employee was about double (23) that of Service Merchandise employees (11). Comdata men eliminated over 50 percent more miles than women co-workers [mean of 49.6 km (31 mi) compared to 32 km (20 mi)]. The amenity utilization at SMC of men was similar (10.8) to that of the women (11.2), although women had three times the total VMT as men [587 km (367 mi) 1 659 km (1,037 mi)/587 km (367 mi)]. Managers had a 50 percent high mean elimination compared with non-managers.

VMT eliminations by commute status at Comdata showed non-poolers having the lowest mean elimination of VMT (18), followed by light poolers (29 VMT) and heavy poolers with the highest weekly mean VMT elimination of 73.6 km (46 mi). SMC heavy poolers experience the lowest VMT avoidance due to amenities (10.5), followed by non-poolers (10.9) and light poolers (13.4).

The primary amenity eliminators of VMT at Comdata were the cafeteria, education, the fitness facility, and the ATM. The Service Merchandise cafeteria was a top mile and trip eliminator with a total of 1 064 km (665 mi) or about 27 trips avoided per day. Other amenities at Service Merchandise responsible for avoided VMTs were the ATM (210), direct deposit (166), stamp machine (107), dry cleaning pick-up (93), and travel agency (82). The least influential amenities were the clinic, college classes, childcare, track, and company store.

Amenities proved to be a substitute for trip-making. They allowed non-poolers to contribute to trip reduction by removing weekly miles that non-poolers would have traveled as part of the home-based work trip, mid-day trip or a later home-based non-work trip. The most influential amenity on trip elimination at both work sites was the cafeteria.

ENVIRONMENTAL IMPACTS OF AMENITIES

The greenhouse gas (global warming) impacts of employee amenity use and resultant VMT were calculated. Data for vehicle speed,

TABLE 2 Total Miles Eliminated by Amenity and Company

	COMDATA	SMC	TOTAL
Cafeteria	350	665	1,015
Fitness	161	4	165
Company Store	0	2	2
ATM	85	208	293
Direct Deposit	51	135	186
College	248	41	289
Childcare	27	10	37
Nurse	na	30	30
Travel Agency	na	82	82
Stamp	na	107	107
Cleaners	na	93	93
Other	205	27	232
	1,124	1,404	528

average daily traffic vehicle occupancy, VMT, and link grade were collected as inputs for the MOBILE5 air emissions model. MOBILE5 is an air quality model developed by the Environmental Protection Agency (EPA). University of Tennessee researchers performed modeling work under contract to the TMA Group as part of a study of greenhouse gas impacts of Transportation Demand Management for the Tennessee Department of Economic and Community Development Energy Division. Masses of greenhouse gases per day were calculated for carbon dioxide, carbon monoxide, non-methane hydrocarbons, and methane (MHC) for each of the 30 links in the study area. Average values were developed by dividing the total pounds of emissions per day per gas by the total vehicle miles of the links. These average pollutant values were then applied to the miles reduced and eliminated by the various amenities with the following results:

- The analysis showed positive environmental impacts of site level amenities from both the reduction and the elimination of VMT. Employee use of on-site amenities at both sites for one week, where a trip was shortened as a result of the amenity use, resulted in a reduction of [101 kg (225 lb)] of greenhouse gases. The cafeteria was responsible for the largest reduction of carbon monoxide pollutants [31.5 kg (70 lb)] followed by the ATM [18.45 kg (41 lb)] and stamps [17.55 kg (39 lb)].
- Employee use of amenities resulted in the elimination of vehicle miles of travel and the removal of a total of almost 411.3 kg (914 lb) of weekly air pollutants from the air. The full service cafeterias, ATM and college classes resulted in the most significant air pollutant savings. Table 3 presents the total weekly pounds of pollutants saved due to the utilization of the various corporate amenities present at the two work sites.

SUMMARY

The data revealed that certain demographic groups, such as working women with young children, are more vulnerable than others, such as male executives, to the trip chaining phenomenon. Therefore, trip chain responsibilities fall hardest on the market segment who otherwise are most likely to rideshare or take transit. Trip chain data indicate that access to personal mobility to fulfill essential functions is a necessity, not simply a convenience. Traditional ridesharing and TDM strategies designed to equalize or increase the convenience of carpooling or transit do not present a strong enough incentive to penetrate the trip chain segment of the potential market. Enrichment at the site level must be added or integrated into the mix of tools.

The survey of amenity use showed that the major attractiveness of all the on-site amenities for employees—and correspondingly for management—was their importance to worker job satisfaction and work productivity. Employees perceived the on-site amenities as having greater impact on their productivity and job satisfaction than on their ridesharing. There was a high correlation between the amenities that were rated as important to productivity and satisfaction and their actual utilization by the employees.

Direct deposit ranked first in all areas of worker perception of its importance—ability to rideshare, enhancing satisfaction and increasing productivity was the most frequently used amenity. The second most important amenity, as it related to productivity, satisfaction and frequent use, was the cafeteria. The second most important amenity in regard to improved ability to ridesharing, however, was childcare while the cafeteria was ranked as being third in importance to ability to rideshare.

The presence of on-site amenities had a marked effect in reducing or eliminating total VMT by employees. However, VMT were

TABLE 3 Total Weekly Air Pollution Gases Eliminated by Amenities

AMENITY	CO_2	CO	NOx	NMHC	NC	TOTAL
Cafeteria	270.92	14.74	2.15	1.73	.42	289.96
ATM	114.71	6.24	.91	.73	.18	122.77
Educ.	113.14	6.16	.90	.72	.17	121.09
Direct Deposit	72.82	3.96	.58	.47	.11	77.94
Gym	64.60	3.51	.51	.41	.10	69.14
Stamps	41.89	2.28	.33	.27	.06	44.83
Cleaners	36.41	1.98	.29	.23	.06	38.97
Travel Agency	32.10	1.75	.25	.21	.05	34.36
Child Care	14.49	.79	.11	.09	.02	15.50
Clinic	11.75	.64	.09	.08	.02	12.57
Company Store	.78	.04	.01	.01	.00	.84
Other	80.34	4.37	.64	.51	.12	85.98
Total	853.94	46.46	6.76	5.45	1.31	913.93

more likely to be eliminated than reduced by the availability of on-site amenities. Commuters responsible for the "eliminated" miles through on-site amenity activity tended to be women with infants who carpooled two days a week. Heavy poolers were likely to report VMT elimination due to the utilization of on-site services. Solo drivers estimated that without the availability of the on-site amenities, an additional 3,017.6 km (1,886 mi) would have been traveled.

IMPROVING LIVABILITY OF ACTIVITY CENTERS

Recommendations regarding site amenities, land use, and delivery systems are presented below. The suggestions are aimed at improving the livability of existing suburban office centers, as opposed to creation of new residential/office mixed use centers.

Land Use and Development

Land use is the key component in achieving realistic solutions to suburban travel problems. Better analyses of customer/commuter demographics will develop an understanding of travel behavior and on-site needs so that an appropriate mix of amenities can be pursued. Land use becomes the playing board on which to encourage and distribute the office park amenities, facilities and services that will accommodate commuter needs and substitute for trip-making. Land use factors that relate to transportation include the density, scale, mix, design, and location. Infilling to increase the land use mix is attractive because small-scale adjustments in the land use/transportation relationship can be made incrementally and do not incur great infrastructure costs for either the community or the developer.

Trip chaining data indicated the importance of integrating carpool/vanpool and transit services with supportive land use at the site level. The analysis of amenity use at two corporate sites provided direction as to the kind of micro-scale changes in the physical design and integration of land uses that will contribute to vehicle trip reductions. In particular, strategically locating food services, day care facilities, convenience retail, banking and fitness facilities in office centers would assist other TDM measures in the reduction or elimination of total vehicle miles of work trip travel.

The overriding reality is that people like to live and work in the suburbs, so developers will continue to build there. Therefore the marketplace will continue to provide planners, developers and employers with numerous opportunities to retrofit a greater diversity and sense of place into existing suburban landscape.

The proximity of land use types to one another is equally or more important as density because it is the salient factor in actual employee use of facilities. If employees leave the front door of the building, they are lost to the parking lot. Therefore, a guiding principal in redevelopment should be to improve the proximity between uses. Design that incorporates enclosed walkways to tie buildings and uses together should be encouraged so that when amenities become available in adjacent buildings, neighboring workers can use them. Site design features, such as landscaping and enclosures, that keep workers from being enticed by the lure of the parking lot need to be applied with a certain discipline. Landscaping can be used to direct pedestrian flow between buildings with primary amenities.

TDM and transit professionals should be alert for opportunities to influence the development, adoption and proper application of

guidelines, regulations and incentives that promote enriched sites, mixed land use and connections between sites. Land use planners should be alert for logical opportunities to encourage amenities. Developers may be more receptive to retrofitting or including amenities during the expansion or relocation process so that amenities can be negotiated as TDM-oriented conditions of plan approval. Land that is waiting for development can be put into an interim use as jogging, walking and hiking trails. Desirable uses, such as educational facilities and child care centers, might be "recruited" by relaxing certain requirements, such as parking spaces. Or, projects that TDM supportive elements could receive expedited processing though approvals in a "fast tracked permit process."

Contrary to many other TDM measures, infilling does not rely on *changing* human behavior but appeals to the way people want to live and work. Successful infill strategy will result in an increase in mid-day walking activity, better internal traffic flow and more effective utilization of activity center road capacity as "trips not taken" create new capacity.

Service Delivery

In suburban settings with little redevelopment potential, the provision of services can be accomplished through concierge arrangements that bring services to the employee. A concierge could also sell transit passes, provide transit schedule information and coordinate Guaranteed Ride Home needs. Concierges can be managed by the development company, property manager or a transportation management association organization. TMAs and TMOs have developed nationwide to address congestion, air pollution regulations and mobility concerns. In performing their role as implementing agents for congestion management, TMAs have developed the characteristics that would make them effective deliverers of shared tenant services. These characteristics include flexibility, private-sector approach, established relationships with the development and employer communities, credibility with the commuting public and employers and in-depth understanding of the market area. The addition of tenant services would give TMAs a new, unique product that would also enable them to offer a new method of air quality compliance to their members.

Shuttle Service

Where shared ride services are not yet in place and it is not possible for employees to walk to access needed services, then local circulator buses can be effective to give riders access to a broad range of services and stores. Service must be frequent enough for workers to return to work without abusing lunch hour limits. The private sector, transit authorities and local jurisdictions can pursue joint development of shuttle service and of childcare centers and retail at rail centers.

Technology has a still undefined role to play in the delivery of services to the site. Electronic super highways have the potential to revolutionize access to information. Electronic bill-paying and video conferencing are already fairly commonly accepted transactions that substitute for trip-making and on-line computer services are becoming commonplace in many households. Future consumers will use technology in ways to conduct business and perform essential transactions currently available only by personal automobile.

RECOMMENDATIONS FOR FUTURE RESEARCH

Travel diary data fills a gap that currently exists between the transportation planning profession's understanding of site impacts and the regional travel choice models. It provides more complete information on the total trip (before, during and after work). Additional, more widespread data gathering on the whole work trip is recommended. Doing so will aid in the construction of better models that are sensitive to consumer choice and behavior, particularly with respect to trip chaining as well as a better understanding of congestion-related household factors.

Trip elimination associated with site amenities has air pollution reduction benefits but a "trip not taken" is difficult to measure. Additional studies to document the VMT and greenhouse gas reduction achieved by the installation of amenities at employer sites are in order to give transportation planners confidence in their credibility as transportation control measurers.

In addition, new models need to be developed that are sensitive to the type of reductions that land use changes can make. New land use and air quality models should allow for the analysis of trip chaining as it impacts VMT and speed and for the calculation of emission reductions resulting from new services and facilities, particularly at large employer sites or transit stations.

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Five-Year Results of Employee Commute Options in Southern California

ROY YOUNG AND RONGSHENG LUO

To give employers in Southern California a sense of what their efforts have accomplished and to provide other metropolitan regions that are currently developing and implementing similar employer trip reduction regulations with some guidelines for setting goals and expectations of progress, an analysis of 5 years of employer trip reduction plans and average vehicle ridership (AVR) survey data compiled by the South Coast Air Quality Management District is presented. The following areas are covered: (a) employer and employee coverage, (b) AVR progress and determinants of progress, (c) commute mode share progress, (d) telecommuting, (e) compressed work week schedules, (f) charge-for-parking, and (g) incentive programs.

As part of the Air Quality Management Plan for the South Coast Air Basin, mandatory employer-based vehicle trip reduction regulation was adopted as a strategy to reduce air pollution from mobile sources. Rule 1501, developed and implemented by the South Coast Air Quality Management District (SCAQMD), was enacted in December 1987 (then called Regulation XV) giving large employers in Los Angeles, Orange, and the nondesert portions of San Bernardino and Riverside counties the responsibility to create and implement programs to reduce the number of vehicles arriving at their work sites during the morning peak hours. This study is a report of the accomplishments of these employer efforts since the first plan was approved in December 1988 through November 1993, exactly 5 years.

Rule 1501 specifically requires that all employers with 100 or more employees at any work site complete and file a trip reduction plan outlining how they intend to increase the average vehicle ridership (AVR) toward a specified goal within 1 year of the approval of the plan. AVR is defined roughly as the number of employees reporting to work at the peak morning hours (originally 6 to 10 a.m. and subsequently changed to the 4-hour period between the hours of 5 and 11 a.m., when the majority of employees arrive at the site), divided by the number of motor vehicles driven to work by these employees. The ratio is calculated over a 5-day work week to account for the use of compressed work week (CWW) schedules and telecommuting. The goals are set by geographical location: 1.75 for the central business district (CBD) of Los Angeles with high employment density and significant access to transit, 1.5 for other developed urban and suburban areas, and 1.3 for outlying, low-density areas.

Notices of the requirement to comply with the regulation were sent to targeted employers in phases, first to the largest employers in the region, and, then over time, to progressively smaller and smaller sites, of those identified as having 100 or more employees.

Employers may choose any number of incentives and disincentives to convince their employees to use alternatives to driving alone to work. Plans submitted to the SCAQMD are reviewed by staff specialists who determine whether adequate effort is being expended by employers. The SCAQMD has decided not to require use of any preassembled packages of strategies, allowing maximum flexibility for employers to customize strategies for their sites. Plan approval is based on some determination that the proposed program will achieve additional AVR progress toward the site's AVR target. Hundreds of firms have been fined for being in violation of the regulation, but in most cases the reason was for not submitting a plan and not a consequence of poor AVR performance.

The data for this study come from the SCAQMD Rule 1501 data base compiled from employer trip reduction plans (TRPs) submitted by employee transportation coordinators (ETCs) and signed by the highest-ranking managers at these sites. The data base has some limitations for any analysis seeking to report levels of progress and reasons for progress. First, it contains no information on individual commuters, as all information in an employer TRP is aggregated and reported at the site level. Second, data on incentives include only limited descriptions (e.g., carpool subsidy amounts are just estimates, dates of actual implementation are not specified). Third, some reporting requirements and definitions have changed over time. Fourth, there is no record of trip reduction results from employer-based programs in place prior to the regional regulation.

This paper, a revision of the executive summary of a larger study, outlines the major research findings: employer and employee coverage of the regulation over time; AVR progress and possible determinants of progress; commute mode share progress; levels of telecommuting, CWW schedules and charge-for-parking; and incidence of use of incentive elements. After the summary of key findings, conclusions relating to employer accomplishments reached as a result of the analysis are outlined. We did not make any recommendations for policymakers or employers because our aim is merely to describe the vehicle trip reduction achievement. A determination of the effectiveness and cost-effectiveness of the regulation is also beyond the scope of this study.

A full detailed report has been developed as a reference document with statistics for employers and groups looking to make performance comparisons and projections. Both the executive summary and the full report are the first steps in an effort to provide employers with site-specific reports for site performance evaluation.

KEY FINDINGS

Employer and Employee Coverage

Rule 1501 was enacted in 1987 and called for an annual plan submittal. However, the interval between consecutive plans tended to be longer than 1 year, especially in the early years of implementa-

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tion. Moreover, notification to comply was phased in starting with the largest employers. As a result, not until 1992 did a majority of the regulated sites have 1 full year of TRP experience.

As of November 1993, 6,604 employer sites had at least one plan approved. Of the 6,604 sites, 0.2 percent had five plans approved, 16.4 percent had four plans approved, 28.6 percent had three plans approved, 33.6 percent had two plans approved, and 21.1 percent had just one plan approved. On average, these sites have 2.4 plans approved, representing roughly an average of 1-1/2 years of TRP experience.

Figure 1 illustrates the coverage of Rule 1501 over time in terms of the number of employees working at regulated sites. The coverage numbers represent the total number of employees and not just the number of employees arriving during the peak a.m. period (AVR and mode split data shown in subsequent figures represent only employees at regulated sites arriving at work during peak hours). As of November 1989, a total of 854,000 employees were working at sites with one plan approved. One year later, 1,269,000 employees were working for employers with one plan approved, but only 245,000 employees were working at sites with two plans approved, indicating at least 1 full year of trip reduction program experience. A total of 2.3 million employees work at sites subject to the regulation, which represents over a third of all workers in the region. Peak-arrival employees represent 70 percent of total employees at regulated work sites. Not until 1992 did a majority of employees at sites covered by the regulation have 1 full year of TRP experience.

AVR Progress

Base-year Aggregate AVR

Before analyzing progress in AVR, we need to explore possible explanations for base-year AVR. A previous study, based on a sample of 1,110 sites, used analysis of variance to test the hypothesis that a site's AVR would depend on its geographic location, its size or number of employees, its industrial sector, and the date of employer survey (*1*). It found that geographic location and industrial sector are only marginally significant, and size is not unless combined with industrial sector. By using virtually the same classifications of geographic location, size, and industrial sector, our analysis—based on the 6,324 sites with at least one approved plan and valid data—produced only slightly different results. Still, a regression analysis indicates that the relationship between base-year AVR and geographic location, size, and industrial sector is very weak. In conclusion, it is apparent that these variables are not predictors of site AVRs at the start of compliance with Rule 1501.

Aggregate AVR Progress

Because of a lack of sound AVR data before inception of Rule 1501, the authors looked only at sites with at least 1 full year of trip reduction program experience, that is, those sites with two or more plans approved, with valid AVR data available. As of November 1993, 4,999 sites had two or more plans approved with valid AVR information in the data base; on average, these sites have 2.8 plans approved, or roughly 2 full years of trip reduction program experience on average under the regulation. The initial or base-year aggregate AVR for these 4,999 sites was 1.205. As of November 1993, the aggregate AVR for these sites increased to 1.257, representing an increase of 4.3 percent.

Although not strictly a normal distribution, there is a concentration of sites at the middle ranges, representing modest gains or losses. The highest concentration of sites (1,209) falls in the AVR change of little or no gain (0.000 to 0.049 AVR change from initial to current plan). At the extremes are 520 sites for which AVR increased 0.2 AVR point or more, and 235 sites for which AVR decreased more than 0.2 AVR point (Figure 2).

AVR progress for each of the four counties covered by Rule 1501 is similar, with the exception of Orange County, the second largest county. The absolute value of AVR increase (0.07) and the percentage increase (6 percent) were the same for Los Angeles, Riverside, and San Bernardino. Orange County employers achieved an increase of 0.01 in AVR, representing only a 1-percent gain.

Analysis of AVR Change

The analysis of AVR change examines the relationships between AVR change and: (a) site characteristics, (b) duration of program implementation, and (c) initial AVR.

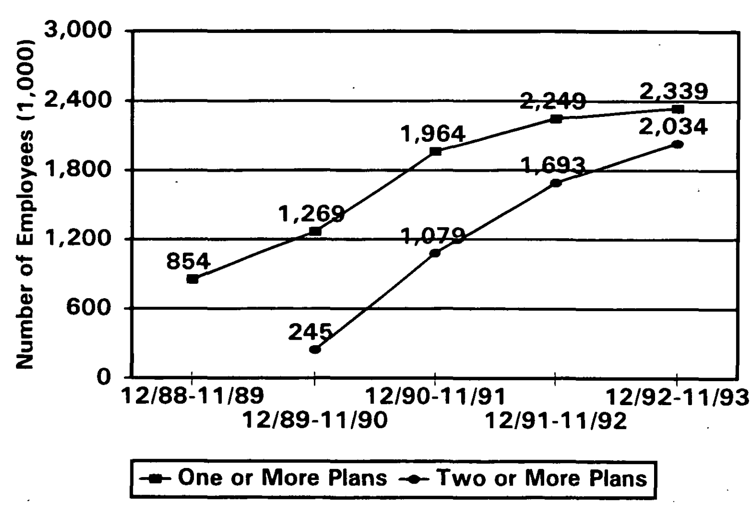

FIGURE 1 Rule 1501—employee coverage over 5 years.

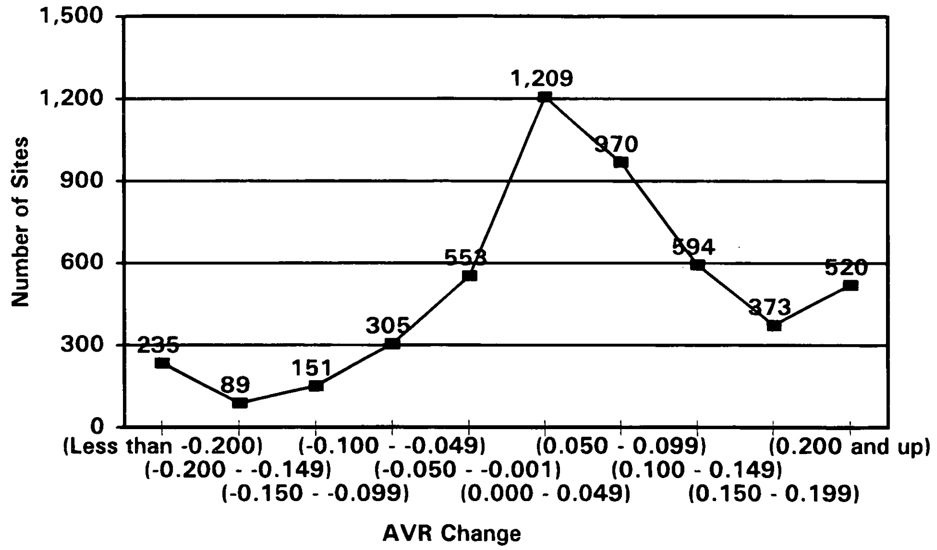

FIGURE 2 Number of sites by AVR change: first plan versus current plan.

The same earlier study of Rule 1501 mentioned previously, which compared Year 1 and Year 2 plans at 1,110 sites that were the first to complete a year of TRP implementation, concluded that none of the site characteristics examined (size, geography and industry) were found to be significantly related to AVR progress (*1*).

Now that more sites have appreciably more history, a similar analysis was conducted using data for 4,999 sites with two or more plans approved. Although we discovered a statistically significant relationship between AVR change and site characteristics, the relationship is very weak, suggesting that site characteristics cannot explain the change in AVR.

Although not related to site characteristics, the earlier study found that the AVR change was attributed to implementation of the TRP (*1*). Therefore, it is reasonable to assume that duration of program implementation would have a stronger impact on the change of AVR than the site characteristics. We repeated the previous statistical analysis adding duration as a new independent variable. In addition, a stepwise regression model was also constructed. Both analyses did point to a statistically stronger impact of the duration on AVR change than the site characteristics. However, again, the relationship between AVR change and duration is so weak (adjusted $R^2 = 0.01$) that it is virtually meaningless, and it reflects the fact that, on average, AVR progress is greatest in the early years of compliance, dropping off significantly after Year 2.

This is most apparent in an analysis of the AVR change year-by-year, which provides a clearer understanding of the weak relationship between AVR change and duration. Furthermore, progress year by year can be most accurately assessed using the same base of employer sites in each plan sequence rather than a varied base of employer sites. Therefore, a panel of 817 sites with four or more AVR surveys is used to chart AVR progress year by year. The 817 panel sites, on average, are much larger than the whole regulated site population and had a lower initial aggregate AVR. However, their industrial composition and geographic distribution are similar to those of the total regulated employer population. Progress at these sites was actually steepest between the second and third plans, with aggregate AVR increasing from 1.220 to 1.271. We found more modest AVR progress from the first to the second plan sequence, 1.196 to 1.220, and from the third to the fourth plan sequence, 1.271 to 1.288. This pattern of AVR change to some extent explains the weak relationship between AVR change and duration. It also suggests it first takes some time for employers to implement plans, to achieve an adequate level of awareness of program elements among employees, and for employees to make mode changes. Then, once a significant shift takes place, additional progress comes more slowly (Figure 3).

In general, the higher the initial AVR, the lower the percentage gain in AVR. In fact, sites with an initial AVR of 1.50 and above actually experienced a 14-percent decrease in AVR on average (Figure 4). Our correlation analyses show that AVR change has a much higher though negative correlation with initial AVR than with duration, industry, location, or size.

Thus, the strong negative correlation between AVR change and initial AVR, together with the weak correlation between AVR change and duration of program implementation, indirectly supports the finding of earlier studies that there exists a threshold capping level of increase in ridesharing from employer-based vehicle TRPs (*1,2*).

Commute Mode Share Progress

Overall Commute Mode Share Progress

Figure 5 shows the change in commute mode shares from the first approved plan (initial or base plan) to the most currently approved plan at the 4,999 sites that have two or more plans approved and valid information in the data base.

The drive-alone share of commute trips decreased from 73.5 percent to 67.2 percent a decrease of six share points or a 9.6-percent decline. The decrease in the drive-alone share was almost entirely the result of increased carpooling (from 15.5 percent to 21.4 percent share of commute trips). In addition, the vanpooling share increased (from 1.2 percent to 1.9 percent), the transit share increased only slightly (from 4.0 percent to 4.3 percent), and the

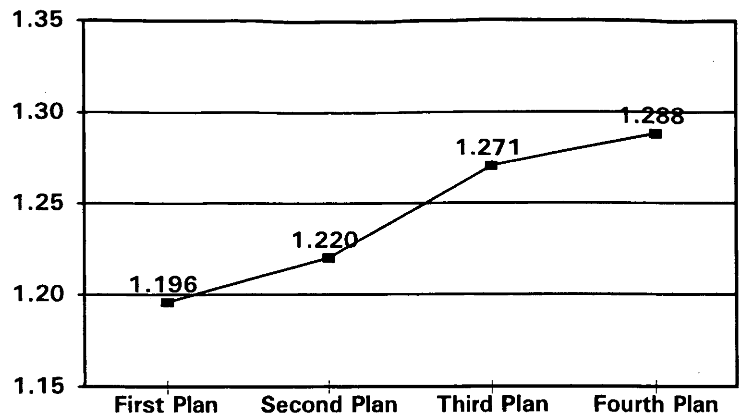

FIGURE 3 Aggregate AVR progress by plan for 817 sites with four or more approved plans.

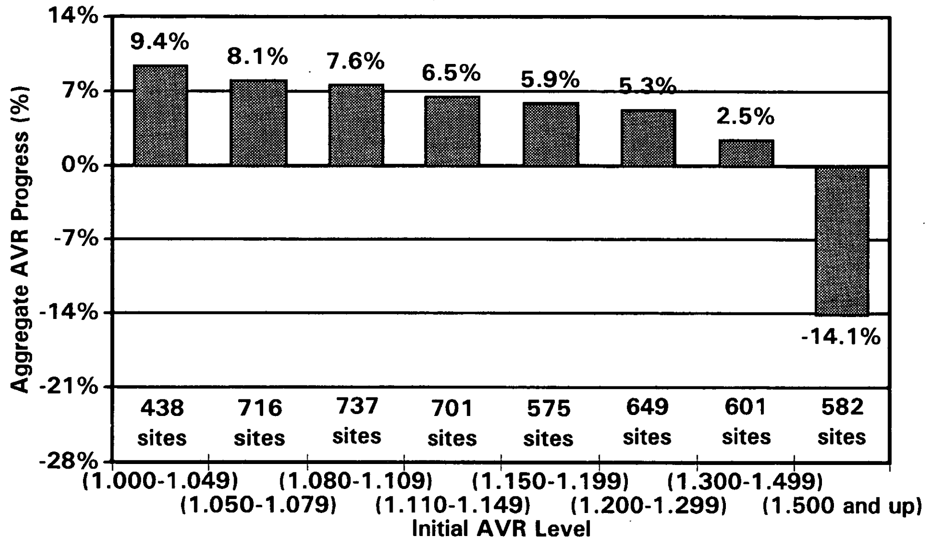

FIGURE 4 Aggregate AVR progress by initial AVR: first plan versus current plan.

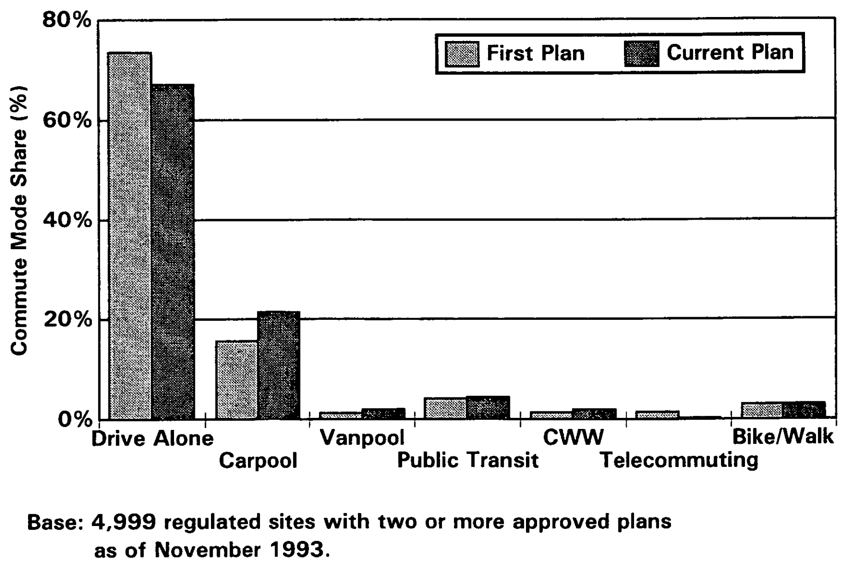

FIGURE 5 Commute mode share progress: first plan versus current plan.

CWW day off share increased (from 1.3 percent to 1.9 percent). The telecommuting share, however, decreased (from 1.4 percent to 0.3 percent). The combined shares for bike and walk modes did not change (3.0 percent).

Change of Carpooling and Transit: All Sites versus CBD Sites

At all regulated sites with two or more AVR surveys (4,999 sites), the carpooling share (21 percent) is currently five times the size of the transit share (4 percent). In fact, carpooling increased 6 share points and the transit share did not change at these sites, from the initial to the most current plans. At 188 Los Angeles sites located in the CBD, where transit is more likely to be an option, the carpool and transit shares are roughly the same (21 to 22 percent), with carpooling increasing 4 share points and transit increasing 3 share points, from the initial to the most current plans.

Reduction in Vehicle Trips

To translate the commute mode share progress into vehicle trips reduced, the inverse of AVR, vehicle trips per 100 person trips or VE ratio is used because it directly measures the vehicle trip reduction relative to employee trips. The following analysis first estimates the overall vehicle trips reduced at the 4,999 sites with two or more approved plans from the initial plan to the current plan. Then, to look at year-to-year change, the VE ratios for the 817 sites with four or more approved plans are calculated for each year.

Overall Vehicle Trip Reduction The VE ratio at the 4,999 sites with two or more approved plans declined from 82.96 vehicle trips per 100 employee trips in the first approved plan to 79.55 vehicle trips per 100 employee trips in the most currently approved plan. However, if the VE ratio had remained the same 82.96 vehicle trips per 100 employee trips from the first survey to the current survey, vehicle trips would have increased 9.12 percent—the same growth rate of total employee trips—to 1,987,283. Because of the decline in the VE ratio, the actual vehicle trips have increased only 4.6 percent to 1,905,283. Therefore, the difference is 81,538 (1,987,283 − 1,905,745) vehicle trips per day, which represents the vehicle trips that have been effectively eliminated at these sites. These vehicle trips represent a 4.8-percent reduction compared to the 1,987,285 vehicle trips we would expect in the absence of the regulation.

Vehicle Trip Reduction Year by Year: A Panel Analysis To estimate vehicle trip reduction year by year, the VE ratio is calculated for the same 817 panel sites with four or more approved plans for each plan sequence. The index declined consistently from 83.62 in the initial plan to 81.95 in the second plan, down to 78.71 in the third plan, and further down to 77.64 in the fourth plan. This represents a total decline of 5.98 vehicle trips per 100 employee trips, or a 7.2-percent decline over the VE ratio in the base year, at these sites over a 3-year period. As a result, a total of 40,043 vehicle trips have been eliminated per day at these sites, a 7.2-percent reduction in daily vehicle trips, over a period of about 3 years.

Telecommuting, CWW Schedules, and Charge-for-Parking

Telecommuting

Rule 1501 currently defines telecommuting as "an employee working at home or at a satellite work center provided the center reduces an employee's work trip by at least 20 mi. one way for an entire work day" (*3*). This definition was tightened from the definition originally used: "Telecommuting means working at home or at satellite work stations using electronic or other means to communicate with the usual place of work" (*3*). Therefore, results reported indicating the change over time should be used with caution.

To understand telecommuting activity level, AVR survey data were reviewed. Because the data are aggregated at the employer level, and because each respondent reports mode choices for 5 days, we cannot say with certainty how many employees are telecommuting (100 telecommuting responses may be 100 employees telecommuting 1 day during the survey week, 50 employees each telecommuting two times a week, or any other combination). We therefore report telecommuting activity in terms of the share of all employee or commute "trips" or days. Over 8 in 10 (83 percent) work sites do not have any telecommuting at all based on their most current AVR survey data. Of those sites reporting some telecommuting activity, only a very small proportion of sites has a meaningful level: merely 1 percent of sites have activity greater than or equal to 5 percent of all employee days (Figure 6).

In fact, as discussed in the previous section, over time, telecommuting as an overall share of employee days at regulated sites with two or more plans approved has declined. The tightening of the definition of telecommuting by SCAQMD in February 1993, which imposes conditions to the eligibility of working at a satellite work center as a telecommuting credit, may somewhat contribute to this decline (*3*). But it by no means can fully explain such a large decline because most telecommuting took place at home rather than at telecommuting centers. An examination by industry revealed that nonbusiness entities (e.g., government agencies) accounted for a large share of the decline. The larger the site, the more likely there is to be some telecommuting. However, the larger the site, the lower the actual share (percentage of all AVR survey responses).

CWW Schedules

CWW schedule is an alternative to the normal five 8-hour work days in a 1-week schedule. Rule 1501 recognizes three compressed work week schedules: (a) three 12-hr workdays in 1 week (3/36); (b) four 10-hr workdays in 1 week (4/40); and (c) 8 hours over 9 workdays in a 2-week period (9/80).

Like the analysis of telecommuting activity, the analysis of CWW schedules is conducted using AVR survey data aggregated at the employer level. But unlike telecommuting, CWW day-off responses are indicated by schedule type (4/10, 9/80, 3/36), and each schedule type implies a number of days off per week. Therefore, from number of days off by schedule type in the AVR data base, we can derive the number of employees who are working CWW schedules at any given site.

Compared to telecommuting, CWW schedules have been offered by more regulated employer sites. Nearly one-third (32 percent) of the 6,483 sites with reliable data in the data base report that there are some employees working a CWW schedule based on their most cur-

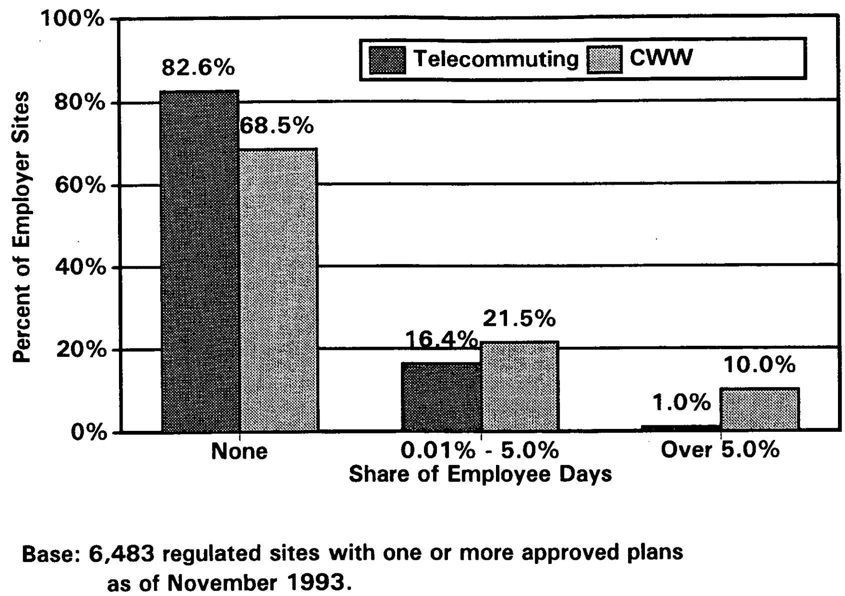

FIGURE 6 Telecommuting and CWW schedule activity.

rently approved plans as of November 1993. Still, employee participation rates are very low. Only 1 in 10 sites in the data base shows a CWW share of employee days of 5 percent or greater (See Figure 6).In fact, as a share of all employee days, CWW days off remain small, increasing from 1.3 percent of employee days in initial trip reduction plans to 1.9 percent in the most current AVR surveys of sites with two or more plans approved (see previous section). Similar to telecommuting, the larger the site, the more likely it is that some employees work CWW schedules. However, the larger the site, the lower is the CWW days-off share of employee days.

Charge-for-Parking Program

Although charging-for-parking is known to be the most effective strategy for convincing employees to switch from driving alone to some multiple-occupant mode, it remains unpopular among employers. Just 364 employers (6 percent of regulated sites) report that they charge their employees for some or all of the cost of parking. A sign of the effectiveness of the strategy is that together, these 364 sites have achieved an AVR of 1.37, significantly above the average AVR for the region.

While concentrated in the CBD and satellite business centers, the location of employers who pass some of the cost of parking along to their employees is more widespread geographically than originally thought. More than three quarters of the 364 sites were located in suburban area while less than one quarter of the 364 sites were located in the central city area of downtown Los Angeles. This suggests that a charge-for-parking policy may be suitable for employers in a wide range of locations, although certainly not in outlying areas.

Incentive Programs

The last section of the study covers the strategies used by employers in their vehicle trip reduction programs. Table 1 gives the number and percentage of sites incorporating each incentive group as part of their strategy. (Totals represent numbers reported in trip reduction plans filed, indicating only that an element in the specific group is used. The level and weight applied to the incentive in the actual execution of the program is not reported. For example, the 74.8 percent of employers offering direct financial incentives no doubt differ by the level of financial reward offered, which behaviors are rewarded, and the number of employees who have the opportunity to receive a reward. Therefore, an analysis of the effectiveness of each of these program elements alone and in combination with other elements is not possible with this data.) The most widely used incentives as reported in the most currently approved trip reduction plans are marketing elements, rideshare matching services and facility improvements (over four in five of all regulated employers report using each). Direct financial incentives, offered by 74.8 percent of the sites, is the next most widely used category of incentives. In addition, more than 7 in 10 sites reported that they offer a guaranteed return trip program.

Of all the incentive groups, direct financial incentives most directly rewards employees for using alternatives to driving alone to work. Only employers who offer direct financial incentives actually give some money (cash or redeemable vouchers) to employees who use transit, carpool, vanpool, bike, or walk. While most employers offer some type of direct financial incentives, a closer look at the specific types offered indicates that money is not actually awarded widely.

The most widely offered is ongoing transit subsidies (64.9 percent) as presented in Table 2. Transit subsidies are required by a number of cities including the city of Los Angeles. Still, the transit share of commute trips is low and has remained relatively flat.

Ongoing carpool subsidies are currently offered by 4 in 10 employers. As carpooling is the most widely used alternative and has experienced the most dramatic increase in use of all alternatives since the regulation has been in effect, this incentive is likely to account for the largest direct (out-of-pocket) cost to employers. Still, the majority of employers do not offer these subsidies.

Overall, as a group, the share of employers offering direct financial subsidies declined 15.6 share points, from 69.1 percent in the initial plan year to 53.4 percent in the current plan year. In addition, by

TABLE 1 Regulated Sites Offering Incentives by Group

	Sites with Offerings	
Incentive Groups	Number	Percent
Marketing Elements	4,918	90.5
Rideshare Matching Services	4,604	84.7
Facility Improvements	4,382	80.6
Direct Financial Incentives	4,066	74.8
Guaranteed Return Trip Program	3,905	71.8
Employee Benefit and Services	3,459	63.6
On-site Services	2,967	54.6
Direct Non-Financial Incentives	2,840	52.3
Flexible Work Hours	1,606	29.5
Compressed Work Week	1,268	23.3
Telecommuting	555	10.2
Other (Not classified by other codes)	354	6.5
Parking Management	343	6.3
Transportation Allowances	36	0.7

specific element, a comparison is made of the incidence of offerings used in the first year to the incidence of offerings in the most current year at 4,032 sites with two or more plans approved (Figure 7).

Strikingly, there was a decline in the incidence of use for all elements. It seems as though employers have cut back their investment in vehicle trip reduction and that the SCAQMD has lowered its compliance standards.

A determination of the effectiveness and cost-effectiveness of specific strategies is outside the scope of this study. As stated earlier, the data compiled by the SCAQMD will not allow these analyses, largely because descriptive details of incentives and timing of implementation are not recorded.

CONCLUSIONS

First, progress, both in terms of aggregate AVR increase and vehicle trips reduced, has been significant, but short of targets. Progress in the second year tends to be greater than in the first year; however, progress in the third year, for the small number of employers with enough history, slowed dramatically.

Secondly, AVR progress levels are relative to the nature of the programs being implemented by employers and the compliance standards applied by the SCAQMD. Increases in carpooling account for most of the progress, primarily because employers have emphasized strategies that support carpool formation rather than strategies that are more disruptive to existing organization and work, such as charges for parking, CWW schedules, and telecommuting. Transit is still not a prevalent option, and, therefore, did not show any significant increase in use, except in downtown Los Angeles.

Third, employers looking to minimize the cost of compliance have cut back on the use of direct financial incentives to encourage ridesharing. It appears as though costs incurred by employers have largely gone to finance investments in "soft" strategies—such as marketing, guaranteed ride home, rideshare matching—which are necessary, but not sufficient, inducements to change commute modes.

TABLE 2 Regulated Sites Offering Direct Financial Incentives by Element

	Sites with Offerings	
Direct Financial Incentive	Number	Percent
On-going Transit Subsidies	3,528	64.9
On-going Carpool Subsidies	2,164	39.8
On-going Walk to Work Subsidies	1,923	35.4
On-going Bike to Work Subsidies	1,910	35.1
On-going Vanpool Subsidies	885	16.3
Other Subsidies	860	15.8
Introductory Transit Passes/Subsidies	423	7.8
Subsidized Vanpool Seats	167	3.1

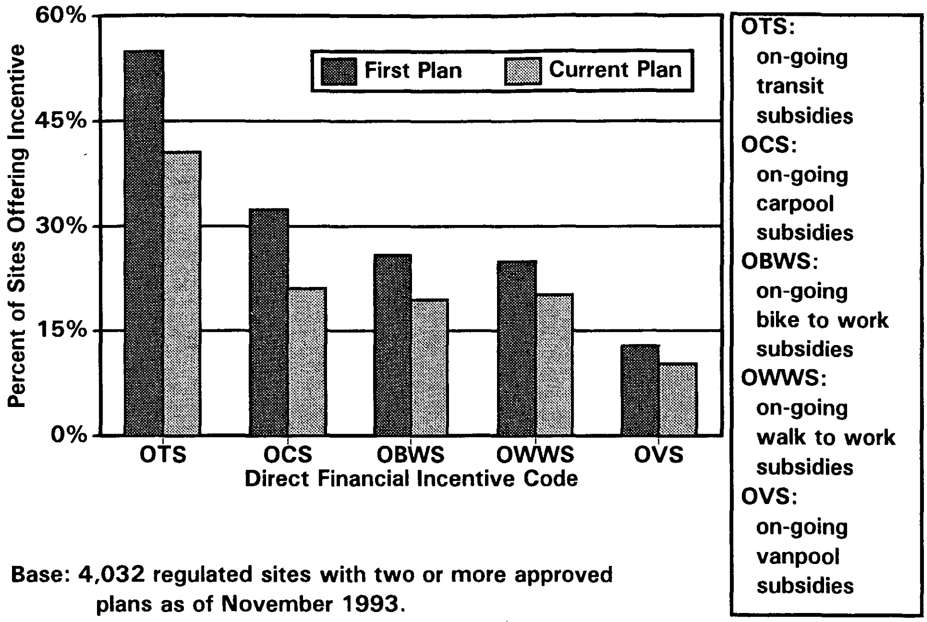

FIGURE 7 Ongoing direct financial incentive offerings: first plan versus current plan.

Moreover, absolute AVR progress achieved by employers approximates a bell curve, with majority of employers making only very modest gains. Employers making the most AVR progress are those with the lowest initial AVRs. Site characteristics such as size, industry, and geography do not predict AVR change, which suggests that other tangible and intangible factors acting in combination determine the success or lack of success of any one site.

In addition, the phased-in approach to the introduction of the regulation means a large portion of the targeted employer population did not implement a program until several years after the adoption of the regulation. Therefore, several years later, progress may fall short of expectations because program history is not as broad or deep as commonly believed. Further, a study of effectiveness and cost-effectiveness can only be done using a site-by-site comparison of strategies employed and results achieved, among sites with the same number of years of implementation experience, and with more TRP details than are currently available in the data base.

Finally, if employers are to have a role to play in working toward solutions of the problems exacerbated by economic growth—namely, air pollution and congestion—an evaluation of the merit of the vehicle trip reduction, or "ridesharing," regulation must weigh emissions reduction achieved against employer investment made, compared to investments in alternative strategies required from employers to achieve similar benefits.

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