NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE **81**

EXPERIENCES IN TRANSPORTATION SYSTEM MANAGEMENT

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EXPERIENCES IN TRANSPORTATION SYSTEM MANAGEMENT

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AREAS OF INTEREST
    PLANNING
    OPERATIONS AND TRAFFIC CONTROL
    (HIGHWAY TRANSPORTATION)
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TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C.
NOVEMBER 1981

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the Academy and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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PREFACE

There exists a vast storehouse of information relating to nearly every subject of concern to highway administrators and engineers. Much of it resulted from research and much from successful application of the engineering ideas of men faced with problems in their day-to-day work. Because there has been a lack of systematic means for bringing such useful information together and making it available to the entire highway fraternity, the American Association of State Highway and Transportation officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize the useful knowledge from all possible sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series attempts to report on the various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which they are utilized in this fashion will quite logically be tempered by the breadth of the user's knowledge in the particular problem area.

FOREWORD

By Staff
Transportation
Research Board

This synthesis will be of special interest to traffic engineers, planners, and others seeking information on the application of transportation system management (TSM) actions in different operating environments. Both successful and unsuccessful TSM experiences are analyzed.

Administrators, engineers, and researchers are faced continually with many highway problems on which much information already exists either in documented form or in terms of undocumented experience and practice. Unfortunately, this information often is fragmented, scattered and unevaluated. As a consequence, full information on what has been learned about a problem frequently is not assembled in seeking a solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of synthesizing and reporting on common highway problems. Syntheses from this endeavor constitute an NCHRP report series that collects and assembles the various forms of information into single concise documents pertaining to specific highway problems or sets of closely related problems.

There are more than 150 actions that can be included in a TSM program. This report of the Transportation Research Board summarizes experiences with these actions and provides guidelines within the context of nine operating environments, ranging from a freeway corridor to a local neighborhood. Recommendations for future research needs are included.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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This synthesis was completed by the Transportation Research Board under the supervision of Paul E. Irick, Assistant Director for Special Technical Activities Division. The Principal Investigators responsible for conduct of the synthesis were Thomas L. Copas and Herbert A. Pennock, Special Projects Engineers. This synthesis was edited by Nancy A. Ackerman.

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Valuable assistance in the preparation of this synthesis was provided by theTopic Panel, consisting of Albert A. Grant, Director, Department of Transportation Planning, Metropolitan Washington Council of Governments; John O. Hibbs, Chief, Traffic Performance and Programs Division, Office of Traffic Operations, Federal Highway Administration; Thomas Hicks, Assistant Chief Engineer, Traffic, Maryland Department of Transportation; Harvey R. Joyner, Vice President, Barton-Aschman Associates, Inc., Washington, D.C.; Gary E. Maring, Chief, Transportation Systems Management Branch, Federal Highway Administration; Adolf D. May, Professor of Civil Engineering and Research Engineer, University of California at Berkeley; Michael D. Meyer, Professor of Civil Engineering, Massachusetts Institute of Technology; Sandra Rosenbloom, Associate Professor, Department of Community and Regional Planning, University of Texas at Austin; Richard P. Steinmann, Community Planner, Office of Planning Assistance, Urban Mass Transportation Administration; and Warren O. Somerfeld, Director of Transportation, City of Madison Transportation Department. David K. Witheford, Engineer of Traffic and Operations, Transportation Research Board, assisted the Project 20-5 Staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

EXPERIENCES IN TRANSPORTATION SYSTEM MANAGEMENT

SUMMARY

Transportation system management (TSM) has broadened from a list of low-cost actions to a concept for the most productive use of existing transportation resources through coordinated operations and improved management. A problem in approaching TSM has been the lack of a classification scheme with which to narrow the list of candidate actions. More than 150 different TSM actions have been identified. An attempt to implement these actions one by one overlooks the interaction among them.

In this synthesis operating environments are suggested as subsystems of the transportation network through which TSM analysis and implementation can be organized. Operating environments may be related to major transportation facilities, such as freeway corridors; to major urban concentrations, such as employment sites or commercial centers; and to geographical settings, such as neighborhoods.

Operating environments offer several advantages as an approach to TSM analysis and implementation: (a) they delineate an area that is consistent with traditional analysis, (b) the responsibility for the TSM lead role can be more easily identified, (c) support roles and activities can be easily related to the operating environment, (d) each environment can have identifiable goals and measurable objectives, (e) operating environments are compatible with planning analysis techniques to project impacts of TSM strategies, and (f) a constituency is readily identifiable within the operating environment.

To study the experiences with TSM, nine operating environments were used in this synthesis: freeway corridor, arterial corridor, central business district (CBD), regional operating environment, neighborhood, major employment site (non-CBD), outlying commercial center, major activity center, and modal transfer point. For each of the nine environments, the synthesis gives the characteristics, TSM options, motivation for action, goals and objectives, implementation experiences, and guidelines.

The successful TSM experiences reviewed for this synthesis had the following common characteristics: a strong, innovative person keenly interested in urban transportation; coordinated teamwork among transportation entities; an identifiable problem; adequate planning analysis to determine system impacts; and proper packaging of TSM strategies and support measures.

Unsuccessful TSM experiences had the following characteristics in common: a withdrawal of traveling privileges, lack of a perceived problem, imbalance between operating costs and level of service rendered, and inadequate enforcement.

Areas for future research include the following: long-range impacts of extended application of certain TSM measures, interrelationships among TSM actions and support measures, and enforcement of TSM measures.

CHAPTER ONE

IMPLEMENTATION AND OPERATING ENVIRONMENTS

Transportation system management (TSM) has received continuing attention since it was introduced in the mid-1970's. Understanding of TSM—as both an important concept and a structured approach to implementation—has evolved in technical literature and in common practice by local transportation professionals. TSM has broadened from a list of low-cost actions to fulfill federal requirements to a concept for the most productive use of existing transportation resources through coordinated operations and improved management. Recent federal guidelines have built upon improved understanding of TSM and have referred to it as a concept or "a philosophy." Rules and regulations on urban transportation planning in the *Federal Register* (*1*) define TSM as "a philosophy about planning, programming, implementation and operations that calls for improving the efficiency and effectiveness of the transportation system by improving the operations and/or services provided." TSM, then, focuses the attention of planners, designers, and operators alike on a common endeavor: to improve the transportation system through service and operations and to stage facility improvements in support of the common effort. TSM is, therefore, a point of beginning; the goal is first to analyze the system and then to improve its operation prior to capital-intensive projects.

This point of beginning has not been easily recognized; neither does it lend itself well to traditional approaches or to common urban structures. Given an enlightened understanding of the TSM philosophy, how does one proceed within one's realm of limited responsibility in the total urban system? Because a large number of the possible TSM measures affect the total system, and because many public and private agencies must be involved in the TSM philosophy, some structure must be used to move from a point of beginning to structured analysis and staged implementation.

This synthesis presents descriptions of TSM experiences in nine different urban operating environments, which, it is hoped, will be viewed as an appropriate structure for TSM analysis and implementation.

PROBLEMS OF TSM IMPLEMENTATION

Perhaps the most common reaction to TSM during its early years was to think of it as "just a list of things that we've been doing all the time anyway." This was not totally inaccurate, inasmuch as TSM includes good traffic engineering practice, which has been encouraged by the Traffic Operations Program to Increase Capacity and Safety (TOPICS) and other similar efforts. But what is overlooked by such a reaction is the "system" in TSM—the synergistic impact of compatible TSM measures when applied to a transportation system or subsystem. To approach TSM on a systems basis, one must move in an analytical way from a long list of possible actions to a workable program of alternatives with projected impacts. A point of departure is a classification scheme to narrow the list of candidate actions.

The lack of a classification scheme for TSM has been one of the more onerous problems faced by transportation professionals in approaching TSM. Tabulations have been developed in which more than 150 different TSM actions have been identified. Should they be approached individually, or can the TSM measures be grouped into categories that might better foster their implementation? Obviously, any attempt to implement TSM actions one by one overlooks the interaction among such measures. Yet no easy classification system is apparent. Grouping by functional responsibility in the common urban organizational structure overlooks the need for a coordinated and cooperative attack. It is perhaps this fragmented structure that has prevented the natural implementation of TSM actions thus far. Similarly, a classification scheme based on an objective—increased transit ridership, for example—fails to recognize properly the difficulties in implementing policies needed to support the objective—auto-restrictive measures, for example.

Four classification systems have been suggested for grouping TSM measures: (a) the compatibility of the individual techniques and the applicability of packages to different types of congestion problems (*2*); (b) common institutional problems and the strategies that can be used to overcome them (*3*); (c) the scope and complexity, design detail, planning analysis, and degree of coordination required for each measure (*4*); and (d) supply/demand impacts and the grouping of measures to produce a desired shift in transportation system equilibrium (*5*).

Classification of TSM measures must be carefully considered in a structured approach to TSM, which also must recognize the problems in implementing TSM. A report developed as a result of a conference on the state of the art and the future of TSM listed 15 causes for problems in TSM implementation (*6*).

1. *Political sensitivity.* The action has a potentially controversial effect on a sizable group of voters, and public officials are thus unwilling to consider its implementation.
2. *Nonvisibility to the public.* The action is not a visible solution in that the public does not identify it as a solution to some problem. Public officials favor actions that indicate that major steps are being taken to help their constituents.
3. *High labor costs.* Many TSM actions require a large support staff for successful operation. Given the high cost of labor, such a requirement is an important consideration.
4. *Public-private interface.* Some TSM actions, such as ride-sharing programs, require active interaction between public planning agencies and employers. Such interaction

has not often occurred in the past and in many cases represents a new step that must be taken to initiate a TSM strategy successfully.

5. *Local agency coordination.* The types of TSM actions listed above usually require the participation of many different agencies in an urban area. The problems related to achieving the required coordination inevitably delay the process of project implementation.

6. *Lack of public interest.* Unless faced with a serious problem, the public's interest in transportation will be negligible. There is thus little motivation for public agencies to actively consider high-achievement TSM actions.

7. *Complex funding processes.* The funds to support a TSM action often come from special programs that require interagency agreements. Also, those TSM actions that do not meet the criteria of federal categorical programs are not considered over those that do.

8. *Lack of leadership.* Given the complex institutional structure in most urban areas, it is difficult to find one agency that can take the lead in identifying TSM actions. Thus, there is often no institutional home for the types of actions being considered.

9. *No legislative authority.* Many agencies have no legislative mandate to examine high-achievement TSM actions and may in fact face legislative guidelines that forbid doing so.

10. *Resistance to a federal mandate.* In some regions of the country, the fact that TSM actions are being supported by federal agencies is reason enough not to consider them,

11. *Lack of governmental awareness.* Some local officials and transportation planners might be unaware of the advantages and effectiveness of the high-achievement TSM actions. The solution to this problem is to increase efforts at information dissemination.

12. *Uncertainty of project outcomes.* Whereas the evaluation of many traditional transportation alternatives uses an extensive analysis methodology to minimize the uncertainty surrounding their impacts, no such methodology is available for TSM actions. Thus, the uncertainty related to the outcome of the project creates a hesitation in considering its implementation.

13. *Agency biases.* Because many of the TSM actions considered do not fall logically under the purview of one agency and most agencies are concerned with doing a good job and minimizing the level of public scrutiny of their actions, an agency is biased toward familiar actions. Innovative projects, especially those requiring cooperation with other agencies, do not receive high priority.

14. *Insufficient professional capability.* The analysis of many of the high-achievement actions requires professional skills that are not available in most agencies.

15. *Perceived safety and enforcement problems.* The possibility of serious safety problems or the perception that the action is unenforceable may cause planners to discount the desirability of some actions.

Obviously, a structured approach that recognizes a systems or subsystems approach to TSM must address many, if not all, of the above problems and must adopt a TSM classification scheme to match alternative solutions with problem areas.

OPERATING ENVIRONMENTS: A NEW APPROACH

Operating environments are suggested as subsystems within the transportation network through which TSM analysis and implementation can be organized. Operating environments may be related to (a) major transportation facilities, such as freeway corridors, arterial corridors, and modal transfer points; (b) major urban concentrations, such as major employment sites, major activity centers, and outlying commercial centers; and (c) geographical settings within urban areas, such as neighborhoods, central business districts, and regional environments. No extraordinary effort should be made to specifically delimit the various operating environments. They should be used primarily to broaden the conceptualization from the specific problem area (e.g., location of congestion) to an area of impact within which TSM measures to reduce demand and increase supply can be evaluated.

Operating environments appear to offer several advantages as an approach to TSM analysis and implementation:

- Operating environments delineate an area of analysis that is consistent with traditional analysis and problem solving. The freeway corridor, for example, is the area of analysis for freeway design, and an easy transition is possible to evaluate TSM strategies within the same area.
- Responsibility for the TSM lead role may be more easily identified in terms of an operating environment. The regional environment, for example, points to the metropolitan planning organization (MPO), and the central business district (CBD) environment suggests the municipal traffic engineer in a lead role.
- Support roles and activities can easily be related to the operating environment. The municipal traffic engineer might be identified as the lead professional for TSM at a university complex (major activity center), with the campus transportation office and local transit operator in support roles. Support activities such as off-campus parking and campus traffic barriers also can be related to the major activity center operating environment.
- Identifiable goals and measurable objectives can be identified for each operating environment. Major employment sites, for example, suggest a goal of employee satisfaction, with objectives to minimize travel time (minutes) and maximize convenience (walking distance from parking place).
- Operating environments appear to be compatible with planning analysis techniques to project impacts of various TSM strategies (e.g., the arterial corridor is easily adapted to network analysis and focusing techniques).
- A constituency is readily identifiable within most operating environments. The neighborhood operating environment, for example, immediately identifies the residents as the principal constituency for TSM evaluation.

EXPERIENCES IN TSM

This synthesis summarizes TSM experiences in nine operating environments. It contains implementation experiences primarily in the United States and in different geographical areas. The TSM experiences selected for a brief description were those that are practical and also represent a creative approach to improved efficiency of the urban transportation system. It is recognized that TSM measures are successfully implemented daily as a part of good professional practice. Unfortunately, many of these successful endeavors are not reported, nor are their results monitored. This effort is therefore limited and includes only those implementation results that have been documented. Impacts of TSM experiences have been included as reported, and no effort has been made to verify results.

Traffic Engineering

Good traffic engineering has made significant improvements to traffic flow in all U.S. urban areas. The three E's—engineering, education, and enforcement—remain the backbone of any program to make efficient and effective use of the urban transportation system. Such traffic engineering measures as signal timing, coordinated signal systems, improved signing, and pavement markings are encouraged for initial consideration in TSM alternatives. Many such actions can be implemented with little cost and with minimum administrative delay. Unfortunately, the impacts of much "good practice" have not been adequately reported; however, experiences of such practice have been included here when results were available. References are included at the end of this chapter for traditional literature on traffic engineering improvements (*7–9*).

Use of This Synthesis

It is hoped that this synthesis can serve as a reference for staff personnel charged with a TSM responsibility. Readers may refer directly to any operating environment without missing relevant material in other chapters. Obviously, other operating environments could be identified. A prime example is the central business district of a suburban city that lacks the transportation characteristics of a central city CBD but falls between the arterial corridor, major activity site, and outlying commercial center operating environments. Readers are thus encouraged to relate their interest to one or more operating environments that may be useful. In the example above of a suburban CBD, readers will want to refer to the arterial corridor, major activity site, major employment center, and outlying commercial center for related TSM experiences.

Title VI of the Civil Rights Act of 1964: Nondiscrimination

Much of TSM is restrictive in nature; that is, it involves parking restrictions, ramp metering, and the like, and care must be taken to ensure that such restrictions are nondiscriminatory. Section 601 of the Title VI requirements states: "No person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance."

TSM Measures

There is no clear delineation of TSM measures for each operating environment, nor should there be. Ride-sharing, for example, fits well within the operating environments of the major employment site, the major activity center, the CBD, the region, and, if organized at the trip origin, the neighborhood. Although some preference is given to the operating environment in which the greatest potential for success exists, identical TSM measures are identified herein for several operating environments.

Goals, Objectives, and Planning Analysis

Each implementation experience herein was evaluated against the goals and objectives established, either explicitly or implicitly, prior to implementation. For each operating environment these goals and objectives were grouped into a table, which also identifies the measures of effectiveness and the TSM measures that appear to be most appropriate. Planning analysis, as used herein, refers to the evaluation of alternative TSM measures and the projection of impacts from individual TSM actions and from the synergistic effects of compatible TSM measures within an operating environment. It is recognized that some TSM measures require little or no planning analysis prior to implementation. This is particularly true of traffic engineering techniques. Successful implementation of TSM measures, however, is often accomplished as a result of creative analysis and the quantification of positive impacts. Techniques available for this analysis are discussed briefly for each operating environment.

Guidelines and Support Activities

From the implementation experiences, general guidelines were developed for the TSM measures. These guidelines should provide at least a rudimentary framework for other implementation attempts. In addition to the guidelines, support activities that are necessary for the successful implementation of a particular TSM measure are identified. For example, enforcement is a necessary support activity for a neighborhood parking program.

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CHAPTER TWO

FREEWAY CORRIDORS

The urban freeway represents the highest type of highway facility and is defined by the American Association of State Highway and Transportation Officials as "a highway with full control of access and no at-grade intersections" (1). The freeway incorporates in its design the most advanced features for the rapid and uninterrupted movement of roadway vehicles. The freeway *corridor*, however, includes parallel arterial roadways, transverse arterials that feed the freeway, and the express and fixed-route transit systems that operate on or parallel to the freeway. In the freeway corridor, then, transportation system management (TSM) strategies cover much more than traffic engineering principles on the freeway itself; they also include the *operation* of the transportation subsystem within the freeway corridor. This includes transit and other high-occupancy vehicles and the arterial street system.

CHARACTERISTICS

Freeway corridors are both radial and circumferential to a central city, and they offer potential for TSM applications. Both encounter peak traffic flows, and many urban freeways are subject to congestion and poor levels of service during daily peak periods. It is usually this daily congestion that results in public demand for improved and more efficient traffic management. Because radial freeways often provide access to the core employment center of the urban area and for that reason are supplemented by parallel transit routes, they usually provide more TSM opportunity for preferential treatment for high-occupancy vehicles than do circumferential freeways.

Peak conditions on radial freeways occur between 6:00 a.m. and 9:00 a.m. and between 4:00 p.m. and 7:00 p.m., during which time the primary trip purpose is the work trip. It is this period in which the travel demand exceeds the capacity of the freeway and in which TSM measures can be most effectively employed.

TSM OPTIONS

Any TSM measure that reduces urban vehicular travel will affect the freeway corridor. Increased transit ridership through reduced fares or an intensive marketing campaign will benefit the freeway corridor. Similarly, alternative work hours that assist in spreading peak traffic demand over time and TSM measures that spread the traffic demand over space (same mode but on different facilities) also benefit the freeway. The impacts of these related TSM measures are, however, often imperceptible and are offset by increased urban growth and travel demand. The synergistic effects of regionally applied TSM strategies have yet to be measured in an urban area, and little technology is available to project these impacts in advance of implementation. Thus, no attempt is made here to identify all TSM measures that are available to the highway engineer for more efficient operations of the freeway. Rather, emphasis here is on TSM options that fall within the freeway right-of-way. The other TSM strategies are considered support measures and are discussed later.

TSM measures that can be related to the freeway are (a) ramp access control through ramp closure and ramp metering; (b) separate, reversible lanes for high-occupancy vehicles (HOVs); (c) freeway lanes for exclusive use by HOVs during peak hours, which may be further stratified into an added freeway lane for HOVs (add-a-lane), and the use of an existing freeway lane for HOVs (take-a-lane); (d) contraflow lanes for HOVs during peak hours; and (e) preferential access for HOVs.

More work has been accomplished in system management on freeways than in any other operating environment. Freeway operations efforts since the early 1960s have produced meaningful results in many traffic surveillance and control projects, all of which could be classified as TSM. In order to maintain an acceptable scope for this chapter, only recent examples of surveillance and control projects have been included; many exciting and successful projects were, by necessity, omitted.

MOTIVATION FOR ACTION

Freeway congestion and reduced speeds during peak hours are the primary impetus for seeking alternative solutions. Public resistance to major freeway widening and construction projects has forced the transportation professional to seek ways of improving the efficiency of the existing freeway system. Freeway operation has, in fact, become a major discipline unto itself as ways have been sought to improve the efficiency by which larger numbers of persons (in contrast to vehicles) could be moved within freeway corridors. Motivation in recent years has come from factors originally thought to be outside the transportation perspective. Federal mandates to urban areas to reduce the emission of pollutants from auto traffic, plus higher cost and reduced availability of motor fuel, have necessitated more efficient transportation operations.

TSM, then, in freeway corridors is motivated by: (a) freeway congestion and the demand for more efficient use of existing facilities, (b) federal and state requirements to reduce air pollution and achieve air quality standards, and (c) concern for efficient use of motor fuels in transportation system operations.

GOALS, OBJECTIVES, AND PLANNING ANALYSIS

Goals and objectives relating to TSM in the freeway corridor environment encompass the broad range of transportation goals and objectives. Few overall goals and objectives of the urban transportation system itself are not in some form a part of freeway goals and objectives. Seen in its broader perspective as a mover of people and goods rather than merely vehicles, the freeway becomes a multimodal embodiment of the urban transportation network. Goals, objectives, and measures of effectiveness (MOEs) for TSM measures discussed in this chapter are summarized in Table 1.

Planning analysis is of utmost importance in the implementation of TSM strategies within the freeway corridor. Because freeway traffic flows approaching capacity are sensitive to incidents or slight changes in volumes, care must be taken in the planning and design of TSM measures to consider all elements of system operation. Transportation control measures, without planning evaluation, not only can be detrimental to traffic flows but also can be counterproductive to the very objective they are designed to achieve. Travel models have been effectively applied to freeway operations (*2–6*) and permit the evaluation of alternative TSM packages prior to implementation. Such planning analysis is strongly encouraged to eliminate counterproductive TSM measures early in the process and to reduce the probability of public rejection of effective TSM strategies.

IMPLEMENTATION EXPERIENCES

Upgrade and Control Program for the Los Angeles Freeway Network

This project (*7–11*) illustrates strategies of ramp control and surveillance of a total urban freeway network. The California Department of Transportation, District 7, currently meters approximately 450 directional miles (724 km) of freeway in an urban area. Through signal control at 580 ramps, local control through microprocessors, closed-circuit television (CCTV) cameras at one-mile (0.6-km) intervals, and computer override capability at a central control, District 7 has been able to reduce congestion, increase speeds, reduce total emissions from autos, and minimize delays due to freeway incidents.

The Los Angeles Upgrade and Control Program is a 13-year effort to improve freeway flows, reduce air pollution, and conserve energy. The urban freeway system of more than 600 miles (960 km) was basically complete in the mid-1960's; the need for access control became apparent in 1968, with increased congestion following widening projects to gain capacity. Following approval of a 1970 report that recommended a 10-year program to develop adequate ramp control, initial projects were identified to add capacity at bottlenecks and to meter sections of congested freeways. By 1972 nine directional miles (14 km) of freeway were metered, and in 17 percent of the total freeway system metering was either completed, budgeted, or under construction.

By January 1978 the control system had been expanded to 202 directional miles (325 km) of metered freeway and 259 metered ramps. An evaluation report in June 1978 reported the following effects:

- Total freeway delay reduction was 11,280 vehicle-hours per day.
- Net delay reduction after subtracting delays at metered on-ramps and on arterial streets (diverted trips) was 8,470 vehicle-hours per day.
- Average freeway speed on metered portions was increased by 16 miles per hour (26 km/h).
- Accidents were reduced between 20 and 50 percent.
- Estimated reduction of carbon monoxide for the total

TABLE 1

GOALS, OBJECTIVES, AND MOEs FOR THE FREEWAY CORRIDOR OPERATING ENVIRONMENT

Goal	Objective	MOE	TSM Measures for Each Goal
Maintain or improve the quality of transportation services on the existing transportation system	• Minimize Travel Time	• Person Hours of Travel • Vehicle Delay	Ramp Access Control Preferential Access for HOV Exclusive Lanes for HOV
	• Minimize Travel Costs	• Point-to-Point Out-of-Pocket Travel Costs	
	• Maximize Safety	• Accidents • Accident Rate	
Increase the efficiency of the existing transportation system	• Minimize Auto Usage	• Number of Carpools • Traffic Volume	Ramp Access Control Preferential Access for HOV Exclusive Lanes for HOV
	• Maximize Transit Usage	• Transit Passengers	
Minimize the undesirable impacts of existing transportation facilities	• Minimize Air Pollution	• Tons of Emissions	Ramp Access Control Preferential Access for HOV Exclusive Lanes for HOV
	• Minimize Energy Consumption	• Energy Consumption	

system based on corridor calculations was less than 1 percent.

- Fuel savings of 10,000 gallons (38,000 L) per day were estimated for the total system.

Signal control is provided by 400 microprocessors in field locations operating ramp signals in a fixed-time/time-of-day mode. Freeway conditions are monitored by a control center computer with override capability on local microprocessors. Detection is provided by loop detectors in freeway lanes and on-ramps.

Incident management provides a further reduction of congestion through rapid response to an average of 20 major incidents per month (a major incident is defined as a lane blockage of two or more lanes for more than 2 hr). The control center is manned 16 hr per day, seven days a week, by a traffic engineer, a maintenance representative, and a law enforcement official. The California Highway Patrol maintains a liaison officer at the traffic system operation section for close coordination of design and operations. As a result of close coordination between operation and enforcement, violations of ramp signals are less than 5 percent. Estimated time for completion of the total system of ramp metering is between 2 and 3 yr. (This information is from a personal interview with Richard J. Murphy, California Department of Transportation, Traffic Operations Systems, February 5, 1981.)

Minneapolis Ramp Metering and Preferential Bus Access

This project (*12, 13*) provided for preferential bus access and for surveillance and ramp metering on approximately 18 miles (29 km) of I-35W in Minneapolis. The significance of the project is its combined use and evaluation of two TSM strategies, plus support measures of express bus operation, park-and-ride lots, and bus shelters.

The I-35W corridor extends approximately 2 miles (3 km) on either side of the freeway south from the Minneapolis central business district (CBD). The project included the metering of all freeway access ramps within the corridor, construction of nine bus access ramps, installation of 71 mainline vehicle detector stations, and 12 CCTV camera locations. The objective of the project was to improve the efficiency of the existing freeway through improved traffic operation and increased transit use.

Express bus operation in mixed flow began in the fall of 1972, with no surveillance or ramp control. Construction of the nine preferential bus ramps was completed in 1973, and ramp metering and surveillance began in the spring of 1974. The project was evaluated against the preestablished objectives after 6 months of operation.

Three types of bus ramps were used for the preferential access: (a) slip ramps from the frontage roads, (b) widened ramps at existing locations, and (c) dual ramps with medians, also at existing locations. Of the three types, the slip ramp was reported to provide the best access; both other types prevented bus access when queues extended onto surface streets. Once they had entered the freeway via the special ramps, buses moved in mixed flow to their destinations.

After 6 months of ramp metering and preferential bus access, northbound a.m. peak travel had decreased 4 percent and southbound p.m. peak travel had increased by 2 percent. Northbound a.m. mean speeds increased 32 percent, from 34 mph to 45 mph (55 to 72 km/h), during the peak hour. Southbound p.m. mean speeds increased 18 percent, from 34 mph to 40 mph (55 to 64 km/h), during the peak hour. No negative impact on parallel arterial streets or on CBD streets was reported. Average delays at ramp meters during the peak hour ranged from 0.1 to 2.5 minutes. The violation rate at ramp controls was 1 percent.

Transit use for CBD-oriented trips increased from 33 percent before full express bus service to 39 percent after the project was completed. Express bus service produced travel time savings of 25 percent to 50 percent, compared with transit routes on parallel arterial facilities. Express bus speeds increased from 39 mph (63 km/h) before ramp metering to 48 mph (77 km/h) after ramp metering. Contraflow bus lanes in the Minneapolis CBD also contributed to increased travel speeds.

Express bus ridership increased from 2,100 average daily passengers after initiation of the express bus service to 7,100 daily passengers at the end of the evaluation. The required subsidy on each express bus passenger increased to $0.61 per passenger from $0.42 per passenger on the initial express bus runs. For comparison purposes, it should be pointed out that the deficit per bus passenger on the local system was $0.16 at the time express bus subsidy was $0.61, reflecting higher costs of the express bus due to the limited number of runs during the peak hour. Park-and-ride lots and shelters were used by 15 percent of the total express bus passengers. At the end of the 6-month study period, 1,050 auto drivers (31 percent of all express bus users) had shifted to transit.

The metering system has maintained the capacity of I-35W to the present. As of December 1980, northbound a.m. peak-hour mean speeds were 47 mph (76 km/h) averaged over a 5-yr period. Similar results were reported in the p.m. peak-hour travel, and traffic accidents decreased 21 percent, from 421 accidents per yr for 2 yr prior to metering to 334 accidents per yr over a 5-yr period following the installation of metering. Freeway volumes increased by 17 percent from 1973 to 1978, and ridership on I-35W express buses increased to 11,300 riders per day in 1979. These express buses currently carry 42 percent of all person-trips to the Minneapolis CBD. Other freeway segments are programmed for ramp metering in the Minneapolis-St. Paul area by 1983. (This information is from a personal interview with Glen C. Carlson, Manager, Traffic Management Center, Minnesota DOT, December 3, 1980.)

Shirley Highway Reversible HOV Lanes

The separate, reversible lanes for buses instituted in 1969 in the Shirley Highway (a radial freeway from Washington, D.C., into Virginia) constituted the first "busway" in the United States. It is an illustration of a freeway in which lanes are separated from regular traffic and are reversed daily to meet peak-period demands for express buses.

The reversible HOV lanes were opened in stages beginning in 1969, when the first section of 4.8 miles (7.7 km) was opened. The freeway cross section consisted of three freeway lanes in each direction plus the two reversible lanes in the median. In late 1975 the total 11 miles of reversible lanes were completed. Bus service was developed in increments to match the staged development of the busway. Ninety demonstration project buses were purchased for the project and were put in service between 1971 and 1973. Three fringe parking lots were opened in 1971–72, two lots using shopping center parking and one being constructed as a permanent park-and-ride facility. Bus passenger shelters were installed during 1973 and 1974. In December 1973 the reversible lanes were opened to car pools with four or more occupants. Transport operations were assumed by the Washington Metropolitan Area Transit Authority (WMATA), and transit service was expanded within the corridor.

The Shirley Highway reversible lanes project (*14*) was an Urban Mass Transportation Administration (UMTA) demonstration project. As such, it sought to demonstrate that bus-on-freeway operations can improve the quality of bus service and lead to increased ridership. Goals were to improve efficiency of the freeway, reduce travel time for both autos and buses, improve transit service, and reduce auto emissions and energy consumption. After the project was complete, 92 percent of all express buses arrived at the first stop in Washington within 6 min of the scheduled time. Prior to the project only 33 percent had such schedule reliability. Daily a.m. peak period (6:30–9:00) patronage on express buses rose from 4,200 riders in June 1969 to 16,000 riders in November 1974.

In November 1974 the Shirley Highway carried nearly 36,800 persons during the morning peak period. This includes 16,100 bus riders and 4,630 car poolers on the reversible lanes, and 16,070 auto commuters. The average number of persons per lane during the a.m. peak hour (7:00–8:00) was 2,310 per freeway lane and 6,080 per reversible lane. Thus, per lane, the reversible lanes carried 2½ times the commuters in the freeway lanes. A total of 7,600 autos had been eliminated daily from the freeway during the peak period, resulting in a 21 percent reduction in auto emissions and a 23 percent reduction in gasoline consumption.

In 1980 there were 9,053 autos per hour inbound on the freeway at the maximum point during the a.m. peak hour and 2,372 HOVs in the reversible lanes. The total for inbound vehicles during a 13-hr count for freeway and HOV lanes was reported as 60,400 vehicles. During the peak hour the two HOV lanes carried 58 percent of the total inbound commuters, compared with 42 percent carried by the three freeway lanes. (This information is from a phone conversation with Ronald Sarros, Assistant Director of Transportation Planning, Metropolitan Washington Council of Governments, February 19, 1981.)

Banfield Freeway HOV Lanes

The Banfield Freeway (I-84) in Portland, Oregon, was initially constructed (1951–58) as a six-lane facility from the Portland central area to 39th Avenue and as a four-lane facility from 39th Avenue to 74th Avenue. In 1975 HOV lanes were added to the freeway. This project (*15–18*) illustrates the add-a-lane procedure for reserving a freeway lane for HOV.

The Banfield Freeway is the primary commuter route to the Portland CBD from east Multnomah County. Between 1960 and 1970 the average weekday traffic on the freeway increased from 40,000 to 100,000 vehicles. By 1975 serious peak-hour congestion on the four-lane section reduced the average speed to less than 15 mph (24 km/h). Also, the pavement had deteriorated to an unsafe condition.

A technical advisory committee consisting of representatives from the Oregon Department of Transportation (DOT), the Oregon State Police, the City of Portland, Multnomah County, Tri-MET (regional transit operator), and local civic groups was formed by the Oregon DOT to evaluate alternatives on the Banfield Freeway. The decision was made to replace the median barrier, overlay the roadway surface and the shoulder with asphaltic concrete, restripe the four-lane segment for six lanes, and operate the median lane as an HOV lane between 74th and 21st avenues westbound and between 44th and 74th avenues eastbound. Buses were to operate in mixed flow in all other segments. No shoulders were available for emergency parking, so seven parking bays were provided. When the construction was complete in December 1975, HOV lanes were reserved for buses and car pools (three or more persons) for 24 hr daily. After substantial public criticism, reservation of the HOV lane was reduced to the hours between 6:00 and 10:00 a.m. westbound and 3:00 and 7:00 p.m. eastbound.

Objectives of this project were to (a) reduce air pollution by increasing the number of persons per vehicle; (b) reduce traffic congestion on the freeway and on parallel arterial facilities; (c) improve safety; (d) reduce travel time and fuel consumption; and (e) provide an interim, low-cost improvement to the freeway "until such time as a major revision can be accomplished." An evaluation study conducted after 18 months of HOV lane operation reported the folowing results:

- Increased average weekday traffic on the freeway (higher than projected for the freeway, had the HOV lane not been added);
- Three percent decrease in traffic volumes on three parallel arterials;
- Increased average peak-hour occupancy rate for all lanes, from 1.217 to 1.262 persons per vehicle;
- Annual travel time savings of 62,500 person-hours;
- Increased express bus ridership (two-way), from 300 to 633 persons per day;
- Increased car pools during peak-hours, from 106 to 578;
- Increased air pollution (2 percent).

In February 1979 the HOV lane was opened to car pools of two or more persons. This change resulted from the finding that in the a.m. peak hour 3,750 vehicles used the two freeway lanes and 200 vehicles used the HOV lane. As a result of the change, average speeds in the freeway lanes increased from 33 to 48 mph (53 to 77 km/h) in April 1980. In January 1981, 1,244 car pools used the HOV lane during the a.m. peak and 747 carpools during the p.m. peak. Violation rates decreased from 24 percent during the a.m. peak prior to the two-person car pools to 4 percent after; however, the violation rate has since increased to 9 percent in January 1981 (*19*). On April 15, 1980, enforcement on the Banfield Freeway was transferred from the Oregon State Police to the City of Portland. (This information is from personal interviews with Robert N. Bothman, Administrator, Metropolitan Branch, Oregon DOT, and Laurel Wentworth, City Planner, City of Portland, February 4, 1981.)

Miami I-95 Exclusive Bus/Car Pool Lane

The significance of this project lies in the provision of additional freeway lanes for exclusive use of buses and car pools, the construction of a new park-and-ride lot and its direct connection to the exclusive lanes via a "flyover," and the provision of new buses for express operation on the freeway to three major employment centers. The objectives of the project (*20–23*) were to reduce congestion on I-95 and increase the operating efficiency of the freeway through preferential treatment of HOVs.

The I-95 corridor for this project is approximately 11 miles (18 km) in length from north of the Miami CBD to the Golden Glades Interchange. The corridor connects the residential areas in northern Dade and southern Broward counties with the Miami CBD, the Civic Center area, the N.W. 36th Street employment area, and the Miami International Airport. Prior to the project, I-95 consisted of five lanes in each direction between the Miami CBD and the Airport Expressway, four lanes in each direction between the Airport Expressway and N.W. 135th Street, and three lanes in each direction from N.W. 135th Street to the Golden Glades Interchange.

Under the project an extra lane in each direction was constructed in the median for exclusive use by buses and car pools between the Airport Expressway and the Golden Glades Interchange. The existing median lane of the 10-lane section south of the Airport Expressway was used as a continuation of the exclusive bus/car pool lanes. No barrier exists between the exclusive lanes and the regular lanes. Only overhead signing and a single solid paint stripe separates the exclusive lane. Construction of the exclusive bus/car pool lanes was completed in December 1975 and was opened for express buses and car pools with three or more occupants. Three occupants were considered the minimum for a car pool inasmuch as studies had found that up to 29 percent of all vehicles had two occupants and only 5 to 7 percent had an occupancy of three or more. The car pool occupancy was later reduced to two, due to enforcement problems.

Express bus service had been provided on I-95 since 1974, and buses were switched to a parallel arterial during construction of the new exclusive lanes. Thirty new, full-size buses were purchased for the project and were placed in operation in March 1976. A 1,000-space park-and-ride lot was constructed at the Golden Glades Interchange and was connected to the exclusive lanes through a flyover, which was completed in June 1976. Transit service was expanded to 55 trips per day, and new residential areas north of the Golden Glades Interchange were served.

At the completion of the project, travel times decreased for all traffic. Afternoon peak period express buses experienced a decrease in travel time of 40 percent (12.8 min to 7.8 min during the three-person car pool operation. A 27 percent reduction (from the original 12.8 min to 9.4 min) occurred after two-person car pools were permitted in the exclusive lane. The number of southbound vehicles on I-95 during the a.m. peak increased 20 percent—from 15,200 before the lanes were opened to 18,200—reflecting improved travel conditions. Car pools increased from 390 three-person car pools prior to the project to 680 three-person car pools during the three-person phase, and to 540 three-person car pools after the two-person car pool was permitted. Transit ridership on the express buses rose from 1,064 daily trips in May 1974 to 1,683 daily trips after project completion, and transit travel times were reduced.

Enforcement was difficult even though seven officers were assigned to the section of freeway with exclusive lanes. With no storage capacity adjacent to the exclusive lane, officers had difficulty stopping violators. An officer either could follow violators to their destination or require them to traverse three to four lanes to the outside shoulder. The violation rate was 75 percent (three out of every four vehicles in the lane were illegal) with the three-person car pool. This rate was reduced to 37 percent after two-person car pools were permitted. No statistical increase in accidents occurred after the project was implemented.

San Bernardino Freeway Express Busway

This project (*24–26*) illustrates the successful addition of a busway in a major freeway corridor while maintaining the capacity of the existing freeway. The project cost was high ($57 million) and far above that cost normally thought of as low-cost TSM, but it provides an excellent example of joint use of right-of-way for multimodal operation.

The busway in the Los Angeles San Bernardino Freeway (I-10) corridor is an 11-mile (18-km), double-lane roadway for HOVs. With off-line stations, park-and-ride facilities, feeder bus lines, outlying park-and-pool lots, and a downtown reserved (contraflow) bus lane, the busway "is the most complete facility of its kind in the country." The first segment (east portion) was opened in January 1973, and the west portion was opened in May 1974. All parking facilities were completed by March 1976. The facility was operated for buses only until October 1976, when the lanes were opened to car pools (three or more occupants) between the hours of 6:00 and 10:00 a.m. and 3:00 and 7:00 p.m.

The eastern segment of the busway is in the median of the freeway. The busway's directional lanes are 17 ft (5 m) wide and are separated by a median barrier, and both lanes are separated from the freeway lanes by a 10-ft (3-m) "buffer shoulder" with flexible posts. In the western segment of the busway, lanes are 12 ft (3.6 m) wide, separated by a 20-ft (6-m) median and median barrier. The western segment of the busway is physically separated from the freeway on the north side of the freeway. Special access ramps for buses and car pools are provided at only two locations in each direction. A major bus station is provided at the eastern terminus, and there are two off-line stations along the busway.

The goals of this project were to (a) provide added corridor capacity, (b) reduce environmental impacts of corridor travel, (c) improve level of service for corridor travelers, (d) reduce the personal cost of travel, (e) improve the safety of corridor travel, and (f) provide for future contingencies (e.g., a future rail line). An evaluation report in July 1978 highlighted the following results:

- Bus ridership grew from 1,000 to 14,500 daily passenger trips and has generally stabilized since 1976.
- Opening the busway to car pools more than doubled the number of car pools, with an increase of 800 newly formed car pools.
- Average occupancy per car pool was 3.3 persons.
- Freeway traffic remained at or near capacity for about 3 hr out of each 4-hr a.m. and p.m. period.
- Although the freeway demand was near capacity during most of the 4-hr period, the busway showed a sharp 1-hr peak, which may have been "an expression of desired commute times versus the capacity-constrained commute times on the freeway."
- Travel time for buses on the busway is 14 min, which includes two station stops. Car pool travel time is 12 min. Freeway travel time is 30 min during normal operations and greater during incidents on the freeway.
- Vehicle miles of travel were reduced by 150,000 miles (240,000 km) per day from only those trips attracted to the busway.
- Reduction in air pollution emissions ranged from 10 to 20 percent and energy savings ranged from 7 to 10 percent of the 4-hr peak direction totals on the freeway.

Diamond Lane Project for Exclusive Bus/Car Pool Use

This project (*27–30*) because of the negative public reaction to it, is perhaps one of the best-known exclusive bus/car pool lane projects in the United States. It illustrates the take-a-lane concept for HOVs on a major freeway.

The Santa Monica Freeway runs for 14 miles (23 km) west of the Los Angeles CBD to Santa Monica. The corridor contains numerous arterials, and the area is served by local transit as well as express buses on both arterials and the freeway. The Santa Monica Freeway consists of four and five lanes of traffic in both directions. Before the diamond lane project only four feeder/express routes operated on the freeway. Volumes on the freeway were as high as 240,000 vehicles per day. The freeway was equipped before the project with ramp metering in which 31 on-ramps were metered, 12 of which provided preferential access to buses and car pools (two or more occupants).

The diamond lane project consisted of removing the median lanes from normal flow and dedicating their use to transit vehicles and car pools (three or more occupants) from 6:30 to 9:30 a.m. and from 3:00 to 7:00 p.m. The median lanes were painted with white, diamond-shaped symbols to signify their exclusive use. The project, which was adopted by the Southern California Association of Governments (SCAG) in 1974 as part of the Transportation Control Plan to meet requirements of the Clean Air Act of 1970, had as its other objectives the conservation of motor fuel and the improvement of the operating efficiency of an urban freeway through greater use of HOVs.

The diamond lanes were opened on March 15, 1976, and operated for 21 weeks, until a U.S. District Court ruled the project invalid because an environmental impact report had not been filed. During the operation the project was the subject of public criticism, and at least 245 articles and editorials in opposition to the project appeared in three major Los Angeles newspapers.

During the first seven weeks of the diamond lane operation, freeway volumes during the seven peak hours dropped 32 percent, from 113,000 vehicles to 77,000. During the last seven weeks this volume had increased to 102,000, 9 percent less than before the project implementation. The City of Los Angeles traffic engineer estimated that traffic volumes on parallel arterials were up by 17 percent during the project. Although the ramp metering effort had made the peak hour trip time shorter and less variable, trip times in nonpriority lanes increased after the diamond lanes were opened. Travel time from Santa Monica to the Los Angeles CBD increased from between 17 and 20 min to between 27 and 35 min.

Travel times in the exclusive lanes decreased, even with the delays in crossing three travel lanes to the diamond lane. The eastbound travel time for car pools was reduced from 22.7 min prior to ramp controls to 20.5 min during the last seven weeks of the diamond lanes. Travel times, however, had averaged 15.7 min after ramp metering had been provided but before diamond lanes were implemented. Bus travel times, for a sample of 15 trips, decreased 42 percent, from 57 min from Santa Monica to the Los Angeles CBD to 33 min with the diamond lanes.

Transit ridership increased with the diamond lanes and the provision of park-and-ride lots. Express bus trips in the corridor increased from 18 before the diamond lanes to 74 after implementation of the project. Bus ridership on all freeway routes increased from 1,171 daily trips to 3,793 daily trips during the last week of operation. Surveys indicated, however, that it was the expanded transit coverage that attracted commuters to buses rather than time savings and reliability of operation. The official park-and-ride lots were not judged to be successful; however, several informal lots operated effectively with the express bus service. Express buses proved to be very costly because only a few buses could make more than one run during the peak hour.

Accidents increased to a rate of twice that before the exclusive lane was implemented. Accident rates were higher in the freeway lane adjacent to the diamond lane as motorists' attention was diverted to the faster-moving traffic in the diamond lane. Enforcement proved extremely difficult, with violations in the exclusive lane running as high as 20 percent.

Although coordination meetings were held with agencies, civic groups, and news media personnel prior to implementation of the diamond lane, many of the persons did not perceive the importance of the project or the negative public reaction and for this reason did not participate regularly in the planning. The project vividly pointed out the problem of take-a-lane implementation of HOV lanes. (This information is from a personal interview with C. Gary Bork, Senior Engineer, Traffic Operations, California Department of Transportation, February 5, 1981.)

Boston Southeast Expressway Downtown Express Lane

The dedication of the Southeast Expressway lane for HOVs was proposed to reduce auto traffic on the freeway during a reconstruction project that reduced freeway capacity by 25 percent. The project (*31–34*) provides another illustration of problems encountered in the take-a-lane concept of reserved lanes for HOVs.

The downtown express lane was instituted in May 1977, 4 weeks prior to the start of the construction project. The reserved lane operated inbound only during the a.m. peak (6:30–9:30 a.m.) for buses and car pools (three or more occupants). Access to the reserve lane, which was identified by pavement markings and plastic inserts, was gained from the normal freeway lanes. An extensive effort was made in the month prior to opening the express lane to inform the public through the news media of the need for and operation of the express lane.

During the initial months of the construction period (June–September) the operation of the freeway deteriorated to the extent that there appeared to be little difference between the express lane and the regular freeway lanes in terms of congestion and vehicle occupancy. Vehicles in the regular lanes during this construction period did not experience a decrease in service; rather travel times decreased for both the reserve lane and the freeway lanes as the average vehicle occupancy increased from 1.30 to 1.36 persons per auto. Compliance was voluntary, and the violation rate ran as high as 80 percent. No increase in accidents was reported.

Strict enforcement began on October 17, 1977, and violators were mailed a $20 citation through license plate identification. The violation rate declined to 35 percent; however, congestion in the freeway lanes became intolerable, and the average trip took almost 8 min longer on the 8-mile (13-km) section. After 2½ weeks of intense public pressure on state officials, the reserved lane operation was suspended. Local news media described the suspension as "good news."

Other observations and results of the project were as follows:

- At the suspension of the express lane, the freeway was carrying 8 percent fewer people and the number of automobiles had declined 16 percent.
- During the month before the freeway construction, over 50 percent of the reduction in autos was attributed to higher vehicle occupancy. Ridership on parallel rapid transit facilities increased to account for 25 percent of the reduction in autos. The remainder of the reduced number of autos diverted to alternative routes.
- Bus ridership on freeway routes increased by only 6 percent during the project.
- The compliance rate was inversely proportional to the number of car pools available to fill the lane during voluntary compliance.

Houston North Freeway Contraflow Lane

In August 1979 the Texas State Department of Highways and Public Transportation and the Metropolitan Transit Authority began operation of express bus and van pool service on the median lane of the off-peak direction on the North Freeway (I-45) in Houston. The significance of this project (*35,36*) lies in its use of the contraflow concept for HOV lanes. It is the longest (9.6 miles) (15 km) contraflow project in operation and the only one that operates during both peak periods.

The North Freeway varies from 6 lanes at the northern end of the HOV lane to 10 lanes near the Houston CBD. The facility was considered appropriate for contraflow lane operation because the traffic split between peak and off-peak traffic was 65/35 and parallel arterial routes in the corridor were available for any diverted traffic. The project was initiated by the City of Houston and was funded as an UMTA demonstration grant. Total capital cost of the project was $2.2 million, which included a ramp metering system in both peak and off-peak directions, overhead lane signs, and three park-and-ride lots. Entry into the contraflow lane is controlled by manually operated gates. Plastic pylons, placed and removed daily, separate the contraflow lane from opposing traffic.

The contraflow lane is reserved for buses and van pools (eight or more occupants), and no thought is currently being given to permitting its use by car pools. The contraflow lane operates between the hours of 6:00 and 8:30 a.m. and 4:00 and 6:30 p.m. Enforcement was initially provided by six Houston Police Department patrols, but after 8 weeks the number of patrols was reduced to two. Monthly cost of pylon placement, enforcement, facility maintenance, and repair is $45,000.

Speed limits for the contraflow lane were initially established at 45 mph (72 km/h), primarily for reasons of safety. After an excellent safety record was established—only two accidents after 650,000 vehicle-miles (1,000,000 km) of travel in the contraflow lane—the speed limit was raised to 55 mph (88 km/h).

Use of the contraflow lane initially was 1,200 persons-trips per peak period. After 44 weeks of operation this figure had risen to 4,300 person-trips. Bus ridership increased from less than 500 person-trips per peak hour to 2,400. Travel time on the contraflow lane during the a.m. peak is approximately 11 min, and travel time for the corresponding distance on the freeway is 33 min. The contraflow lane has not changed operating characteristics of the freeway peak direction of travel.

Golden Gate Bus/Car Pool Lane, Van Pool, Free Toll Program

The Golden Gate Bridge Highway and Transportation District (GGBHTD) provides transit service from Marin and Sonoma counties to San Francisco, operates reversible lanes on the Golden Gate Bridge, provides a van pool program, operates a ferry system, provides free bridge tolls for car pools to increase ride-sharing, and, with the California Department of Transportation, operates contraflow and with-flow bus/car pool lanes on the U.S. 101 freeway. The significance of this project (*37–39*) is the combination of TSM measures implemented by a single transportation agency.

The U.S. 101 freeway is the major north-south facility from San Francisco to residential areas north of San Francisco. The Golden Gate Bridge has six undivided lanes, two of which are reversed for a four/two operation during the peak hours. U.S. 101 has four freeway lanes in each direction and serves as the central trunk line of the transit system.

The California Department of Transportation operates an exclusive bus/car pool lane on U.S. 101 to promote ride-sharing and to increase the speed and schedule reliability of buses. The exclusive lane consists of a 3.7-mile (6-km) with-flow lane southbound in the a.m. peak and a 7.7-mile (12-km) combination contraflow and with-flow lane northbound in the p.m. peak. All with-flow lanes are opened to car pools and van pools with three or more persons. Only buses are permitted on the contraflow lanes. Two southbound lanes are used for the single northbound contraflow lane. Pylons are manually placed in the southbound number three lane, which serves as a buffer between regular traffic flow and contraflow buses. Electronic signs operate at the northern terminus of the contraflow lane when the reverse flow is in operation. The exclusive lanes operate between 6:00 and 9:00 a.m. and between 4:00 and 7:00 p.m.

Express buses on the exclusive lanes save 6 min in travel time during the a.m. peak and 3 min in the p.m. peak. Schedule reliability improved significantly with the operation of the exclusive lane. A total of 225 buses operate on the exclusive lane, carrying 8,300 passengers daily and having an occupancy rate of greater than 90 percent.

Bridge tolls and transit fares are balanced by GGBHTD for operating revenues and modal split. Auto bridge tolls and transit fares are often raised concurrently to maintain the modal balance. Free bridge tolls are provided to car pools with three or more passengers.

In October 1977, as part of an UMTA demonstration program, GGBHTD began the operation of a van pool program in which vans purchased by GGBHTD were leased to qualified drivers of van pools. Within 8 months, 30 van pools had been organized, and they contained 287 commuters. The average round trip per van is 80 miles (130 km). Van pool drivers are provided with personal-use incentive up to 350 miles/month at $0.11 per mile (560 km at $0.07/km). No excess passenger fares are paid to the driver. GGBHTD vans are used to seed van pool groups of privately owned or employer-owned vans on a continuing basis. Marketing is accomplished through distribution of van pool applications to potential van poolers as they pass through the bridge toll gate.

San Antonio Freeway Corridor Management

In 1975 the Texas State Department of Highways and Public Transportation (SDHPT) organized a team in San Antonio to coordinate freeway operations and corridor management. The concept of a corridor management team (CMT) has since been expanded to six Texas cities. The SDHPT circulates a bimonthly corridor management report to all district offices summarizing activities of the various CMTs. This effort (*40,41*) illustrates a low-cost means of identifying and coordinating TSM actions within the freeway corridor environment.

In San Antonio the CMT membership consists of representatives from SDHPT district traffic engineering, city traffic engineering and public works, the metropolitan transit authority, and the city police department. Members sign a letter of agreement and meet monthly to discuss problems and corridor studies. Written minutes are provided for each meeting.

The San Antonio CMT initially responded to a corridor problem of radial freeway congestion adjacent to the CBD and three ramps serving the CBD. In response to decisions by the CMT the state conducted speed/delay studies on the freeway to determine sources of the congestion; the city conducted speed/delay studies on alternate routes; the police department accumulated accident data; and the transit agency conducted extensive time studies on scheduled bus routes in the vicinity. From the CMT came a decision to adjust cycle lengths on ramp meter controllers, adjust signal timing on parallel arterial routes, and select alternate routes for park-and-ride express buses. The public was informed of these activities through the public affairs offices of all agencies. Congestion on the freeway was reduced as a result of the CMT's efforts.

Other areas of involvement of the CMT include special events, inclement weather conditions, high-accident locations, traffic control plans, and citizen complaints.

EVALUATION AND GUIDELINES FOR IMPLEMENTATION

Perhaps more work has been done on identifying and evaluating TSM measures for the freeway corridor than for any of the other TSM operating environments. Capelle (*42*) has provided an excellent overview of freeway management opportunities to solve both recurring and nonrecurring freeway problems. Levinson and others (*43,44*) have developed state-of-the-art evaluations and guidelines for effective use of buses on freeways. Rothenberg (*45*) and Samdahl and Rothenberg (*46*) have similarly suggested guidelines for HOV systems and means of providing preferential access to freeways by HOVs. Many of these TSM measures have been successfully implemented on urban freeways through projects funded by the Federal Highway Administration and UMTA, including ramp metering, busways, and combinations of management support techniques such as surveillance, changeable message signs, and accident removal.

Yet many opportunities remain for the implementation of TSM measures within the freeway corridor. Implementation has been made easier by experience and the standardization of techniques, so fewer hit-and-miss approaches are necessary. The guidelines included in this section reflect standard criteria developed thus far. Future opportunities also lie in combined strategies affecting travel demand and improving segments of the urban trip and mode choice before reaching and after leaving the freeway.

The primary reason for the advanced implementation of freeway TSM may lie in the fact that in most urban areas the state department of transportation or the highway department has the responsibility for freeway operation. This focus of responsibility may be contrasted with the fragmentation of TSM responsibility in other operating environments. TSM still requires coordination with the municipal traffic engineer and the metropolitan transit authority, yet the leadership is clearly defined.

Guidelines

The following guidelines build upon and summarize conclusions from other work and from implementation experiences in freeway TSM.

- Freeway ramps should be metered to maintain maximum capacity and to discourage use of the freeway for short trips.
- Points of major freeway congestion suggest possible locations for exclusive bus facilities.
- Use of existing freeway lanes in the direction of heavy flow for exclusive use by buses and car pools is generally not considered feasible. With-flow exclusive bus/car pool lanes are generally accepted by the public when the lanes are added to the freeway for that purpose.
- Contraflow lanes for exclusive bus/car pool use are feasible when a large imbalance exists in peak directional flows and when sufficient capacity remains in the off-peak direction after removing the contraflow lane.
- With-flow lanes appear to work best when separated from the general lanes by a permanent barrier. The "appearance of permanence" of the exclusive lanes seems to be an important factor in a commuter's switch to HOVs.
- Public acceptance of the exclusive lane, particularly the with-flow design, is fostered when the bus/car pool lane is well used. This argues for a strong express bus and park-and-ride program.
- Traditionally, exclusive lanes have been implemented with the initial intent of serving only buses; however, in most cases car pools were later permitted to use the lane. Exclusive lanes should consider car pools in the preliminary design of the facility.
- Median lanes rather than curb lanes should be considered for the bus/car pool lane because of the predominance of right-hand entrance and exit ramps in freeway design.
- A median between directional bus/car pool lanes should be included if possible to permit storage for enforcement and emergency parking for disabled vehicles.
- Bypass lanes at metered entrance ramps should be provided for bus access. Design should permit buses to enter independent of the ramp queue.
- Park-and-ride locations should be well chosen to provide an improved level of service to the user. Most success has been achieved when park-and-ride lots are readily visible, paved, fenced, and well lighted.
- Direct bus access from park-and-ride lots to exclusive bus lanes should, if possible, be provided to decrease total travel time.

Support Activities

TSM measures in the freeway corridor quite often require support policies, activities, and measures for successful operation. These support measures include the ones listed below.

Enforcement. Strict enforcement of all freeway TSM measures is necessary, particularly in with-flow bus/car pool lanes. Enforcement procedures should be designed into the project from its original conception.

Bus Collection and Distribution Systems. In addition to park-and-ride lots, bus collection systems expand the service area of transit within the corridor. Similarly, distribution systems and preferential treatment for buses in the CBD or other employment centers is necessary to support freeway express bus service.

Ride-Sharing Programs. Ride-share (car pools and van pools) matching programs and van purchase efforts, whether at a municipal or regional level, provide support for HOV lanes on freeways.

Car Pool Parking. Professional and inexpensive car pool parking in the CBD or other major activity centers served by the freeway encourage the use of car pools and support the HOV lane.

Park-and-Ride Facilities. Park-and-ride facilities are an important support element for exclusive bus lanes on freeways, particularly when the lots are well located and properly equipped.

Freeway Operational Measures. Measures to improve traffic operations are important support activities for freeway TSM. These include surveillance, changeable message signs, communications, and service of incidents.

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CHAPTER THREE

ARTERIAL CORRIDORS

An arterial street is defined by the American Association of State Highway and Transportation Officials (AASHTO) as "a highway primarily for through traffic, usually on a continuous route. Arterial streets cover the range of facilities between freeways and local streets" (*1*). An arterial corridor should include the watershed of trips on the arterial and the collector and local street system within that watershed. In evaluating transportation system management (TSM) for the arterial corridor, one must consider the network within the watershed as a subsystem of the total urban transportation system and look for TSM opportunities within the subsystem in addition to traffic engineering improvements on the arterial facility itself.

Arterial corridors are both radial and circumferential to a major central business district (CBD), and both offer unique opportunities for TSM. Often radial arterials parallel urban freeways and in many instances had served as the major intercity route before the freeway was constructed. With the heavier traffic volumes now on the freeway, these radial arterial facilities offer unique opportunities for TSM in express bus routes and preferential signal treatment for through traffic. Circumferential arterials offer similar potential for TSM in coordinated signal systems and crosstown transit routes.

CHARACTERISTICS

The two characteristics that distinguish arterial streets from freeways are (a) the intersecting streets that cross the arterial at grade and (b) the access provided to abutting property. Speeds on arterials are thus much lower, travel times longer, and potential for conflict with opposing traffic much greater. On the basis of function, arterial streets may be classified as either principal or minor arterials. The principal arterial serves the longer trips and the higher volumes of traffic. The minor arterial interconnects and augments the principal arterial and freeway systems.

These two major characteristics of principal arterials—longer trips and higher volumes—are, of course, the limiting factors in their capacity for efficient movement of vehicles. Yet it is these two characteristics that provide the greatest opportunity for TSM. If access to the arterial facility can be controlled or limited and if the traffic conflict caused by intersecting streets can be minimized by TSM measures, significant saving in travel time can result, and capacity in terms of both persons and vehicles can be increased.

TSM OPTIONS

Improving the efficiency of an arterial street can be related to increasing the person-capacity of the facility with minimum changes to the prevailing roadway. This capacity is determined by the occupancy of vehicles using the facility, roadway conditions, and intersection design and operation. Following are roadway conditions that relate to capacity: lane width, lateral clearance, parking lanes, turning lanes, storage lanes, surface condition, alignment, and grades.

Intersections with cross streets and resultant delays to arterial traffic are major restrictions to traffic flow. Roadway widening only at signalized intersections can often improve traffic flow equivalent to that achieved by widening the entire roadway. Following are design and operational factors that affect the capacity at signalized intersections: width of approach, parking conditions, turning movements, signal control, interconnection of signals at multiple intersections, percentage of trucks, and bus loading.

When considering TSM for an arterial corridor, one should consider first the measures that would positively affect the above conditions, in the following order: (a) intersection design and operation, (b) roadway conditions, and (c) vehicle occupancy. TSM options under each category are listed below (*2–6*).

Intersection Design and Operation

1. Correcting offsets.
2. Addition of left-turn and right-turn lanes.
3. Intersection widening.
4. Improved intersection geometrics.
5. Bus loading at midblock.
6. Turn prohibitions.
7. Traffic signal modernization.
8. Traffic signal coordination and improved timing.
9. Computer control of traffic signals.

Roadway Conditions

1. Removal of on-street parking.
2. Restricting curb openings and property access.
3. Continuous median or restricted median openings.
4. Left-turn prohibition.
5. Bus turn-outs or loading bays.
6. Unbalanced flow.
7. Conversion to one-way pairs.
8. Restriction of truck traffic.

Vehicle Occupancy

1. Improved car pool, van pool, and transit marketing.
2. Separate high-occupancy vehicle (HOV) lane for buses, car pools, and van pools.

3. Preferential treatment for HOVs through traffic control devices.
4. Intersection access control and preferential bus/car pool access.

MOTIVATION FOR ACTION

TSM actions in arterial corridors are quite frequently motivated by congestion and the resultant delays and high accident rates on the arterial facility itself. In many instances, however, TSM measures are implemented in response to a recognition of unused capacity on the arterial, particularly when considered in relation to congestion on a parallel freeway. In other words, motivation often comes from traffic conditions outside the arterial corridor. New express transit routes are sought, for example, and the arterial is seen as a direct alignment with unused capacity.

On the arterial itself, opportunities can be seen for TSM. For example, on arterials with unbalanced flow during the a.m. and p.m. peak periods, the unused capacity in the contraflow direction is seen as a means to encourage use of HOVs. Other opportunities may be seen to improve the efficiency of the facility through improved traffic engineering features. Some of the more common motivations for TSM measures within an arterial corridor are listed below:

- Traffic congestion problems on the arterial street.
- Sluggish traffic flow through intersections.
- Restrictions on traffic flow at midblock locations as a result of access drives, parking, reduced lateral clearance, etc.
- Recognized inefficiency in unnecessary traffic signal delays through poor signal timing or lack of signal coordination.
- Excessive accident rates or accident severity.
- Traffic congestion on parallel freeways and/or arterials and a search for supplemental capacity.
- Recognition of unused capacity and potential for diverted traffic.
- Recognition of unused contraflow capacity and the potential to encourage HOVs.
- Environmental requirements to reduce emission from mobile sources.

GOALS, OBJECTIVES, AND PLANNING ANALYSIS

TSM goals in the arterial corridor deal primarily with improved traffic conditions, in contrast to goals in other operating environments, where the focus is on factors other than mobility. Some goal conflict, of course, is apparent between the abutting property owner contesting for access to the arterial and the auto driver on the arterial seeking improved traffic flow. Table 2 includes some of the more common goals and objectives associated with arterial TSM measures and the measures of effectiveness (MOEs) for their evaluation.

Many of the traditional traffic engineering measures, such as on-street parking removal and restriction of property access, can be accomplished with little analytical evaluation

TABLE 2

GOALS, OBJECTIVES, AND MOEs FOR THE ARTERIAL CORRIDOR OPERATING ENVIRONMENT

Goal	Objective	MOE	TSM Measures for Each Goal
Maintain or improve the quality of transportation services on the existing transportation system	• Minimize Travel Time	• Person Hours of Travel • Vehicle Delay	Interconnected Signal Systems Computer Controlled Signal Systems Traffic Engineering Features such as: Addition of Turn Lanes Intersection Widening Improved Intersection Geometrics Removal of On-Street Parking Restricting Property Access
	• Minimize Travel Costs	• Point-to-Point Out-of-Pocket Travel Costs	
	• Maximize Safety	• Accidents • Accident Rate	
Increase the efficiency of the existing transportation system	• Minimize Auto Usage	• Number of Carpools • Traffic Volume • Vehicle Miles of Travel	Exclusive Bus/Carpool Lanes Preferential Treatment for HOV through Signal Control Devices
	• Maximize Transit Usage	• Transit Passengers	
Minimize the undesirable impacts of existing transportation facilities	• Minimize Air Pollution	• Tons of Emissions	Exclusive Bus/Carpool Lanes Preferential Treatment for HOV through Signal Control Devices Intersection Access Control Interconnected Signal Systems Computer Controlled Signal Systems

prior to implementation. Much is to be gained, however, by an analysis of the arterial corridor and the evaluation of alternative TSM packages prior to implementing TSM within the corridor. Such planning analysis can range from manual calculations on individual TSM measures to traffic simulation for determining the synergystic impacts of combinations of TSM strategies. Literature is available on both approaches to the planning analysis (*7–10*).

IMPLEMENTATION EXPERIENCES

Miami South Dixie Highway Bus/Car Pool Lane

This project (*11,12*) is illustrative of an exclusive bus/car pool lane and signal modifications on a six-lane divided arterial. Modifications to the South Dixie Highway (U.S. Hwy. 1) established a separate lane for express buses and car pools for a 5.5-mile (8.9-km) segment from Sunset Drive to the Miami CBD. The goal of the project was to increase the people-moving capacity of the arterial facility while providing incentives for use of the new capacity by HOVs.

The project was initiated by the Florida Department of Transportation (DOT) and Metropolitan Dade County on July 22, 1974. At first, buses were operated in a contraflow lane and car pools (two or more occupants) used the median, with-flow lane exclusively. In April 1976 the operation was changed to combine bus and car pools for exclusive use of the median, with-flow lane. Hours of operation for the exclusive lane were 6:00 to 9:00 a.m. and 4:00 to 7:00 p.m. Signal modifications included improved progression, extended cycle length (from 90 to 144 sec, with additional green time for the arterial facility), and reduction to two phases, with left turns from the arterial prohibited. Fifteen signalized intersections were included in the project.

Traffic operational modifications supported the exclusive lane. Signing was placed to identify the separate lane for buses and car pools. Roadway striping was used at all median openings to prohibit left turns through the bus lane. Left turns onto the arterial facility were permitted. The operation has been heavily enforced and has resulted in a violation rate in the car pool lane of less than 8 percent.

Car pools were encouraged by the concomitant establishment of a car pool parking lot in downtown Miami. This lot, which was centrally located, was available only to car poolers and required a minimum parking charge. Within 2 months of the opening, the car pool lot was used 100 percent.

The Metropolitan Transit Authority provided 31 express buses for the a.m. peak and 30 for the p.m. peak. Park-and-ride lots were established at several shopping centers along the arterial. Buses also circulated in neighborhoods to collect passengers and stop at the park-and-ride lots before entering the bus lane. One-way fare in 1976 was $0.60.

An evaluation of the project was conducted after 12 months and again after 2 yr of operation. Transit and car pool travel time had decreased by 5 to 10 min after 2 yr. Bus ridership in the corridor had increased fivefold and has now stabilized at 2,100 passengers per day. Auto occupancy for the facility has increased from 1.38 to 1.60 persons per auto. HOVs on the exclusive lane now carry 40 percent of the total persons using the arterial facility during the peak hour. The facility now carries daily 2,400 more persons in 350 fewer vehicles.

A survey of transit riders and car pool users revealed that 94 percent of the transit riders used the service to get to work and 77 percent had used the auto prior to the express bus service; almost two-thirds of the new transit users had driven alone. Most changed because of the convenience of the express bus. Park-and-ride provided 60 percent of the rider access to the express bus, with over 36 percent walking to the stations. Fuel and time savings were the principal reasons given by new car poolers for their change of mode.

Enforcement played an important role in the success of the project. The cost of manually placing traffic cones for protection of the contraflow lane was the primary reason for switching to with-flow operation.

Honolulu Kalanianaole Highway Bus/Car Pool Lane

This project (*13,14*) illustrates the operation of a contraflow bus lane on a four-lane undivided arterial. The bus/car pool lane was initiated as a joint project of the Hawaii State DOT and the City and County of Honolulu Department of Transportation Services to relieve morning peak congestion and provide inducement for increased use uf HOVs.

Kalanianaole Highway is the major roadway serving the eastern portion of the island of Oahu. Rapid urbanization had by 1973 increased the traffic volumes on the arterial facility to the extent that heavy congestion and long delays characterized the facility, particularly during the morning hours. Studies in 1971 and 1972 recommended an exclusive bus lane, and household surveys indicated that express bus service to downtown Honolulu and the University of Hawaii was feasible. The Hawaii Kai express bus began service on August 21, 1973, in a contraflow lane for 1.9 miles (3.1 km) on the four-lane undivided section of the highway and in a with-flow exclusive lane (median lane) for about one-half mile (0.8 km). Fourteen buses operated to the Honolulu CBD, and six buses provided express service to the University of Hawaii from 6:00 to 8:00 a.m.

On September 15, 1975, the exclusive bus lane was opened to car pools with three or more occupants. The action was in response to interests expressed by state and local elected officials, plus the public at large.

The operation of the contraflow lane permits peak-hour westbound traffic to use the inside lane of the normally eastbound direction. The contraflow lane is delineated by the placement of traffic cones and portable traffic signs. Eastbound traffic is handled by the single lane during the a.m. peak. At Kirkwood Street the Kalanianaole Highway becomes a six-lane divided arterial and the bus/car pool lane crosses the median and continues with-flow in the median lane.

An extensive study by the Federal Highway Administration (FHWA) in 1977 evaluated the project against criteria that included modal split, vehicle and passenger volumes, effectiveness of traffic control devices, and public attitudes. The exclusive lane in 1977 carried approximately 16 buses with 660 riders and 1,200 autos with 3,600 occupants during the 2-hr operation.

The average auto occupancy for Kalanianaole Highway increased from 1.70 with the opening of the exclusive lane to car pools to 1.84 a year later. Bus patronage remained constant between initial opening of the exclusive lane to buses and the evaluation almost 4 yr later. Transit ridership as a percentage of the total person-trips on the facility declined from 16 to 11 percent. This, of course, reflects increasing volumes of total traffic (including car pools), which increased 22 percent—from 3,850 vehicles during the peak 2-hr period to 4,730 vehicles in 1977. The auto traffic in the exclusive lane is only 21 percent of the total vehicular traffic but carries 39 percent of the total auto-person trips.

In a comparison of travel times in late 1976, buses and car pools on the bus/car pool lane required only 7 min to traverse the study limits, and traffic on regular lanes required 10 min. Average auto travel time on the study section of Kalanianaole Highway decreased 10 percent with the bus/car pool lane, despite a 3 percent increase in vehicle-miles of travel and a 10 percent increase in person-miles of travel.

The project was judged a success by the public, as revealed in attitudinal surveys. More than 70 percent of users, elected officials, and the public at large felt the exclusive lane had improved traffic conditions. Eighty percent felt that more people were using car pools. Ninety-two percent of users indicated that their trip purpose was the work trip, and 12 percent of respondents had switched from non-car-pool vehicles to car pools.

In the analysis, the need to remove legal constraints prior to the project was noted, as was the resistance to the exclusive lane developed by abutting property owners, who felt the facility was being used to benefit suburban dwellers at their expense and inconvenience.

Madison (Wisconsin) Arterial Contraflow Bus Lane

This project (*15*) provides an evaluation of a contraflow bus lane on a major arterial serving as a portion of a one-way couplet. Its significance lies in the evaluation that occurred following removal of the bus lane after 13 yr of operation.

A contraflow bus lane was constructed along a 0.9-mile (1.4-km) section of University Avenue in 1966 in conjunction with one-way traffic flow on University Avenue (westbound) and parallel West Johnson Street (eastbound). University Avenue consisted of four lanes for westbound traffic plus one added lane for eastbound bus service. The one-way arterial pair provides principal access to the Madison CBD through the University of Wisconsin campus.

Opposition to the bus lane began to develop in 1967, when a student walked into the side of a bus in the contraflow lane and was seriously injured. Unauthorized use of the bus lane by bicycles increased to the point where, in 1978, the lane was being used by 300 bicycles per hour operating with 40 buses per hour. Opposition to the contraflow lane was vocal and argued that the operation was unsafe with the amount of bicycle traffic and the large volumes of pedestrians crossing University Avenue.

A 90-day trial was ordered by the City Council in April 1979 for relocation of the eastbound bus routes to West Johnson Street to operate in mixed flow. During the trial the contraflow lane was closed to all traffic except eastbound bicycles. Prior to the trial period the curb lane of University Avenue had been reserved for westbound buses, right-turning vehicles, and bicycles. Evaluation of the change was accomplished by the City of Madison and the University of Wisconsin based on the criteria of traffic performance, safety, transit revenue and ridership, and environmental measures. Results were as follows:

- Even with additional weaving and turning maneuvers, bus travel times in mixed flow on West Johnson were actually lower than on the contraflow lane. This may have reflected the impact of very poor pavement conditions in the contraflow lane.
- Bus-related accident rates showed a significant increase on West Johnson Street, and there was not significant evidence that the relocation was safer.
- Bus passenger surveys indicated a significant decline in perceptions of bus service after the relocation to West Johnson Street, with users preferring the contraflow lane by 67 percent to 26 percent.
- Seventy percent of the bus users in the corridor were forced to cross an additional major street and walk further to reach their destination.

The evaluation report concluded that the contraflow lane did "provide more convenient transit service, more efficient overall transit and traffic operations, and a higher level of safety." Buses still operate in mixed flow on West Johnson Street.

Southampton (England) Bus Priority Scheme

The city of Southampton is a large international seaport, university center, and industrial area. It is divided by the River Itchen, and limited crossings had restricted the development on the east side of the river until increased auto use following World War II resulted in increased urbanization. The main access to one of the major river crossings was A3024, a major arterial facility that extended 3.4 miles (5.5 km) from the river to the city boundary. Because of increased congestion on A3024, a unique scheme was developed to control access to the arterial and provide preferential treatment for buses. This project illustrates the combination of access controls, coordinated signal systems, and priority bus controls as TSM improvements to a radial facility (*16*). Although the project employs access controls that are not generally acceptable in the United States, it has application in this country through its combination of compatible TSM measures.

In 1973, prior to the TSM improvements, A3024 had several cross streets and side streets, many of them without signals, with high volumes of autos and buses. Congestion during the morning peak mandated improved traffic flow by some means other than the addition of roadway lanes. A scheme was developed by the Southampton City Engineer's Department to add additional traffic signals, install a coordinated signal control system, restrict auto access from cross streets and at the city boundary, permit ready bus access to the arterial, and permit traffic to cross at selected points.

Aided by the University of Southampton, the city conducted impact studies before the installation, during the various stages of implementation, and 1 yr after completion of the project.

Sixteen new signal installations provided control at cross streets, side streets, and the city's entry point. Signals were linked and controlled by a master controller, which selected one of nine predetermined timing plans based on the degree of congestion on both the arterial facility and cross streets. Loop detectors were installed to measure traffic volumes and identify queues. Cross streets and side streets were categorized according to the access to be provided to the arterial. Three different types of side street approaches were identified: those for buses only, those for cross traffic only with only buses permitted to enter the arterial roadway, and those for general traffic to turn onto the arterial roadway.

All controls operated during the morning peak only, from 7:00 a.m. to 9:30 a.m. No preferential treatment was given to buses once they were on A3024, inasmuch as it was theorized that reduced congestion would require no preferential treatment for buses.

Interim studies were conducted after signals were installed and coordinated. With the coordination signal system, travel times were reduced anywhere from 6 to 10 min along the 3.4-mile (5.5-km) trip, with the greatest time savings coming toward the end of the peak period. Delays to cross streets and side roads, however, were greater with the coordinated signals, but on trips to Southampton on A3024 the access delays were offset by reduced travel time on the arterial.

After the signal control plan was modified to restrict access from the side streets and to give preferential access to buses, the average bus travel time on A3024 from the city boundary to the river decreased from 16.5 min to 13.9 min. There was no immediate change in the number of bus passengers, but the buses were able to maintain a scheduled arrival time with minimum delay. In the study after 12 months of operation, bus ridership had increased by 9.6 percent during the morning peak; however, total vehicle flow had increased by 7.2 percent, so the modal split between bus and auto travel remained about the same.

The scheme significantly reduced congestion; average vehicular travel times from the city boundary to the river decreased from 12.8 min to 9.4 min. An average delay of 4.1 min, however, was experienced at the traffic signal that controlled access to A3024 at the city boundary. The average delay at side streets to enter A3024 increased from 2.1 min to 3.1 min. Delays to crossing traffic decreased with the new control system. The entry delays at side streets was more than offset in reduced travel times on A3024, depending, of course, on the location of the side street.

About 1 vehicle in 100 ignored traffic controls. In the study 12 months after implementation, the level of violations had increased, many cars flagrantly ignoring red traffic signals to gain access. Side streets designated for auto access naturally experienced greater queues and required greater enforcement.

Bus passengers saved about 8 percent of the door-to-door travel time. About 80 percent of the total travel time savings accrued to bus passengers as a result of the preferential treatment.

Dallas Reserved Bus Lanes

This project (*17*) illustrates the use of reserved bus lanes on two radial arterials in Dallas, Texas. The two arterials, Harry Hines Boulevard and Fort Worth Avenue, are both six-lane divided major arterials that approach the CBD from two directions. In the project the curb lane on both facilities was reserved during peak hours for bus and right-turn traffic over a 2-mile (3.2-km) segment. Both roadways had a 35-mph (56-km/h) speed limit. Thirty-two buses were operated on one bus route in the peak period directional flow on Harry Hines Boulevard. Forty-three buses were operated on five routes in the peak directions on Fort Worth Avenue. Harry Hines Boulevard serves large traffic generators, such as a major hospital complex, and both serve low-density commercial and industrial land uses. Neither facility operated at capacity before the bus lane was reserved.

Bus lanes were implemented in March 1974, and before and after studies provided analysis and comparisons. Objectives of the project were to improve transit level of service, gain transit ridership, and reduce air pollution. Results of the studies, which were conducted for 1 week in the month preceding implementation and for 1 week in the month following implementation, were as follows:

- Bus ridership changes were not significant.
- Speeds on both facilities increased from 4 to 5 mph (6.4 to 8 km/h) with implementation of the bus lane. After the reserved bus lane, 85 percent of the traffic in the peak-period direction exceeded the posted speed limit.
- No adverse effect on the level of service of vehicular traffic was measured.

Sacramento County Signal Preemption for Buses

This demonstration project (*18*) evaluated signal preemption by two express buses on a 3.8-mile (6.1-km) segment of a suburban arterial street. Its significance lies in the priority treatment of buses in mixed flow through the use of a signal emitter on buses to obtain and/or extend the green phase on noninterconnected traffic signals.

Greenback Lane is a major four-lane, divided arterial in Sacramento County, California. The demonstration portion of Greenback Lane connects a major shopping center, with parking facilities for park-and-ride commuters, with I-80. Express buses used this portion of Greenback Lane for commuter service to downtown Sacramento and had to move through nine independent full-traffic-actuated signals to reach I-80. The project equipped two express buses with emitters, mounted a detector at each signal (for each direction), and installed a phase selector in the signal controller cabinet. The effective range of the emitter was 800 ft (240 m). Total material cost was $865 per bus and $1,000 per intersection.

Objectives of the experiment were to minimize express bus trip time; determine impacts of signal preemption on arterial and cross-street traffic, accidents, and speed; and evaluate the preempting device. A 3-month evaluation was conducted from June to September 1975 through the use of time-lapse photography, manual traffic counts, floating-car speed checks, accident reports, and on-board bus passenger counts and time/delay checks. Results of these studies are summarized below:

- On-board ride checks indicated a 24 percent reduction in bus travel time on Greenback Lane during the a.m. peak and a 22 percent reduction during the p.m. peak.
- Floating-car studies revealed a 9 percent reduction in travel time during the a.m. peak and a 30 percent reduction during the p.m. peak; the difference between the floating-car studies and on-board ride checks was attributed to procedural differences.
- Increased bus speeds were due mainly to reduced stopping time rather than reduced running time.
- Time-lapse photography revealed no increase in congestion, delay, or surging in either arterial or cross-street traffic.
- Smoother flow resulted on the arterial because a large platoon of vehicles moved with the bus.
- No accidents were reported during the operation, and no unusual conditions or traffic movements were reported.

No attempt was made in the study to reach conclusions on the relationship between the number of buses with preemption equipment and the traffic volumes on the cross streets; nor was an attempt made to determine the extent to which additional buses could be provided with preemption equipment without significant delays to cross-street traffic.

Minneapolis Arterial Traffic Control System

This project (*19*) provides an example of traffic control on arterial roadways through a computer-controlled traffic signal system. In Minneapolis a central computer controls 90 percent of all traffic signals in the CBD and on arterials within the city.

A Traffic Operations Program to Increase Capacity and Safety (TOPICS) study in 1968–70 identified the need for centralized control on arterial roadways. In January 1978 implementation of the system was accomplished through a joint effort of the City of Minneapolis, Hennepin County, the State of Minnesota, and the FHWA. The objectives of the project were to improve speeds, reduce delays, provide additional capacity, and improve the traffic flow quality on arterial roadways.

Before and after studies were conducted on the arterial networks controlled by the computerized traffic signal control (CTSC) system and consisted of volume counts, travel time, and delay studies. Traffic volumes on the arterial routes studied increased by only 2 percent between the before and after studies, so valid comparisons were possible on travel time and delays.

The operational strategy on external routes was to give preferential treatment to priority traffic flow depending on the time of day and the peak direction of travel. Space-mean speeds (total time of all vehicles in a roadway segment divided by the total distance traveled) were determined for both preferential and nonpreferential traffic flows, and an analysis was conducted to determine whether the improvements in average system speed had been achieved by improving preferential traffic flow at the expense of nonpreferential traffic. The following table provides a comparison of arterial space-mean speeds before and after implementation of the coordinated signal system.

ARTERIAL SPACE-MEAN SPEEDS (mph)

	Preferential		
	Before	*After*	*%*
A.M.	24.6	25.6	+ 4
P.M.	18.5	22.0	+19
	Nonpreferential		
	Before	*After*	*%*
A.M.	24.1	26.5	+10
P.M.	20.4	21.8	+ 6
	Combination		
	Before	*After*	*%*
A.M.	24.5	26.2	+ 7
P.M.	19.3	21.9	+14

It will be noted that both preferential and nonpreferential traffic benefited from CTSC. The nonpreferential benefited more in the a.m. peak and preferential traffic more in the p.m. peak. Delays were calculated on arterial routes based on an "ideal" speed during a.m. and p.m. peaks and during the off-peak. Delays were reduced by 30 to 32 percent in both peak periods and by 10 percent during the off-peak. The probability of a vehicle having to stop on arterials was decreased by 33 percent in the a.m., 13 percent in the p.m., and 6 percent during the off-peak. Average stop time per arterial link was reduced by 34 percent in the a.m., 15 percent in the p.m., and 16 percent during the off-peak.

Overland Park (Kansas) Traffic Control System

In 1980 the City of Overland Park, a suburb of Kansas City, put 55 of its 84 signals under computer control. This project is significant in that it illustrates effective TSM measures in traffic control on major suburban arterials (*20,21*). It is also significant that the Overland Park traffic control system has sufficient capacity to extend computer control on major arterials through the adjacent community of Lenexa under contract agreements between the two cities.

Prior to installation of new signals and the signal control system, Overland Park leased the majority of the 40 existing signals from the local power company. The existing signals were not interconnected, and the controllers were the electromechanical, fixed-time type. Through the use of federal TOPICS monies, Overland Park installed a computer-controlled traffic signal system on its major arterial network. A total of 64 system detectors monitor traffic flow and feed data to the computer center over a shared coaxial cable TV network. The software for the system is an extended version of the Urban Traffic Control System developed by the FHWA.

The objective of the Overland Park traffic control system was to reduce travel time, fuel consumption, and air pollution. Travel time and speed/delay studies were conducted both before and after installation of computer equipment on five arterials in Overland Park on which 43 signals provide traffic control. Results are as follows:

- Travel times during the a.m. and p.m. peak periods were reduced 8 percent.
- Delay was also reduced by 8 percent.
- Overall speed was increased by 10 percent.
- Average number of stops was reduced by 24 percent.

Santa Barbara Signal Timing

The City of Santa Barbara, California, retimed seven signals on a major arterial for reduced delay and fuel consumption. The significance of this project (*22*) lies in the fact that the signals had been retimed only 2 yr previously; the project illustrates improvements in traffic flow that can be gained with very low cost TSM measures.

In January 1976 the City of Santa Barbara began a program to retime its signals to reduce the amount of fuel consumed by unnecessary stops and delays. The first project was on outer State Street, where seven signals were retimed using TRANSYT/6, a computer program initially developed by the Transport and Road Research Laboratory, England, for off-line optimization of signal timing. The signals on State Street had been retimed 2 yr previously using the TRANSYT/5 program.

In the State Street project, timing plans were developed for both peak and off-peak periods. Fuel consumption was compared under both traffic actuation and fixed-time operation. Fuel consumption was measured by a test vehicle with a fuel meter, and speeds/delays were measured through use of the floating-car technique. Results were as follows:

- Semiactuated signal operation was the most efficient plan. This was due to reduced side-street phases during semiactuated operation when pedestrian push buttons were not operating.
- Fuel consumption was reduced by 9 percent and 7 percent in the a.m. and p.m. peaks, respectively.
- Travel times during the a.m. peak were reduced by 15 percent.
- Travel times during the p.m. peak were not reduced significantly.

Evaluation of the project concluded that the retiming might have been one of the most cost-effective investments the city had made.

Baltimore County Arterial Bicycle Lanes

This project illustrates three types of low-cost, on-road bicycle lanes used in Baltimore County, Maryland (*23–25*). The significance of this project lies in the design guidelines for bicycle facilities on major arterial roadways. The work built upon guidelines previously developed by AASHTO. Three types of improvements were implemented: wide curb lanes that provided additional width for bicycle travel; shoulder improvements; prohibited parking near intersections for better sight distances for bicycles.

York Road in Baltimore County, a newly constructed, five-lane roadway, was marked to designate two 14-ft (4.3-m) curb lanes to permit bicycle lanes at the curb. Remaining roadway lanes were reduced in width to 11 ft (3.4 m). Other portions of York Road used a curb lane width of 12 ft (3.7 m) with less success in providing room for motorists to avoid bicycles. On other arterials with parking permitted, an outside lane of at least 14 ft in width was necessary to permit bicyclists to avoid conflict with opened doors of parked cars.

Baltimore County applied slurry seal to existing shoulders for a smoother riding surface. In other cases the roadway surface was extended onto the shoulder for smoother riding quality. Angle parking was removed from two streets, and the gained roadway width was used for bicycle lanes.

Studies were conducted on lateral placement of vehicles and bicycles in the wider curb lanes. The average lateral clearance between the bicyclist and motor vehicles was 5.0 ft (1.5 m) in a 12-ft (3.7-m) lane and 5.3 ft (1.6 m) in the 14-ft (4.3-m) lane. The difference was not statistically significant. When no bicycle was present, the average distance between the curb face and motor vehicles was 4.1 ft (1.25 m) in the 12-ft lane and 5.3 ft (1.6 m) in the 14-ft lane.

Guidelines developed by Baltimore County are summarized later in this chapter. Reference should also be made to FHWA guidelines.

EVALUATION AND GUIDELINES FOR IMPLEMENTATION

The arterial corridor provides an excellent opportunity for the application of TSM measures dealing with traffic engineering techniques. However, when total capacity of the arterial is viewed in persons rather than vehicles, TSM measures that give preferential treatment to HOVs are also highlighted. Some goal conflict may be expected between abutting property owners, who use the arterial street for access, and auto drivers, who use the arterial for longer trips. This conflict is possibly easier to solve on the principal arterial than on the minor arterial because of the recognized need for restrictions on facilities with high volumes. Nevertheless, consideration of TSM measures must recognize this conflict and deal with it prior to implementation.

The municipal traffic engineer is the professional who is closest to the arterial corridor, and it is usually this individual's responsibility to achieve improved efficiency through TSM. Coordination is necessary with the local transit operator and is especially necessary with the local police unit for enforcement. Some consultation is often necessary with abutting municipalities through which the arterial passes. However, in many TSM measures dealing with traffic engineering, the municipal traffic engineer can take immediate action with little or no coordination required.

Guidelines

The guidelines listed below may be considered in the application of TSM to the arterial corridor.

Exclusive Bus/Car Pool Lane and Preferential Treatment for HOVs

1. The termini of an exclusive traffic lane are the critical points where traffic operational problems can arise. Care should be taken in the design of the project to reduce conflict and confusion at the termini as much as possible.
2. Proper and adequate signing and pavement markings are important in conjunction with an exclusive lane, especially with contraflow lanes. Such signing and pavement markings should be considered in the initial design of the project, and the daily cost of placing and removing the signs should be built into the operating budget.
3. Enforcement is difficult for preferential treatment for buses and car pools. Police support should be secured early in the project and the importance of enforcement continually stressed. Safety is an important factor in the continued operation of the facility.
4. Historically, exclusive lanes have usually been implemented as bus lanes with car pools added later in response to public demands. One should consider car pools in the initial design and promotion of the preferential treatment.
5. Legal constraints to contraflow lanes should be investigated initially in the consideration of the project. Local ordinances may require modification to include "exclusive bus/car pool lanes."
6. Design of exclusive lanes must carefully consider the capacity of remaining lanes to meet the traffic demand. Congestion in these remaining lanes will result in flagrant violations and project criticism.

Interconnected and Computer-Controlled Signal Systems

1. Interconnected signal systems on arterials are an inexpensive means of providing preferential treatment for directional traffic flow and should be considered initially in TSM evaluation.
2. Computer-based methods of optimizing the timing of traffic signal networks (e.g., TRANSYT) are available and should be considered for interconnected signals on arterial facilities.
3. Computer-controlled signal systems provide a means of coordinating flow on the arterial, on minor arterials supporting the principal arterial, and in the CBD, all through a single controller.
4. Computer-controlled signal systems require continuing strong management to monitor, reanalyze, and revise the system.
5. Public acceptability of coordinated signal systems is high and should be considered in evaluating arterial TSM strategies.

Traffic Engineering Measures

1. Good traffic engineering design in an arterial corridor should be the first consideration in improving traffic flow.
2. TSM evaluation should look first at intersection design and operation, then at midblock roadway conditions.
3. Reference should be made to the *Transportation and Traffic Engineering Handbook* (*26*) for specific guidelines.

Intersection Access Control

1. Delays at access points cause enforcement to be difficult, and queuing vehicles are detrimental to abutting properties. Design of access control systems should carefully balance vehicle demand on the principal arterial against that on the side streets.
2. Access control plus preferential treatment for buses has not resulted in significant mode shifts to transit.

Bicycle Lanes

1. Planning TSM for bicycles must be conducted in conjunction with planning for other modes.
2. Areas near major traffic generators should be analyzed for potential bicycle travel.
3. Factors to consider in bicycle lane design include safety, directness, delays, pavement surface quality, truck and bus traffic, traffic volume and speed, and on-street parking.
4. Wide curb lanes can be a benefit to bicyclists on many urban arterials.
5. Prohibition of on-street parking near intersections is an important feature for arterial bicycle lanes.

Support Activities

Many of the TSM measures for the arterial corridor are mutually self-supporting. Exclusive bus/car pool lanes, for example, are supported by a coordinated signal system. Other support measures include the following.

- *Enforcement.* Enforcement is a vital support element of exclusive bus/car pool lanes.
- *Bus Collection and Feeder Systems.* A means of loading express buses through neighborhood circulation systems or feeder routes is a significant factor in the mode choice decision and support express bus/exclusive lane systems.
- *Park-and-Ride Facilities.* For arterial corridors serving longer commuter trips, park-and-ride facilities are supportive of arterial express buses.
- *Ride-Sharing Programs.* Ride-sharing (car pools and van pools) matching programs and van purchase efforts, whether at a municipal or regional level, provide support for exclusive car pool lanes on arterials.
- *Car Pool Parking.* Preferential and inexpensive car pool parking in the CBD or other major activity centers served by the arterial corridor encourage the use of car pools and support the arterial exclusive car pool lane.
- *Signs and Pavement Markings.* Many arterial TSM measures employ techniques that may be unfamiliar to the driving public. Adequate signing is thus an important support feature for obtaining the desired driver response.

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CHAPTER FOUR

CENTRAL BUSINESS DISTRICTS

An exact definition of the central business district (CBD) is difficult, if not impossible. Various attempts have been made to define, delimit, and characterize the CBD and need not be reviewed here. It is generally recognized that CBD characteristics vary depending on the age, function, size, and character of the city itself. For example, the CBD of a city of 100,000, especially if it is the principal city in an urban area, is significantly different from the CBD of a suburban city of similar size. In general, the CBD, as used in this synthesis, is considered the focal point of activity in an urban area; however, transportation system management (TSM) experiences are provided for suburban CBDs as well. The size of the city has been omitted in the definition of the CBD, inasmuch as many TSM measures have application in the CBDs of both large and small cities.

The CBD is of particular interest in the application of TSM to urban transportation problems because in most instances it is the focal point of the transportation network in an urban area. In most cities it has been the most accessible area in the city; however, expanded transportation networks and circumferential routes, plus increased congestion on routes radial to the CBD, have reduced its preeminence in accessibility. Nevertheless, urban transportation problems are often focused within the CBD and quite frequently can be addressed only through consideration of the transportation system to the CBD. Thus, TSM in relationship to the CBD should be investigated for what might be its most successful and rewarding application.

CHARACTERISTICS

The CBD is characterized by dense development, tall buildings (especially office buildings), a concentration of people during business hours, convention facilities, and central governmental functions. The CBD in the average city has developed around the original railroad terminal and the network of railroads that originally served the city. Since World War II the CBD has become the focal point of freeways, as attempts were made to accommodate the vehicular travel demand to the CBD. More recently, urban transportation has focused on transit access to the CBD, which still serves as the central point of transit interchange. Also, recent attempts have been made in many large U.S. cities to attract residential development to the CBD and to increase its nighttime population.

As Murphy (*1*) has pointed out in his work on the CBD, its character and its problems are drawing increased attention.

> As more and more people have come to realize that there is a CBD, the district has developed a dual reputation. It is, as has been pointed out, an area of superlatives, the very quintessence of urbanism, symbolic of the city and of city life. Prosperity or at least intensity of business activity seems almost implicit. On the other hand there is the undoubted problem character of the CBD. Rising land values and correspondingly increasing taxes have been plaguing the district. So, too, have the outlying shopping centers that have been springing up in nearly every urban area and cutting seriously into downtown business. Added to the high taxes of the CBD and the inroads of the shopping centers are the ever-increasing difficulties of access. In spite of the general accessibility from various parts of the city, there is likely to be serious crowding of the streets in and near the downtown area as well as inadequate parking facilities. In view of these problems, it is not surprising that the CBD has attracted much research attention from geographers, social scientists, and planners.

TSM OPTIONS

Several different TSM measures have been implemented in the CBD both separately and in combination. These include (a) designation of auto-restricted zones to encourage transit use and improve pedestrian movement; (b) transit malls to improve transit operations and encourage transit ridership; (c) fare-free transit both within and to the CBD, primarily to improve the competitive business advantage of the CBD; (d) parking programs both to provide more parking and to restrict parking; (e) flex-time, or alternative work hours, to spread the peak in travel demand; (f) express transit to facilitate movement of person-trips to the CBD; (g) coordinated signal systems to improve vehicular flow and pedestrian accessibility within the CBD; and (h) programs to facilitate the delivery of goods and reduce conflict between freight vehicles and other CBD travel.

MOTIVATION FOR ACTION

Motivation for the TSM measures for the CBD perhaps has had a more centralized expression than have the other operating environments—the desire to improve the accessibility and the economic well-being of the CBD. The application of TSM to the CBD is thus enlarged from purely a traffic-related motivation to an economic consideration in which both business and government provide the project support. Generally, the motivation for TSM in the CBD can be traced through the following conditions:

1. Increased amounts of congestion within the CBD and longer travel times to the CBD.
2. Inability of the freeway network and arterial system to physically handle the vehicular travel demand to the CDB.
3. Parking problems in the form of both insufficient number of parking spaces and improper parking controls, which contribute to poor traffic operations.

4. Political decisions to favor transit over the auto in CBD access and internal service.

5. Pressure from economic interests for government action to "do something" to assist the CBD and its economic well-being.

6. Concern for the quality of life in the CBD and a desire to promote the CBD as a place to live as well as a place to work and shop.

7. Requirements of the Clean Air Act of 1970 and subsequent amendments to achieve air quality standards through transportation control measures.

GOALS, OBJECTIVES, AND PLANNING ANALYSIS

Most of the TSM measures relating to the CBD have a basic overriding goal to preserve the economic vitality of its downtown area. Economic motivation has in many instances provided the impetus for implementing TSM activities. These TSM tactics have varied from encouraging transit through auto-restricted zones to improving traffic flow through computer-controlled signal systems, but the basic goal of promoting economic growth has been the same. Of course, this economic vitality is closely related to an acceptable environmental quality, a quality of life acceptable for CBD residential units, a pleasing atmosphere for pedestrians and shoppers, and a satisfactory transportation system level of service, all of which may be considered appropriate goals for TSM.

The wide variety of TSM measures applicable to the CBD and the magnitude of their application determines, as one might expect, the degree to which economic growth can be affected. Auto-restricted zones, for example, involve a considerable amount of preparation and "redesign" of the involved area, but at the same time they probably offer a greater opportunity for a measurable impact on economic vitality. Flex-time, on the other hand, costs very little, requires little physical design or modification, and yet, even in the aggregate, has little measurable impact on CBD economics. Thus, it is necessary to identify goals other than an improved economic vitality, and the objectives associated with these goals, to evaluate the impact of TSM measures.

The goals listed below may be identified with TSM and its application to the CBD in the following case studies.

- To promote desirable economic impacts of existing transportation facilities and services through low-cost modifications in the structure and operation of transportation services.
- To improve the quality of life for residents within the CBD.
- To improve the environmental quality of the CBD through the reduction of noise and air pollution from the transportation system.
- To improve traffic and pedestrian circulation.
- To encourage the use of nonauto modes of transportation and to discourage auto use.
- To improve transit service and stimulate bus ridership.

These six goals may be combined and modified to be compatible with previous work on goals, objectives, and measures of effectiveness (MOEs) (*2*). Table 3 provides such a combination and identifies for each goal the objectives, the MOEs, and the appropriate TSM tactics.

TSM measures in the CBD operating environment should be reviewed in the light of necessary planning analysis that might be accomplished prior to the decision to implement. All require some degree of prior planning and coordination, yet some measures, such as auto-restricted zones, may not be classified as low-cost and may require considerable planning analysis to determine their relative cost and benefit. Then, too, a combination of measures can result in impacts that are significantly different from those obtained by implementing individual actions.

Transit malls and auto-restricted zones perhaps require the most extensive planning analysis because all objectives and MOEs are considered prior to the decision to implement. Fare-free transit can result in significant loss of revenues with little benefit derived if proper projections are not determined in advance. Neither is it an action that is easily rescinded without ridership losses. Although parking programs and flex-time may be considered operational activities that can be implemented with little prior planning, consideration should be given to joint impacts if both measures are implemented simultaneously. Express transit and coordinated signal systems probably can be considered to have a positive impact in most cases where congestion encourages TSM actions. Goods movement programs have significant potential in the CBD environment and, similar to flex-time, coordination and operational study are needed in the absence of planning analysis.

Some consideration should be given to combinations of many of the TSM measures apppropriate for the CBD. Express bus service combined with an auto-restricted zone, a transit mall, a coordinated signal system, and a comprehensive parking program can provide significant mode changes and traffic impacts. Planning analysis should be accomplished to project the combined impacts as a means of both determining the benefit/cost relationship and encouraging the use of TSM strategies. Methodologies that are sensitive to many TSM measures have been developed and applied for CBD planning analysis and provide a relatively inexpensive and rapid means of evaluating alternative TSM packages for the CBD (*3,4*).

IMPLEMENTATION EXPERIENCES

Singapore Area License Scheme

This project has been well documented by the World Bank and illustrates a case of road pricing to reduce congestion (*5*). Its direct application to U.S. cities is questionable; however, the results and impacts identified may provide insight into related measures. Implemented in 1975, the area license project resulted from transportation studies in 1967 and 1974 that had concluded that restraints on car ownership and use would be necessary. The government of Singapore set a specific goal of reducing peak-hour traffic to and within the central area by 25 to 30 percent. The total project consisted of (a) the requirement of a special license to enter the restricted zone, (b) increased parking fees within the central

TABLE 3

GOALS, OBJECTIVES, AND MOEs FOR THE CBD OPERATING ENVIRONMENT

Goal	Objective	MOE	TSM Measures for Each Goal
Promote desirable and minimize undesirable social and economic impacts of transportation facilities	• Promote desirable economic impacts	• Dollar Sales • Employment	Auto Restricted Zones Transit Malls Express Transit Parking Programs Fare-Free Transit Goods Movement Programs
	• Minimize undesirable economic impacts	• Dollar Sales • Employment	
Minimize the undesirable environmental impacts of transportation facilities	• Reduce transportation system noise and vibration impacts	• Noise Levels	Auto Restricted Zones Transit Malls Express Transit Coordinated Signal System Goods Movement Programs
	• Reduce transportation system air quality impacts	• Concentration of Pollutants • Tons of Emissions	
Maintain or improve the quality of transportation service on the existing facilities	• Reduce travel time for the movement of people and goods	• Vehicle Delay • Point-to-Point Travel Time • Vehicle Hours of Travel	Transit Malls Goods Movement Improvements Flex-time Parking Programs Coordinated Signal System Goods Movement Programs
	• Reduce travel costs for the movement of people and goods	• Vehicle Stops • Travel Costs • Point-to-Point Transit Fares	
	• Improve comfort and convenience of the existing transportation system	• Parking Accumulation	
Increase the efficiency of the existing transportation system	• Reduce auto usage	• Traffic Volume • Person Trips • Parking Accumulation	Auto Restricted Zones Transit Malls Flex-time Express Transit Fare-Free Transit Goods Movement Programs
	• Increase transit patronage	• Passenger Miles of Travel • Transit Passengers	
	• Increase pedestrian travel	• Pedestrian Counts	

zone, and (c) a park-and-ride scheme to provide an alternative mode of travel.

The central area was approximately 1.9 × 2.5 miles (3 × 4 km), and 22 entry points were identified. Although the goal was to reduce congestion in both the morning and evening peaks, the restricted time for entry was set for only the morning peak, from 7:30 to 10:15 a.m. An individual was required to have a supplemental license costing about $35 (U.S.) per month or $1.75 (U.S.) per day to enter the restricted area during this time period. All vehicles except buses, commercial vehicles, car pools (at least four persons), and motorcycles required the area license. Taxis were initially excluded but were later required to have the area license. Concurrently with the license requirement, parking rates within the central area were increased approximately 100 percent, and 10,000 parking spaces were opened around the periphery of the restricted zone with special shuttle buses to carry commuters from the fringe parking to the central area. A combined monthly cost of parking and using the shuttle was set at $13 (U.S.).

Licenses had to be obtained in advance either on a monthly or daily basis, and windshield stickers identified properly licensed vehicles. Enforcement was by visual observation, which also identified car pools meeting the requirement for nonlicensed entry.

To determine the impacts of the project, the World Bank conducted extensive before and after studies. These studies were measures of vehicles entering the central area, vehicle speeds within the area, and impacts on different groups of people. Results of these studies are summarized below:

Traffic Counts

1. The number of vehicles (including car pools) entering the restricted zone between 7:30 and 10:15 a.m. fell by 73 percent.

2. The volume of cars entering during the half hour before 7:30 a.m. increased by 25 percent.
3. The number of car pools during the 7:30–10:15 a.m. period increased by about 60 percent, and the proportion of car pools in the traffic stream increased from 7 to 37 percent. Impacts on traffic between 10:15 a.m. and 4:00 p.m. were not documented.
4. Traffic flows in the evening peak changed very little as a result of the area license requirement. (Many work trips to destinations on the opposite side of the area bypassed the area in the morning but returned home through the zone in the evening, when license checks were not in effect.)

Vehicle Speeds

1. Speeds within the restricted zone were 22 percent higher during the restricted hours than during the evening peak.
2. On the peripheral roads around the central area, speeds in the morning restricted period were 20 percent lower than in the evening peak.
3. Speeds for inbound traffic on radial facilities after implementation of the licensing program were 10 percent higher during the restricted hours than before the restrictions were implemented.

Travel Behavior

1. The proportion of trips made by vehicle-owning households fell from 56 percent to 46 percent.
2. The bus share of total person-trips rose from 33 to 46 percent.
3. The car pool proportion of trips rose from 14 to 41 percent of all auto trips.
4. The proportion of work trips that entered the central area before 7:30 a.m. rose from 27 to 40 percent.
5. The number of shopping trips to the central area fell by 34 percent; however, shopping trips outside the central area also fell by 14 percent during the same period.
6. People from non-vehicle-owning households did not change their behavior.

Studies by the World Bank identified complementary measures that contributed to achieving the goal of reducing congestion by 25 to 30 percent.

- Higher parking rates discouraged auto travel to the CBD and encouraged parking in the cheaper periphery lots.
- Improved "ring" roads around the restricted area permitted bypassing the restricted area.
- Expansion of the standard bus service provided an alternative mode of travel.
- Proper delineation of the zone boundary, setting of the hours of restriction, and establishment of the license fee facilitated achievement of the goal.

Boston Auto-Restricted Zone

This project involves a major effort to restrict auto use in the core retail area of 0.7 square miles (1.8 km^2) in downtown Boston. The project (*6–8*) was sponsored by the Federal Highway Administration (FHWA), the Urban Mass Transportation Administration (UMTA), and the Boston Redevelopment Authority and included a major evaluation effort by the Transportation Systems Center. Although full evaluation results are yet to be obtained, preliminary evaluation permits some insight into this project.

An auto-restricted zone (ARZ) is defined as a geographic area in which one or more factors place limitations upon vehicular traffic. Boston's ARZ includes (a) a new circulation system for buses, pedestrians, cars, taxis, and delivery trucks; (b) street improvements to enhance the pedestrian environment; and (c) special 1-yr programs to fund maintenance, promotion, enforcement, and bus operations. Auto traffic was eliminated from an 11-block area, only a few streets remaining open for garage access and taxis. Four blocks were resurfaced with brick, and three others had sidewalks and roadways resurfaced. Six local bus routes were extended into the ARZ, and an express bus loop was extended into the area to accommodate four express routes and one local route. A special transit priority system permits buses to circulate without the interference of auto traffic. A comprehensive signing program was implemented as part of the traffic circulation system.

The plan for the ARZ was prepared with the goal of encouraging the continued physical and economic revitalization of downtown Boston. Objectives within this goal included increased economic vitality, better access for pedestrians, improved accessibility for transit, and improvement of the general image and attraction of the older downtown streets. Preliminary evaluation after 18 months of the revised traffic circulation and 12 months of operation of all the project's aspects indicated positive results in economic activity. Two major surveys were conducted on the behavior of the downtown shopper and worker. Results to date are as follows:

- The volume of pedestrians on streets within the ARZ increased by 5 percent overall on weekdays and Saturdays; weeknight pedestrian traffic increased by 17 percent.
- Sales volumes increased between 5 and 10 percent. Merchants reported a 5 to 15 percent increase of customers in their stores.
- Walking to the ARZ increased from 48 to 55 percent of all trips. Auto use decreased from 11 to 6.5 percent of total trips to the ARZ.
- Transit use to the ARZ by employees increased by 23 percent and by nonemployees by 27.5 percent.
- Traffic rerouting resulted in no appreciable increases in congestion on alternative routes.

The preliminary evaluation indicates that, "from the retailers' point of view," the ARZ has created a new downtown shopping environment, has increased the convenience of shopping, and has provided a new merchandising image for downtown.

The following factors in implementing an ARZ have been identified: (a) ARZs are generally phased in over time and not implemented overnight; (b) autos generally are not totally eliminated from the ARZ, although their circulation is severely restricted; (c) a high degree of accommodation and compromise is necessary, and (d) pedestrian linkages must create a pleasing environment for shopping and working.

Minneapolis Nicollet Transit Mall

The Nicollet Mall in downtown Minneapolis was completed in 1967 and is significant in that it was the first project of its type in the United States (*9*). The major sponsor of the mall was the Downtown Council, a local businessmen's group, which has also provided leadership in elevated pedestrian walkways in the downtown area. A federal Urban Beautification Grant and an UMTA demonstration grant supplied approximately one-quarter of the funds. The remainder was provided by an assessment on abutting property owners.

A transit mall may be defined as a street that has been improved to encourage pedestrian use and that retains a roadway for transit vehicles integrated with the citywide transit system. Access for automobiles is denied or strictly limited, except for cross-street traffic. The Nicollet Mall is a two-lane, two-directional busway on eight blocks of Nicollet Avenue in downtown Minneapolis. (An extension of the mall is under construction at this writing.) Prior to the mall, pedestrian traffic in downtown Minneapolis was heaviest on Nicollet Avenue, but vehicular volumes were lighter than on parallel streets. The mall now carries between 45 and 60 buses in each direction in the peak hour, three times the bus volume prior to the mall. Support facilities include a serpentine roadway, heated bus shelters, and electric snow melting coils in the widened sidewalks.

Extensive before and after studies are not available, but evaluation studies have been conducted to compare the mall with parallel streets. Buses operating on the mall do travel faster than those in mixed flow on parallel streets; however, the time gain is offset by signal delays. In comparing the mall to contraflow bus lanes (in use on other CBD streets in Minneapolis), it was found that buses at the mall moved at a lower speed because of more frequent stops and a different ridership composition on the mall. Heaviest use of buses on the mall is during the lunch hour, indicating a greater use of the mall by persons already in the CBD.

Cordon counts for the CBD indicated no decline in auto trips, and no congestion was reported from traffic diverted to other streets. No evidence was apparent that the mall increased total pedestrian volumes, but pedestrian circulation was improved by an increase in the sidewalk area. Nonpedestrian accidents decreased on the mall, and total pedestrian accidents showed no change.

Improved economic conditions as a result of the mall have been difficult to document. Surveys after the opening of the mall showed a decline in shoppers to the CBD; however, a survey in 1975 concluded that the decline in the downtown area had stabilized and the number of shoppers may even be increasing. Surveys of merchants have reported that the predominant attitude was that the mall had been a good investment. Rents on the mall have been stable, and both public and private ventures on and adjacent to the mall have been extensive.

Chestnut Street Transitway in Philadelphia

The Chestnut Street Transitway became operational in November 1975 and consists of a 12-block section in the retail area of Philadelphia. Chestnut Street was a one-way street prior to the transit mall, with an average of about 12,000 vehicles per day. The transitway consists of a two-lane, two-way roadway for buses. Autos are barred from the mall, but cross-street vehicular traffic is allowed. Taxis are permitted to use one segment to gain access to a hotel and can use the mall extensively at night. Midblock crossings were constructed, and pedestrian amenities were provided.

The city government was the main sponsor for the project (*10,11*); however, the primary motivation was provided by a merchants' group that wanted to improve economic conditions. A major motivation for the mall was the bicentennial celebration in 1976. Chestnut Street contains some of Philadelphia's finest department stores and specialty shops. Major office buildings plus the historic sites on the east end of the transitway contribute to the demand for pedestrian and vehicular traffic. An UMTA grant, state Department of Transportation (DOT) monies, and city capital funds were used to fund the project.

A survey was conducted in 1977 among the 100,000 employees working within a two-block area immediately adjacent to the transitway. From a 15 percent sample of the employees, it was concluded that the transitway was successful in accomplishing the goals of improving the commercial vitality and environmental quality of the area. Only 52 percent of the respondents said that the transitway improved traffic conditions, and only 44 percent said the transitway encouraged the use of public transportation and nonauto means of transportation.

In a 1977 survey of 72 percent of the 258 merchants along the transitway, a little more than half expressed an overall favorable attitude toward the transitway, one-quarter voiced an unfavorable comment, and the remaining were indifferent. Larger businesses, as a whole, were reported to be more favorably disposed toward the transitway than were smaller businesses. Thirty-three percent of the merchants felt that business activity had increased since the opening of the transitway, and 25 percent said it showed a decrease. Two benefits as a result of the transitway were cited by the merchants: the general environment and aesthetic quality of Chestnut Street had been improved, and the transitway had attracted more pedestrians.

The impact of the transitway on transit operations was not significant. Studies conducted on transit travel times on the transitway and on parallel Walnut Street showed little difference between bus travel times in the mixed flow on Walnut and the bus-only traffic on Chestnut.

A diversion strategy aimed at channeling vehicular traffic from Chestnut Street to Market Street, a parallel facility one block north, was developed prior to implementation of the transitway. This plan encouraged diversion to the north rather than to the south, which would have been through a residential area. Although some diversion to the south did occur, the project did reduce congestion due to diverted traffic.

In evaluating the impact of the transitway on air quality, the "hot spot" carbon monoxide monitoring program of the City of Philadelphia reported significantly lower readings on Chestnut when compared to readings on Walnut Street and Eighth Street. Surveys of employees in the Chestnut Street area found that 65 percent believed the transitway had reduced both air and noise pollution.

Seattle Fare-Free Magic Carpet

Seattle's "Magic Carpet" provides an example of fare-free transit within the CBD (*12*). Implemented within a 105-block area of the CBD in September 1973, the Magic Carpet service was evaluated within the first year of service. The primary objectives were to (a) improve downtown air quality through a mode shift from the private auto to transit, (b) reduce intra-CBD auto trips, (c) conserve gasoline, (d) encourage peripheral parking, (e) increase mobility within the CBD, and (f) stimulate retail trade activities.

The Seattle CBD in 1973 was long and narrow, about 1 × ½ miles (1.6 × 0.8 km). The narrow dimension of the CBD consists of steep grades rising from the waterfront. Major activities within the CBD consist of office and retail activities. The CBD is the location of several major corporate headquarters.

In 1973 more than 20 percent of the 200,000 persons traveling to the CBD daily arrived by transit. More than 30 percent of all work trips to the CBD were made by transit. Transit fares in 1973 consisted of a $0.20 base fare, with a $0.10 zone fare. Prior to the Magic Carpet service, the CBD was served with a "shopper's shuttle," which operated on a 5-min headway between 10:00 a.m. and 3:00 p.m. for a $0.10 fare. No transfers were accepted between the shopper's shuttle and regular transit.

The fare-free Magic Carpet service was available 24 hr a day, seven days a week. No fares were collected for persons boarding a bus within the fare-free zone. Passengers leaving the bus within the CBD paid no fare; however, all other outbound passengers paid their fare upon leaving the bus. All passengers inbound to the CBD paid their fare in the usual manner upon boarding the bus.

Evaluation studies within the first year of operation consisted of special surveys of public opinion, analysis of business impacts, bus rider origin/destination surveys, traffic volume counts, parking surveys, and transit travel time measurements. The following results were reported:

- The number of trips by bus inside the free zone increased from 4,100 per day before the fare-free service to 12,258 per day after 9 months of operation.
- An average of 3,105 trips that had not previously been made were made each day via free transit.
- Of the total daily trips on the fare-free service, 5,032 had previously used another mode; 1,005 had used an automobile.
- The primary purpose of the Magic Carpet trips was for shopping and restaurant meals. Over 35 percent of all fare-free trips were made between 12:00 noon and 1:00 p.m.
- Travel times for buses through the CBD increased during the morning peak after fare-free service; however, travel times decreased during the afternoon peak. Travel times were influenced by reduced signal delays resulting from improved signal timing. Increased transit ridership, and hence increased loading times, resulted in offsetting gains by reduced signal delay and thus had little net effect on total transit speeds.
- Annual cost of the fare-free operation was computed to be $128,132, which includes the loss of revenue, increased bus hours of operation, and nonpayment of fares by outbound passengers. No operational cost of the shopper's shuttle was included in the annual cost. This additional cost was underwritten by the City of Seattle.
- The average decrease in vehicular traffic volumes attributable to free-fare transit within the CBD was 2 percent.
- Very few downtown employees shifted their parking locations due to fare-free service.
- Based on surveys of riders and their average purchases and on inquiries of CBD businesses, an additional $5 million each year (or a gain of between 1 and 2 percent) in retail sales was realized by downtown stores due to fare-free transit.
- Additional surveys indicated a very positive response to fare-free transit from employees, business managers, shoppers, and social service agencies.

Trenton Fare-Free Transit

The Trenton, New Jersey, fare-free experiment is a demonstration project under the Service and Methods Demonstration Program of UMTA and is significant in that it evaluates fare-free transit during the off-peak hours *to* the CBD (*13,14*). The primary objectives were to improve transportation flow and reduce energy consumption and air pollution.

Trenton, the central city of Mercer County, has been faced with a declining population; it has been diminishing at the rate of 1 percent per year, to a current population of just over 100,000. The rest of Mercer County, in contrast, is growing, its population consisting of more affluent, younger age groups. Most of the transit system in Mercer County is within Trenton and focused toward the CBD. Thus the project attempted to use improved transit service (free fare during off-peak hours) to improve economic conditions in the downtown area.

Under the project, transit fares were reduced from 15 cents to a free fare between the hours of 10:00 a.m. and 2:00 p.m. and after 6:00 p.m. Monday through Saturday and all day Sunday. Peak-hour fares remained at an average of 30 cents, with a fare of 50 cents for particularly long express routes. The free service began on March 1, 1978, and included all 10 regular fixed routes.

Overall transit ridership increased significantly—24 percent—after implementation of the free fare, going from an average monthly ridership of 542,000 before the fare change to 672,000 after. Discounting seasonal variations, the ridership increase due solely to the fare reduction was 19 percent.

The off-peak ridership increased by 45 percent. Of the total transit trips after the implementation of the free fare, 29 percent had not used transit previously. Of these, almost half had not made the trip previously and the rest had either used the auto, walked, or used some other means of travel. Although the percentage of social trips on transit decreased after the free fare, discretionary travel (personal business, etc.) increased from 11 to 22 percent of the total transit trips.

Some decrease in the level of transit service was reported after the fare change. Rider surveys reported seat availability had been significantly reduced and that free fares had negatively affected operating times and the ability to maintain schedules. Perhaps the most surprising result was the driver and passenger reaction to an increase of "rowdiness, vandalism, and harassment" on the buses during free-fare hours. Revenue losses from the free-fare project amounted to a 25 percent drop in the transit operators' annual revenues. Operating costs increased only slightly. UMTA demonstration funds and Mercer Metro operating funds were used to offset the revenue loss.

In general, CBD trips and transit travel increased during the free-fare experiment; however, negative impacts included lower driver morale and a general decline in the level of transit service. The service was terminated in February 1979 at the conclusion of the demonstration project.

Washington, D.C., Parking Enforcement Program

This TSM project is significant in that all major aspects of parking enforcement—ticket writing, towing and impoundment, vehicle immobilization, and adjudication—were delegated as transportation responsibilities within the District of Columbia government, and techniques employed in part by other cities were combined to successfully administer a CBD parking program (*15–17*).

Starting in 1972, the D.C. DOT conducted a review of existing parking regulations. It was discovered that long-term (commuter) on-street parking was not discouraged by the regulations and their enforcement. Shoppers were denied access to short-term parking, and frustrated short-term parkers would park illegally. This led to increased traffic congestion and decreased safety. Additionally, the 1970 Clean Air Act and its promulgated transportation control plan also created interest in improved parking management. In 1978 two new bureaus were formed under the D.C. DOT: the Bureau of Parking and Enforcement and the Bureau of Traffic Adjudication. Enforcement of parking restrictions was emphasized.

Ticket Writing

In the fall of 1978, 50 civilian parking control aides (PCAs) were employed and given the ticket-writing responsibility. Civilian personnel were used instead of police in order to ensure a priority of parking enforcement and effective traffic flow over crime prevention. In the second month of operation the PCAs averaged 91 tickets per person per day, and the average has since increased to between 100 and 110 tickets per person per day. Thirty of the PCAs were assigned to walking beats in the CBD and the other 20 to motorized parking enforcement on arterials during peak hours. Enforcement procedures and parking regulations are explained in brochures and in colorful fold-out maps (*18,19*).

Towing and Impoundment

The towing operation is performed by a contractor, who is required to have 25 cradle cranes available for use in the District. The contractor must be able to remove and impound approximately 450 vehicles per day between 7:00 a.m. and 7:00 p.m. Vehicles to be towed are identified by the PCA, and a tow vehicle is dispatched by the dispatch office under the D.C. DOT. Vehicles are towed only in the case of a safety or traffic problem. There is no towing for overtime parking. Strict procedures in towing and impounding protect the privately owned vehicle and its contents. The owner of the vehicle pays an impoundment fee, which covers the expense of towing.

Vehicle Immobilization

To provide a parking enforcement procedure on vehicles from outside the District, the D.C. DOT implemented a "booting" program to immobilize vehicles that belong to owners who have four or more outstanding parking tickets (scofflaws). The PCAs check each illegally parked vehicle to determine whether the owner is a scofflaw. If so, booting crews are notified and a metal boot is placed on the vehicle's front wheel. The owner must pay all outstanding fines, plus a $25 boot fine before the vehicle is released. Booted vehicles are towed if not removed within 72 hours. With nearly 100,000 scofflaws on the District's records, the program produces 20,000 booted cars per year.

Adjudication

The adjudication procedure of the D.C. DOT removes the proceeding from a criminal court to an adjudication environment, where hearings are conducted in an informal atmosphere. Vigorous follow-up procedures on ticketed parking violators—through use of a notification system, vehicle registration deferral, and an integrated data system—has improved ticket collection.

District officials report positive impacts of the parking enforcement program. Traffic congestion due to double parking has been noticeably reduced in the CBD. Loading zones, entrances, and taxi stands are now used for their intended purposes. Bus travel time has been reduced during the rush hours.

Parking turnover studies conducted by the D.C. DOT have shown that there has been significant improvement in parking space use since the program began. The percentage of legally parked space-hours has increased from 13 to 54 percent, and the turnover rate has increased from 1.2 to 2.9 per day.

Revenues from the ticket writing, towing and impoundment, and vehicle immobilization programs are sufficient to pay all costs of the increased surveillance and enforcement. Revenues in 1979 from ticket writing increased from $3 million to $4 million, and the increase itself was sufficient to fund the entire ticket-writing program. Fines for overparking amount to $7 million annually. The annual cost for the towing and impoundment program is $1.7 million; revenues are $6.4 million annually. The vehicle immobilization program costs $467,000 annually, but produces annual revenues of $4.1 million.

Portland Downtown Parking and Circulation Policy

In 1973 Portland, Oregon, adopted a plan that encouraged the use of public transit over the private automobile and approved parking management tactics as part of a strategy to improve air quality (*20*). The significance of this TSM measure lies in the combination of parking management tactics with transit actions to achieve a modal change in trips to the Portland CBD.

The Downtown Parking and Circulation Policy (*21,22*) was first adopted by the city council on February 26, 1975, and was updated by resolution on October 3, 1980. The parking management tactics set forth in the policy were:

- A limit on the total number of parking spaces in the CBD.
- Allocation of parking spaces to parking sectors within the CBD.
- Establishment of a parking management program and the designation of a parking manager.
- *Maximum* parking-space ratios (i.e., number of parking spaces per 1,000 square feet of gross floor space) for private-use parking structures.
- Permits for new buildings without parking spaces.
- Parking duration to increase short-term parking for shoppers and reduce all-day spaces for employees.
- Designation of non-automobile-oriented streets for public transit, pedestrians, and bicycles.

In addition to the parking policies, a pair of one-way streets, 11 blocks in length, was reserved for transit. This transit mall was furnished with distinctive bus shelters, street furniture, fountains, and plantings. A second TSM measure related to transit provided a fare-free zone of 300 square blocks in the CBD. And on July 28, 1977, the Portland City Council approved a downtown car pool parking program (*23*). This program permitted a limited number of car pool vehicles to be parked on-street in excess of 8 hr without cost. The primary objectives of the parking and transit policies were to improve public transportation to downtown, accomplish a reduction in the need for parking, improve the efficiency and convenience of parking access, reduce the necessity for through traffic to use downtown streets, and improve air quality in downtown Portland.

By ordinance, the downtown parking supply was not permitted to exceed 40,055 spaces (39,467 spaces in the 1975 policy), which was the number of spaces established by a parking survey in 1975 and revised in 1978 and 1980. The maximum was allocated to 11 parking sectors, and future goals were set for parking space allocations by sector. Every new development in the Portland CBD is reviewed and its impact on the parking supply ceiling evaluated before a building permit is issued.

The Downtown Parking and Circulation Policy sets a maximum limit on the provision of parking for new development but sets no minimum. The maximum ratio for retail and office development is one parking space per 1,000 ft^2 (93 m^2). Ratios were based on percent transit use by downtown employees for long-term parking, and policy options were presented to the city council for decision. Short-term ratios were based on percent transit use by shoppers and visitors.

Short-term parking was encouraged through the construction by the city of two short-term parking garages. Parking charges are set on a straight line basis, with no weekly or monthly contracts sold. More than 200 downtown businesses have participated in a ticket validation system to underwrite the parking cost even when only a small purchase is made.

The car pool parking program designated 2,629 6-hr on-street parking spaces to be used free of charge by licensed car pools. Car pool permits are issued by Tri-MET, the local transit property, which is authorized to issue 500 car pool parking permits each month. The fee per car pool is $15 per month, which authorizes the car pool to hunt for a space among the 2,629 available. In August 1980, after the number of car pool permits had apparently reached a saturation point of 350 and few applications were received for permits due to difficulty in finding a space, the city's Bureau of Traffic Engineering recommended that 200 spaces downtown be reserved for car pools. Upon approval by the council, applications for car pool parking permits were again received, and 500 permits were issued by Tri-MET. (This information is from an interview with Don Bergstrom, City Traffic Engineer, City of Portland, February 4, 1981.) Any existing parking restrictions must be observed (e.g., no parking 4:00 to 6:00 p.m., tow-away zone, etc.). An application must be submitted to Tri-MET naming the place of employment and the car pool members. A permit may be transferred among car pool members and is displayed from the rearview mirror. At least 10 percent of the 500 car pool permits are reviewed by Tri-MET each month to verify the car pool.

Enforcement of the downtown parking policy is accomplished by 16 civilian parking patrol deputies. The entire CBD is covered four times a day. Fines are $3 for overtime parking and $10 for violation of a no-parking zone.

Reported results of the parking and transit policies are as follows:

- Transit ridership has increased from 64,000 passengers daily in 1973 to over 180,000 passengers per day in 1978 (*24*), and in November 1979 transit trips represented 40 percent of the total work trips by downtown employees (*25*).
- Average daily traffic entering downtown in 1973 was 147,000 vehicles and decreased to 95,000 by 1978.
- As of January 1981, 487 car pools were in the car pool parking program, for a total of 1,554 people. Average car pool occupancy was 3.1 persons per vehicle (*26*).
- A survey of the car pools in early 1978 indicated that 58 percent were new car pools, economics was the main reason for car pooling, and 31 percent had been paying between $20 and $29 per month for parking.

Bellevue (Washington) CBD Parking Management Program

Bellevue is a suburban city (population 80,000 in 1980) on the east shore of Lake Washington and is connected to Seattle by two freeways, I-90 and S.R. 520. In order to develop and maintain a strong central core, the City of Bellevue adopted a CBD parking management program as part of a comprehensive plan for the city (*27–29*). The significance of the program is that it represents a TSM strategy to achieve total goals in a suburban CBD and to encourage other modes of travel by limiting parking supply.

As freeway congestion increased on the two freeways to and from Seattle, impetus was provided for commercial and office development on the east side of Lake Washington. From 1975 to 1977 the City of Bellevue adopted land-use policies that permitted higher densities within the CBD. The CBD was clearly identified by policy and consisted of 80 acres with more than 12,000 employees. (This information is from an interview with Tom Noguchi, Transportation Planner, City of Bellevue, February 2, 1981.)

The parking management program is an integrated set of parking management tactics designed to further the attainment of the city's overall goals and objectives. It includes a marketing program, parking enforcement regulations, fringe parking facilities, transit marketing, and programs to encourage use of high-occupancy vehicles (HOVs). The overall objectives were to (a) encourage economic vitality and a healthy tax base; (b) prevent decay in the CBD and provide employment opportunities; (c) implement a balanced transportation network including motor vehicle circulation, public transportation, HOVs, pedestrian circulation, and bicycle circulation; (d) promote circulation alternatives that minimized consumption of energy; and (e) reduce or control transportation-related noise and air pollution.

Implementation of the parking management program was accomplished through reduction of parking supply through the land-use code, reduction of parking supply through incentive programs, and construction of fringe parking facilities by the City of Bellevue.

Under the land-use code the parking management program establishes both minimum and maximum parking requirements for new development to "create market conditions" for CBD parking. Parking requirements may be further reduced by developers through "joint-use" parking for different levels of parking demand during the day.

In the incentives portion of the parking management program, the city permits a further reduction of parking requirements in new developments through a formal agreement among the developer and Seattle Metro (regional transit agency), the Seattle/King County Commuter Pool, and the City of Bellevue for implementation of TSM strategies such as the following:

- Private van pool operation.
- Transit/van pool fare subsidy.
- Elimination of free parking as a fringe benefit.
- Provision of subscription bus services.
- Flexible work hour schedule.
- Capital improvements for transit services.
- Preferential parking for car pools and van pools.
- Establishment of the ride-matching program.
- Reduction of parking fees for car pools and van pools.
- Establishment of a transportation coordinator position.
- Bicycle parking facilities.

Downtown San Francisco Flex-Time Project

In a demonstration project funded by the California Department of Transportation, the Institute of Transportation Studies at the University of California at Berkeley encouraged implementation of flex-time by major employers in downtown San Francisco and monitored results, primarily through surveys of employees, to determine the impacts (*30–35*). The significance of this project lies in its attempt to "sell" flex-time to private-sector employers within a major CBD.

Flex-time is the name given to a system that permits employees to have flexibility in distribution of work hours during a week. Although there are varieties of flex-time, the most common is the one encouraged in San Francisco, in which each employee is allowed to choose when to start work (typically between 7:00 and 9:30 a.m.) and can vary the chosen start time from day to day.

In the first half of 1979, 44 companies in downtown San Francisco were approached to consider flex-time. Letters, over the signature of the mayor, were addressed to the major employers asking their attendance at a meeting to discuss the advantages of flex-time. Thirty-three companies were thoroughly briefed on the benefits of flex-time as well as the results of flex-time implementation at Metropolitan Life in San Francisco. Seventeen companies implemented flex-time, and a sample of employees who switched to flex-time were surveyed for the results reported here.

A goal was established to place 20,000 of the 250,000 employees in downtown San Francisco on flex-time and assess the impacts of trip rescheduling, mode choice, and system operation. Results obtained should assist other areas in setting more specific goals, such as a percent reduction of trips to the CBD, or higher travel speeds during the peak hour.

Subsequent to the implementation of flex-time, 3,000 employees were surveyed, and the results are summarized below:

- Given the opportunity, most workers commute *before* daily congestion develops, and few continue to work conventional eight-to-five hours.
- In many circumstances flex-time can actually foster *increased* car pooling and transit use.
- Net effect of flex-time is a slight overall decline in the number of employees who drive alone to work.
- A total of 75 percent of the employees surveyed reported that avoiding the rush hour was the important motivation in the choice of their work hours.
- Most auto users reported saving time, and 31 percent said they saved more than 10 min each morning.

Results were not reported on the impacts of flex-time on system operations. Calculations produced conclusions that 30,000 downtown workers would have to be placed on flex-time to "have a plausible chance of eliminating standing on

BART during the rush hour." It was further concluded that widespread adoption of flex-time could maintain current system operating conditions despite a forecast of 10 percent in downtown growth over the next 5 yr.

Evaluation of the San Francisco demonstration concluded that the potential of flex-time to improve system operation during the peak hour can be realized only if four conditions are met:

1. Employees who have the opportunity of flex-time must voluntarily reschedule their commutes to avoid the rush hours, in some cases arriving as much as 60 min earlier or later.
2. Flex-time should not encourage commuters to abandon transit or car pools for the superior flexibility of travel alone by automobile.
3. There must be reserve transportation capacity immediately before and after the peak of the peak hour.
4. Firms that employ a relatively large number of people should be persuaded to adopt flex-time.

Seattle Central Business District Flex-Time

Flex-time in Seattle (*36*) is promoted by the Seattle/King County Commuter Pool. An exemplary brochure has been developed for distribution to major employers (*37*). In the fall of 1979 the Seattle/King County Commuter Pool commissioned a study to determine the results of flex-time in eight downtown work places. A total of 1,292 employees were surveyed. Forty-eight percent of the distributed surveys were returned, for a total sample of 626. The study attempted to evaluate the impacts of flex-time on work schedules, travel modes, and system operations.

The degree of flexibility offered by the companies surveyed varied substantially. In 27 percent of the sample, employees could vary their hours from day to day without setting hours in advance. In 49 percent of the sample, employees could vary the length of their lunch period. And in 23 percent of the sample, employees could vary the length of their workday.

Impacts on work schedules included a tendency to change the schedule for an earlier start time and quitting time under flex-time. Fifty-eight percent of the sample shifted to an earlier schedule than the conventional 8:00 a.m. to 4:30 p.m. After flex-time, 54 percent were at work by 7:30 a.m., and 64 percent left before 4:30 p.m. The proportion of employees commuting in the a.m. peak hour decreased from 75 to 42 percent; in the p.m. peak hour the proportion decreased from 77 to 57 percent.

The table below lists the impacts of flex-time on travel mode changes.

Travel Mode	Before Flex-Time (%)	After Flex-Time (%)
Drive alone	23.7	14.1
Share a ride	18.7	23.3
Public transportation	56.3	61.4
Walk/Other	1.3	1.3

Fourteen percent of the employees in the sample reported that they had changed their means of transportation to work since flex-time was adopted. Seventy-five percent of the employees who changed modes switched from driving alone to sharing a ride or transit.

Potential impacts of flex-time were calculated on the assumption that 20,000 CBD employees (of the 150,000 employed in the CBD) would be on flex-time and that their work start times would be similar to those indicated in the sample. It was assumed, then, as indicated in the survey sample, that (a) the percentage starting work between 8:00 and 8:30 would decrease from 58 to 52 percent, which would mean a decrease of 9,000 commuters in the peak of the peak, and (b) large-scale adoption of flex-time could produce an increase in "effective transportation system capacity" that approximated 11 percent.

Richmond Parham Express Bus

This project provides an excellent example of express bus service to the CBD (*38,39*). Begun in July 1973 "to help preserve downtown vitality," the project's sponsors were the Virginia Department of Highways and Transportation, the Richmond Metrpolitan Authority, the City of Richmond, and Henrico County.

Based on origin-destination surveys made in 1964 and on 1970 population and employment figures, ridership forecasts for the 17-mile (27-km), one-way trip estimated 300 persons per day. Travel time comparisons were made for the arterial and freeway routes between the middle- to high-income suburban residential area and the Richmond CBD. Express bus travel times on I-64 and I-95 gave the bus a competitive time advantage over the auto routes on arterials.

Based on these projections, the Virginia Department of Highways and Transportation purchased a tract at the intersection of Parham Road and Fordson Road in Henrico County. A parking lot with bituminous pavement and raised curbs and medians was constructed in 1973 for 170 spaces. Forty-four parking spaces were added to the lot in late 1973 and another 87 spaces in 1974, for a total of 301 spaces.

During the first week of service the average daily ridership one way was 214 persons. A year later this ridership had increased to 548. Average travel time for the buses from the parking lot to the downtown Richmond loop was 20 min inbound during the a.m. peak and 26 min outbound during the p.m. peak. The one-way fare of $0.50 in 1974 compared favorably with the cost per one-way rider of $0.60. All subsidies were underwritten by Henrico County and the City of Richmond. No charge was made for parking.

Surveys conducted shortly after the service began revealed that approximately 25 percent of the riders arrived at the parking lot as an auto passenger ("kiss-and-ride"). Seventy-five percent either walked or brought their own vehicle to the parking lot. Of the riders using the service, 99.1 percent gave their trip purpose as work, the remainder listing school as the purpose of the trip. Upon reaching the downtown loop, 98.3 percent of the commuters were within walking distance of their final destination. Average annual income of the riders was $12,000 (1974 dollars), and more than 65 percent of the riders owned two or more autos.

In September 1980 the average daily one-way ridership had increased to 566. Parking continued to be a limiting factor, although the lot was restriped to add 50 spaces, for a total of 351 spaces. A nearby church parking lot was used for between 80 and 120 cars, and 30 autos per day parked on the side road adjacent to the lot. In a survey taken in June 1979, 365 cars were parking in the Parham express bus lot (capacity was exceeded), 17 were parking on Fordson Road, and 66 used the church lot. Of 573 total commuters, 469 people arrived in 441 vehicles, 22 persons walked to the lot, and 80 people arrived at the Parham lot in a "kiss-and-ride" fashion.

Minneapolis CBD Traffic Control System

The significance of this project lies in the impact of a coordinated traffic control system in the CBD of a major city (*40*). The Minneapolis computerized traffic signal control (CTSC) system currently provides central control of approximately 90 percent of all traffic signals within the city by means of a central digital computer. Thirty percent of the signals under coordinated control are within the CBD.

Installation of the system was completed in January 1978 under the joint sponsorship of the FHWA, the State of Minnesota, Hennepin County, and the City of Minneapolis. Impetus for the project was provided by a 1968–70 Traffic Operations Program to Increase Capacity and Safety (TOPICS) study that reviewed and evaluated the traffic control system. The objectives of the project were to provide additional system capacity, improve speeds, reduce delays, and improve the traffic flow quality of the system.

The Minneapolis CBD is a tightly spaced grid generally served by one-way streets bounded by major freeways and the Mississippi River. Prior to the CTSC system, traffic control in the CBD was provided by local intersection controllers operated with three dials and multiple offsets in a time-of-day mode. The local controllers were coordinated under a master controller with an interconnected system. The system was limited to strategy selection on a time-of-day basis determined by historical data of average conditions and hence was not demand-responsive.

An extensive evaluation effort was undertaken after operation of the system for over 1 yr. Travel time and delay studies were conducted on the same routes both before and after the installation of the CTSC system. Traffic volumes in the CBD increased about 1 percent from the before to the after period, thereby permitting direct comparison of travel times and delays without adjustment for volume changes.

Space-mean speeds (total time of all vehicles in a roadway segment divided by the total distance traveled) for the p.m. period in the CBD are shown in the following table.

CBD SPACE-MEAN SPEEDS, P.M. PERIOD (mph)

Direction	Before	After	% Change
Northbound	13.60	14.66	+ 8
Southbound	12.99	15.74	+21
Eastbound	14.99	15.77	+ 9
Westbound	13.93	16.12	+16

Traffic flow quality was measured through a ratio of space-mean speed to space-mean running speed. With the CTSC system, the CBD in the p.m. period experienced a 23 percent increase in this ratio. Similarly, the total delay for the CBD grid during the p.m. peak was reduced by 22 percent.

Comparisons were made between before and after conditions of the stop probability per link, time per stop, and average stop time per link. In the CBD during the p.m. period, the probability of a stop was reduced by 8.7 percent, the average time per stop decreased by 32 percent, and the average stop time per link was lowered by 38.2 percent.

The evaluation studies reported, however, that the additional flexibility and control capabilities of the CTSC system required additional staff to monitor the day-to-day operation, to review and analyze reports, to identify malfunctioning equipment, and to develop new signal timing plans.

Raleigh CBD Traffic Control System

The Raleigh traffic control system represents the impacts of computerized traffic control in the CBD of a medium-size city. The Raleigh system controls the operation of 153 signals located within the CBD and on two major arterials serving the CBD. The project (*41*) resulted from a TOPICS study that recommended a modernized traffic control system. The project was completed in February 1975. The objectives of the system were to meet the travel needs of an increasing population and to achieve the greatest efficiency from the existing roadway system.

The Raleigh CBD consists of a grid system of one-way streets with signal spacing of about 500 ft (150 m). The signal system prior to the computer-controlled system consisted of individual controllers with a single-dial and single-pretimed-offset with cable interconnect. The age of the control equipment was between 4 and 19 yr, but the equipment had been well maintained.

After one full year of operation, evaluation studies were conducted of travel times and speeds/delays. The average speed during the p.m. peak period increased from 16 mph (26 km/h) before the installation to 18 mph (29 km/h) after. Links were evaluated for a desirable speed range, which was defined as a speed within 20 percent of the speed limit. The percentage of the links within the network having an average speed within the desirable speed range rose from 20 percent of the network before to 40 percent after the project.

The new system was also reported to have reduced the probability of a vehicle stop due to a signal by as much as 30 percent, which means that almost 30,000 fewer stops were made during the p.m. peak hour after the installation. Vehicle delay was also reduced by a range of 12 to 40 percent.

Fort Worth CBD Signal Timing

This project is one in which significant improvements were gained in a CBD signal system through low-cost optimization of signal timing (*42*). The City of Fort Worth (1980 population of 400,000) recognized a need to effect timing changes in its CBD signal network, which in 1976 consisted of 126 interconnected signals controlled by an analog computer. Travel times through the CBD system were reduced by as much as 16 percent during the p.m. peak, and travel speeds were increased by almost 20 percent by using the TRANSYT optimization technique.

The Fort Worth CBD consists of a grid network of closely spaced streets penetrated by several major traffic arteries in both the east-west and north-south directions. These one-way couplets tie directly into the freeway system, forming a CBD loop, and carry significant volumes of traffic through and within the CBD. "Before" studies of travel speeds, travel times, and delays were conducted prior to retiming the signal network. "After" studies were conducted 3 weeks following the timing modifications and after traffic had stabilized.

The TRANSYT program is a digital computer program developed by Dennis Robertson of England's Transport and Road Research Laboratory, Department of the Environment. It is an optimization technique designed to determine optimum signal phase splits and offsets in a system of interconnected traffic signals, the objective of which is to minimize a traffic "performance index." The performance index is an expression of delays and stops within the system in terms of vehicle-hours per hour.

Improvements in the system performance after the changes in signal timing are shown in the following table.

CBD SYSTEM PERFORMANCE:
PERCENTAGE DIFFERENCE AFTER TIMING CHANGES

Time Period	Travel Time	Travel Speed	Stopped Time
A.M.	− 2	+ 2	− 6
Off-peak	−12	+14	−23
P.M.	−16	+20	−39

Nineteen routes through the CBD were evaluated separately during both the before and after studies. While some of the minor routes showed little improvement, travel times on the major routes decreased by as much as 80 percent during the peak periods, and stop times were reduced by as much as 183 percent.

New York City Garment Center Goods Movement Improvements

This project of TSM measures in urban goods movement is one of the few to have been implemented and evaluated. Urban goods movement has received less attention than has the movement of people in urban areas, and only in the last few years have TSM strategies been identified and plans developed for improving the flow of goods. Many of these strategies have been implemented, but few have been evaluated to the extent that generalized conclusions may be reached for application in CBDs. The project of TSM measures in the New York City garment center (*43*) is one of the few exceptions.

The apparel industry is the largest manufacturing industry in both New York City and New York State, employing 105,000 workers in Manhattan alone (*44*). The heart of the apparel industry is the garment center in a 40-square-block area between Fifth Avenue and Tenth Avenue and West 34th Street and West 42nd Street. Thousands of small firms are concentrated within the area. Changes in the apparel industry—plus the trend of movement to the suburbs for better space, lower costs, and easier movement of goods—have resulted in a decline in the garment center. Employment in the center decreased 30 percent, from 108,275 employees in 1964 to 76,400 employees in 1973. Studies were conducted and TSM measures implemented to relieve traffic congestion and strengthen the garment industry's economic ability to function.

Studies (*45*) of the flow of goods within the garment center and the movement by trucks, handcarts, and elevators found that the already busy city sidewalks were being used as loading and unloading areas. It was found to take 10 times as long to unload a shipment onto the sidewalk and deliver it via elevator to a garment center loft building as it took to deliver the same shipment outside the city to a one-story building with a loading dock. The slow delivery of goods at loading facilities was found to cause long parking duration, double parking, and functional delays with moving traffic.

Four TSM measures were selected for implementation from an initial list of 12. There were 11 evaluation criteria ranging from political feasibility to implementation time. The four measures selected were (a) restriction of passenger vehicles without commercial license plates in a six-block area, (b) creation of a left-turn lane on West 35th Street at Seventh Avenue, (c) reduction of truck parking durations from 4 to 3 hr, and (d) construction of 21 curb cuts to facilitate the movement of handcarts on and off the curbs.

The objectives of the TSM measures were to reduce street congestion, increase travel speeds, increase the available space-hours for truck parking, and reduce handcart travel. Monitoring studies using time-lapse photography and other means of data collection evaluated the results of the four TSM measures.

During the first 9 months of passenger vehicle restriction, the average hourly volume of passenger cars declined by 35 percent and of taxis by 9 percent, but the average hourly volume of trucks increased by 4 percent. The average speed of trucks during auto-ban hours increased from 3.0 mph (4.8 km/h) before the restriction to 4.1 mph (6.6 km/h) after the restriction. Truck speeds in times other than the restricted period decreased from 3.2 mph to 2.4 mph (5.1 to 3.9 km/h). After an initial enforcement period of 9 months, volumes and speeds returned to prerestriction levels due to a lack of continued enforcement.

The left-turn lane was judged ineffective because of a lack of enforcement and the obstruction by illegally parked vehicles. A slight increase in the number of left-turning vehicles was noted after the implementation of the left-turn lane. Reduction of parking duration did, after 9 months, result in 95 percent of all trucks parking for less than 3 hr, as compared with 86 percent prior to the restriction. With reduced enforcement, parking durations increased to their previous level. No formal monitoring program evaluated results of the curb cuts to reduce conflict between trucks and handcarts. The program was endorsed as being successful by apparel firms, and the city was requested to install 42 additional curb cuts.

Evaluation studies concluded that enforcement was extremely important in the effectiveness of the TSM measures and stated that TSM measures would be effective only if enforced or if designed in such a way that enforcement is not required.

EVALUATION AND GUIDELINES FOR IMPLEMENTATION

Because the CBD is generally the focal point for commercial activity within an urban area, so it is the focal point of the transportation system. The combination of employees and shoppers, pedestrians and automobiles, transit vehicles and taxis provides a plethora of opportunities for the application of TSM. Add to the demand for reduced congestion the high land and building cost and the difficulty of constructing major capital improvements in transportation, and demand for TSM is increased.

Although transportation activity is concentrated in the CBD, the responsibility for TSM is often quite fragmented. Transit malls, fare-free transit, and express transit fall within the domain of the transit operator and the urban planner. Signal systems, goods movement, and parking programs fall in the province of the traffic engineer. Flex-time is most often left alone with no adopted parent, unless a political or business leader takes the orphan in. Auto-restricted zones, which greatly affect the business community, are often so broad in their influence that they involve the metropolitan planning organization, urban planner, transit operator, traffic engineer, parking coordinator, and even police and fire departments. In very few instances has a single focal point been identified for a concerted TSM approach. Nevertheless, successful implementation of individual TSM measures have provided guidelines for further implementation.

Guidelines

The following guidelines are suggested for TSM measures in the CBD operating environment.

Auto-Restricted Zones

1. Careful consideration should be given to evaluating the economic and traffic impacts of the project prior to the decision to implement.
2. Close coordination with the business community must begin in the early stages.
3. The boundary of the ARZ should be carefully chosen to reduce congestion problems caused by diverted traffic.
4. Because mode shifts are desired, care must be taken that adequate facilities are available for the new mode chosen—for example, pedestrian facilities must be adequate and attractive for former auto users.
5. Improvements must be fully integrated and carefully staged.
6. Proper access must be provided for delivery vehicles, taxis, and emergency equipment.
7. Effective enforcement of traffic, parking, and loading restrictions is critical to the success of the ARZ.

Transit Malls

1. Reduced transit times should not be expected. Concentration of transit riders most often increases bus loading times.
2. Cross streets must generally be left open, and signal timing should be coordinated with loading time for the buses within the mall.
3. Understandability of the transit system is improved by the concentration of buses and transit information.
4. Bus shelters provide convenience and simultaneously keep transit patrons clear of the pedestrian walkways.
5. Proper design should be provided for diverted traffic at each end of the mall.
6. Rear-alley loading is preferred over cross-street loading.
7. Enforcement is necessary to prohibit vehicles other than buses from using the transit mall.
8. Transit malls and other CBD measures, such as express buses and coordinated signal systems, are mutually supportive and should be evaluated together.

Fare-Free Transit

1. An adequate number of vehicles should be assigned to the fare-free system, particularly during the lunch hour, which is the time of heaviest use.
2. Fare collection on leaving the bus at points outside the CBD is difficult.
3. Fare-free transit should not be expected to radically change parking locations within or adjacent to the CBD, nor can fare-free transit be expected to significantly reduce the number of autos within the CBD.
4. Enforcement against vandalism and misconduct may be necessary if local schools are served by the fare-free transit.

Parking

1. Strict enforcement should be considered necessary to reduce the negative impacts of illegally parked vehicles.
2. Immobilization and impoundment should be considered key elements of parking enforcement.
3. An administrative adjudication program that removes the parking violations from criminal court speeds the process of collecting parking fines.
4. Restricted parking programs can be used to encourage transit ridership to the CBD.

Flex-Time

1. Many of the employees under flex-time will choose an early schedule rather than a late schedule so that more hours will be available for home activities in the evening. This can require additional coordination among departments in a major firm.
2. Since flex-time users often use it to coordinate with bus schedules, some preliminary coordination with transit systems should prove helpful.

3. Coordination with major employers is necessary, and detailed explanations of other experience in flex-time are necessary for favorable employer response.
4. An administratively simple program for flex-time is to be favored over and can be anticipated to be more successful than one with elaborate timekeeping procedures.
5. Most employees do not vary their start times from day to day and thus do not require highly flexible transportation supply.
6. Active support from the office of the mayor and continual monitoring by staff should be built into a flex-time program.
7. Flex-time has been found not to encourage commuters to abandon transit or car pools. Program promotion should highlight this finding.

Express Transit

1. Express transit must provide a faster route to compete with auto trips to the CBD.
2. Adequate parking is necessary to attract express transit riders.
3. Parking lots should be located on the CBD side of the catchment area because commuters are reluctant to travel to the lot in a direction opposite to the CBD (*46*).
4. Multiple lots may be desirable to encourage walk trips and "kiss-and-ride" operations.
5. Preferential treatment for buses should be considered in order to provide the express bus an advantage over auto routes to the CBD. Warrants are available for the numerous preferential treatments possible (*47*).

Coordinated Signal Systems

1. Systematic optimization of signal timing plans, regardless of the sophistication of the master control system, is a continuing and productive effort in the CBD (*48*).
2. A computer-based signal system requires continuing strong management to monitor, reanalyze, and revise the system.
3. Traffic control system improvements are relatively free from enforcement problems.
4. Public acceptability of coordinated signal systems is high and should be considered in selecting TSM alternatives within the CBD.

Goods Movement Programs

Even with its potential as a TSM measure in improved traffic flow, goods movement technology is in its infancy in regard to implementation as a traffic function in urban areas. From the efforts to date, however, two guidelines may be derived.

1. The most successful measures are those that do not require constant enforcement.
2. Measures that require enforcement, such as restricted parking and/or loading time, should be rigidly enforced, inasmuch as they will be successful only when enforced.

Support Activities

Support activities for TSM measures in the CBD operating environment are best identified for each TSM tactic; however, two support activities have general application within TSM and the CBD. First, enforcement is a critical support element in almost all TSM measures in the CBD operating environment. This is particularly true for ARZs, transit malls, and parking programs. Coordinated signal systems require the least enforcement. Second, many of the TSM measures are mutually supportive; however, joint evaluation is suggested prior to joint application of all TSM tactics.

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CHAPTER FIVE

REGIONAL OPERATING ENVIRONMENTS

The regional operating environment for transportation system management (TSM) is a geographical area that has been designated for the purpose of developing coordinated long-range plans for an urban area. A region is generally larger than one municipality; in most urban areas a region includes the central city and many surrounding municipalities. The regional operating environment provides opportunities for areawide TSM strategies that are most effective when implemented in the entire metropolitan area.

CHARACTERISTICS

The term *region* in referring to an urban area came into common usage with the national movement toward councils of governments, regional planning agencies, and economic development districts to provide coordinated planning in fragmented urban areas. A region is often larger than a standard metropolitan statistical area (SMSA) and usually encompasses an area within which all urban development is expected to occur during a 20-yr period. In transportation planning, the region fully encloses all of the transportation network identified for systems analysis.

Significant characteristics of a region, listed below, may be identified when the region is considered as an operating environment for TSM. These characteristics generally are those that foster or restrict implementation of TSM measures. These same characteristics also influence the effectiveness of decision making in the total transportation system for the region.

1. A region includes several independent local governments that have responsibility for the construction and operation of the street system within their jurisdictions.
2. The framework of the transportation system within a region is provided by a designated highway network, the construction and operation of which is the responsibility of a state transportation agency.
3. Transit services within a region are often supplied by one or more separate transit authorities. Often privately owned systems also provide transit and paratransit services.
4. A metropolitan planning organization (MPO) has been designated to provide transportation planning and program coordination. In most instances the MPO has no authority or responsibility to implement transportation services.
5. The process of planning, programming, and implementing TSM measures is fragmented among many public and private agencies.

Federal guidelines (*1*,*2*) require that TSM coordination in the planning process is to be accomplished by the MPO; however, involvement of other local agencies—such as the city traffic department, the transit operator, and the state department of transportation (DOT)—in the analyses for TSM measures is emphasized. Under the guidelines the MPO is to analyze regional impacts and "coordinate the overall effort." Work by MPOs during the initial years of TSM was found to be lacking in both analysis and coordination, and the TSM element in the annual transportation program usually consisted of a compilation of TSM-related actions that were already under way or were planned as a part of another program (*3*).

For TSM to be a coordinated effort at the regional level rather than a listing of projects, the MPO must develop both an annual procedure for TSM coordination and an evaluation technology for comparing TSM measures and projecting the synergistic impacts of the TSM programs. Thus, the regional operating environment can be characterized as requiring the TSM analysis common to most other operating environments and also a coordination effort both to encourage TSM and to develop TSM measures into a meaningful program.

TSM OPTIONS

Rarely have TSM strategies been implemented uniformly throughout a region. Several TSM measures, however, have been implemented in subareas that encompass more than one jurisdiction. These include:

- Ride-sharing (car pools, van pools) on an area basis in contrast to implementation by an employer or by a neighborhood.
- Coordinated transit and paratransit services over a large area.
- Brokerage, consisting of a coordinating agency to match car pools and van pools and to make arrangements for public and/or private suppliers of transportation.
- Alternative work schedules, consisting of staggered work hours, flex-time, and so on.
- Reduced transit fares or free-fare transit over a large area.

Quite obviously, almost any TSM measure could be classified as a regional action if it is implemented uniformly throughout a region. Preferential treatment for high-occupancy vehicles, for example, could be a regional measure if it is uniformly implemented on all freeways and arterials in a region. However, because TSM implementation responsibility is fragmented, regional uniformity is rare and TSM measures are most often grouped under operating environments more closely related to practical implementation. Only those listed above are usually approached on a regional basis.

MOTIVATION FOR ACTION

Most TSM measures are implemented in response to a recognized or perceived transportation problem. However, in the regional operating environment this is observed to be the case in only rare instances. Transportation problems are generally related to facilities or small geographical areas (e.g., freeway congestion and neighborhood disruption), and only infrequently are transportation problems thought of in terms of a regional context.

It would appear that most TSM measures implemented in the regional environment came about as a result of federal requirements or grant assistance. Examples are transportation control measures in response to the Clean Air Act Amendments of 1977 or strategies implemented on the initiative of a transit operator in response to an Urban Mass Transportation Administration (UMTA) Section 6 demonstration grant. Regional implementation has rarely been motivated by a specific transportation problem to be ameliorated or solved by TSM. Even national problems, such as an energy shortfall or increased energy costs, are insufficient to motivate extensive regional implementation of TSM without encouragement by federal grant programs. Regional TSM measures, then, are implemented more as a result of a creative program by a local transit operator or traffic engineer than in response to a recognized transportation problem.

GOALS, OBJECTIVES, AND PLANNING ANALYSIS

Goals and objectives for regional TSM are also in response to federal requirements or perceived national goals. These generally relate to an improved environment and/or reduced energy consumption through reduced auto use. Table 4 lists goals, objectives, and measures of effectiveness (MOEs) associated with regional TSM.

Almost all regional TSM measures are thought to produce positive results in the aggregate, so little planning analysis is required prior to implementation. Total impacts have been estimated to determine emission reductions necessary to meet the clean air standards. Little planning analysis has been accomplished on the regional application of TSM measures to provide a means of establishing priorities for TSM implementation. Models are operational for such analysis, however, and their use by MPOs is encouraged to assist local agencies in TSM analysis and in the establishment of program priorities as well as to project the synergistic impacts of a regional program (*4,5*).

IMPLEMENTATION EXPERIENCES

Wilkes-Barre (Pennsylvania) Free-Fare Transit

This project represents a regional approach to free-fare transit as a result of a civil disaster (*6*) but, through a controlled experiment during reinstatement of the fare, provides valuable estimates of free-fare impacts.

Free-fare service was sponsored by the Office of Emergency Preparedness (now the Federal Emergency Management Agency) for 101 days following the Wyoming Valley flood as a result of Hurricane Agnes. Ridership increased from a weekday average of 11,500 trips before the flood to 23,000 trips on the next to last day of the sponsored service. The total increase, of course, could not be attributed to free-fare because of the altered travel habits following the disaster.

To determine the impact of reinstating the fare, a survey of all free-fare riders on the two private transit systems was conducted 2 days before ending the free-fare service. Then, following reinstatement of the fare, all other conditions were held constant during a 6-week period. For one operator the drop in ridership was 15 percent after the $0.15 fare was reinstated; the other system lost 18 percent in ridership. Weighted average drop in passengers was 17 percent.

Denver Free-Fare Transit

In 1978 the Denver Regional Transportation District (RTD), with assistance from UMTA, implemented a free-fare experiment for its entire system, which covers several counties (*7*). This project is significant in that it represents a regional approach to TSM over the entire system of a re-

TABLE 4

GOALS, OBJECTIVES, AND MOEs FOR THE REGIONAL OPERATING ENVIRONMENT

Goal	Objective	MOE	TSM Measures for Each Goal
Minimize the undesirable environmental impacts of existing transportation facilities and services	• Minimize Air Pollution	• Tons of Emissions	Ridesharing Alternative Work Schedules
Increase the efficiency of the existing transportation system	• Minimize Auto Usage	• Number of Carpools, Vanpools • Vehicle Miles of Travel	Ridesharing Brokerage Free-Fare Transit Alternative Work Schedules
	• Maximize Transit Usage	• Transit Passengers	Coordinated Transit and Paratransit Services

gional transit authority. The objectives of the effort were to meet requirements of the Clean Air Act Amendments of 1977 and reduce transportation energy consumption.

The service was initiated in February 1978. Weekday fares were eliminated, except for the hours of 7:00 to 9:00 a.m. and 4:00 to 6:00 p.m. After 2 months in operation, the a.m. peak was changed to 6:00 to 8:00 a.m., during which time fares were collected.

Ridership on the RTD system increased from a monthly average of 2,668,000 passengers in 1977 to 3,973,000 in 1978, an increase of 49 percent. Estimates were made that service expansion and secular growth caused 15 percent of the increased ridership. An increase in ridership of 34 percent was estimated to be attributable to the free fare. Off-peak ridership during the weekday increased between 74 and 155 percent. It was estimated that 13,000 new daily trips were made because of the free fare. Trips that had previously used the automobile accounted for 21 percent of the ridership after free fare. Eighteen percent had ridden the system at another time.

RTD estimated that the increased ridership and more frequent stops caused buses to run behind schedule, particularly during the daily transition from peak to off-peak hours. Complaints against drivers increased. Estimated revenue loss resulting from the free-fare program was approximately $3.7 million for 1978, which represents a 37 percent decrease in revenues. With free fares, the average revenue per passenger dropped 51 percent, from $0.28 per passenger to $0.12 per passenger. Operating costs increased slightly but were not significantly higher.

The experiment was terminated in February 1979 after 1 yr. RTD personnel report a slight decline in total ridership, but by mid-1980 the total ridership had increased to a point above that during the free-fare service. Free-fare service was viewed as a good incentive for increased ridership; however, the critical issue remains one of supply during the peak hour, not necessarily off-peak ridership. RTD now desires to spread the peak through staggered work hours or similar measures. (This information is based on a phone conversation with Sue Landrum, Denver Regional Transportation District, Denver, Colorado, October 19, 1980.)

Negative aspects of the free-fare service were an increase in teenage vandalism and the presence of unsavory characters who chose to ride free for shelter during the late-night hours.

Portland Regional Ride-Share

Tri-MET is the regional transportation agency for the Portland, Oregon, metropolitan area (population 1.2 million). As a multimodal transportation agency, Tri-MET provides, in addition to regular, fixed-route transit, an aggressive ride-share program consisting of car pool, van pool, bus pool, downtown car pool parking, and transportation consulting for local industry. The significance of this project (*8*) lies in its concentration of regional transportation responsibilities in a single regional agency.

The ride-share program began in 1974 as a result of the fuel crisis, and initial emphasis was placed on car pooling. When responsibility for the ride-share project was assumed by Tri-MET, the program was broadened to include the various other transportation functions. The project is funded through Federal Aid Urban System (FAUS) monies at a 90/10 ratio. In the reporting period between February 1, 1977, and June 10, 1979, the project cost was $216,110, of which $21,611 were Tri-MET operating funds and the remainder were FAUS funds.

Considerable emphasis was placed on marketing all phases of the ride-share program. Marketing consisted of highway signs, newspaper ads (plus editorial support), billboards, radio and television, car pool displays at various locations in the downtown area, and distribution of a newsletter to major employers. The car pool program was supported by a matching program plus a downtown Portland car pool parking permit program (described in Chapter 4), both operated by Tri-MET.

In addition to the car pool program, a van pool effort encourages use of van pools by major corporations; a park-and-ride program is operated out of 68 lots with free parking; and car pools, van pools, and park-and-ride buses operate on high-occupancy lanes provided by the Oregon State Highway Division (described in Chapter 2).

As a result of the ride-share program, car pooling increased its share of commuter travel from 6 percent in 1977 to 8 percent in 1979. Transit increased from 7.5 percent in 1977 to 9 percent in 1979. A breakdown by mode of commuter travel in 1979 is shown in the following table:

Mode	Percentage of Market Share (Commuters)
Auto, drive alone	68
Shared ride (2 people)	11
Car pool (3 or more)	8
Bus	9
Bus/Car	3
Other	1

Minneapolis Ride-Sharing Commuter Services

The significance of this project (*9,10*) lies in its demonstration of the use of a regional transit agency to serve as a broker in providing a wide range of ride-sharing services. Funded by UMTA as a 2-yr demonstration project, the project focused on multiemployer complexes outside the central business districts (CBDs) of Minneapolis and St. Paul. The Metropolitan Transit Commission (MTC) of Minneapolis/St. Paul served as broker in the total commuter services effort. Van-pool Services, Inc., contracted to provide marketing, initial matching, van provision, van maintenance, insurance, and driver selection and training. The primary objective of the demonstration was to achieve an overall shared-ride level of 30 percent of all person-trips to the multiemployer complex.

An evaluation report was developed after approximately 9 months of operation at the South Central Minneapolis (SCM) area and the Pentagon Park/Normandale (PP/N) area at the edge of Bloomington. The SCM area is located 2 miles (3.2 km) from the Minneapolis CBD and is served by relatively good bus service, particularly from suburban locations. Total employment is approximately 9,000 in 16 firms. The PP/N area is located 12 miles (19 km) from the Minneapolis CBD. The total employment of 7,600 is divided among more than 300 firms, over two-thirds of which employ fewer than 10 persons.

The evaluation reported that only five vans remained in operation after the first 9 months of the program, with only 329 commuters participating. Surveys had previously indicated that over 4,000 employees in both areas participated in ride-sharing (car pool or bus) at the beginning of the ride-sharing program. After 9 months little change was evident in the percentage of employees involved in ride-sharing. In a similar vein, new applications for van pools had stopped. At the time of the evaluation, applications from 2,500 people had been received; however, 1,369 had lost interest.

The evaluation then concentrated on the reasons for the lack of success in the ride-sharing effort and the poor response by employees. The report concluded that the project had not matured sufficiently to attract interest and that a "critical mass" of van poolers had not yet been attracted to the effort for it to develop attention. The report cited three reasons that ride-sharing was inhibited at the demonstration sites.

First, a fragmented market in multiemployer areas made ride-sharing difficult. A hesitancy was noted among employees to van pool with employees from a different firm. Rotating work shifts negatively influenced the attractiveness of van pooling. Over 40 percent of the employees said they needed their car at work at least 1 day per week. Second, most commuter trips were short in both distance and travel time. The average car pool distance was 10 miles (16 km), and less than 2 percent of the employees commuted more than 20 miles (32 km). Third, conditions were very favorable for drive-alone auto trips. Arterial thoroughfares provided easy access to the areas, and free parking was readily available.

Marketing was originally accomplished through car pool and van pool informational meetings and a manual process of locating and matching potential ride-sharers. This process was highly labor-intensive, so a telephone brokerage system was established. All employees within a zip code area who had work shifts that started within 30 min of each other were mailed a letter, were telephoned within a few days, and were offered assistance. Such a procedure provided an excellent monitoring system and extended the marketing capability.

In late 1979 approval was received to expand the program beyond the demonstration areas, and a marketing program for the entire urban area was begun. As of October 1980, 18 areas were being served by over 100 vans. Marketing is accomplished by billboards, match letters, and phone calls. The phone call effort remains a very important part of the marketing effort and serves to keep files current on potential van poolers.

By late 1980 the program had been subdivided into two major areas. (This information is from a phone conversation with Stephanie Butler, Ridesharing Coordinator, Metropolitan Transit Commission, St. Paul, October 28, 1980.) MTC currently handles with its staff all marketing and matching for the St. Paul effort, and Vanpool Services, Inc., provides a similar service for the Minneapolis area under contract to MTC. Vanpool Services, Inc., has a similar contract for statewide marketing and matching programs outside the twin cities area. Chrysler Corporation, under contract to MTC, supplies, maintains, and insures vans for both Minneapolis and St. Paul. A similar contract is held by Chrysler for the Minnesota DOT, which has developed a statewide program for ride-sharing (*11*).

Both MTC and Vanpool Services, Inc., use the same computer program for ride-share matching, and information is often interchanged for interarea van pools. Most van pools serve multiemployer areas. Fares are based upon the travel distance of a round-trip operation.

Kansas City Area Commuter Parking Lots

This project illustrates a regional approach to commuter parking lots for car pool, van pool, and park-and-ride operations (*12–14*). The Missouri Highway and Transportation Department began developing commuter parking lots in 1973 as a result of the fuel crisis and, as of January 1981, had constructed 53 commuter lots with a total of 3,174 parking spaces.

Fifteen of the commuter lots have been constructed in the Kansas City metropolitan area, with a total of 844 spaces. Construction of the lots was accomplished by state forces on highway right-of-way at an average cost of $205 per parking space. (This information is from a personal interview with George Satterlee, District Engineer, District 6, Missouri Highway and Transportation Department, January 27, 1981.) State funds were used for the construction costs.

Flyers describing the Kansas City commuter lot system and providing a small map for each lot showing its location in respect to the major highway interchange have been distributed. A location guide for the statewide system has been developed by the state for general distribution.

Average daily use of the 844 Kansas City spaces during the last quarter of 1980 was 479 spaces, or 57 percent. Statewide estimates of reduced travel amounted to 21 million miles (34 million km) per year and 84,000 miles (135,000 km) per day. Annual cost savings based on reduced gasoline consumption alone amounted to over $3 million.

Knoxville Commuter Pool

The Knoxville Commuter Pool (KCP) (*15–17*) is perhaps the best-known transportation brokerage program in the United States. It covers a region that is 1,800 miles^2 (4700 km^2) and concentrates on the Knoxville SMSA. Its operation is significant in the different services it provides and in the varied contractual mechanisms it has spawned to provide transportation services.

KCP was initiated on October 23, 1975, under a grant from UMTA to the City of Knoxville, a city of over 180,000 population and a labor force in excess of 100,000. The city entered into a third-party contract with the University of Tennessee Transportation Research Center to establish the brokerage service. In July 1977, KCP became part of Knoxville's Department of Public Transportation Services. When the demonstration grant ended in December 1978, KCP continued as part of the city's operation, although its service area extends over the 1,800 miles^2 mentioned above.

The objective of KCP was to develop and implement low-cost transportation alternatives in a well-coordinated program balanced between public and private sectors. Immediate efforts were devoted to a third-party van pool program of 51 vans, development of a ride-share match program, and elimination of institutional barriers to van pools. These latter efforts consisted of supporting state legislation to legalize van pools and persuading the insurance industry to insure third-party and privately owned vans.

In 1978, KCP evaluated its effort in the Knoxville area and found that 73 percent of all commuters had heard of KCP and 19 percent had received computer match lists from KCP. It was also found that 4 percent of the people in the area's work force had changed their mode of travel as a result of KCP's efforts, which included an active telephone marketing program for potential ride-sharers. In the KCP program for the Knoxville CBD, the percentage of commuter trips in the auto/drive-alone category was 68 percent of the total home-to-work trips to the CBD. It was estimated that this alone saved 2,000 vehicle miles (3200 km) daily and over 130 gal (490 L) of gasoline.

In January 1976, KCP began its third-party van pool program. Prior to this time most van pool programs had been employer-owned and employer-operated. The largest and most recognized such program was that of the Tennessee Valley Authority. The third-party system of KCP was for the purpose of providing the "critical mass" and success record necessary to promote the van pool effort. After initiation of the service, KCP sold the vans to the individual drivers. Assistance was provided by KCP in obtaining financing and insurance for the van pool driver.

KCP also established the Knoxville Area Vanpooler's Association (KAVA) to provide service to private van poolers. These services include the computer matching program, van purchase financing, insurance, and marketing. The financing arrangement enabled 100 percent financing for purchase of van pools by KAVA members. In mid-1978, under the KAVA effort, there were 29 KAVA van pools with 319 riders. In addition, 21 businesses provided discounts to KAVA members, eight financial institutions made loans for van purchases, and nine insurance companies wrote policies on KAVA vans.

The number of vans represented by the membership of KAVA at the end of 1979 was 70 van pools and four bus pools. The average round-trip commuting distance of KAVA members is 77 miles (124 km), the average load being 12 passengers per van. During the first 18 months, KAVA saved an estimated 8 million vehicle-miles (13 million km), 512,000 gal (1 940 000 L) of gasoline, and about \$1.5 million for riders.

A major thrust in van pooling has been provided by the National Association of Van Pool Operators (NAVPO), whose membership in mid-1980 totaled 367 van pool operations and included 75–80 percent of the 8,023 van pools operating in the United States. NAVPO has indicated that transportation brokerage as provided by KCP and others has been of great assistance to van pooling nationwide. (This information is from a phone conversation with Ed Marks, Executive Director, National Association of Van Pool Operators, Knoxville, Tennessee, July 8, 1980).

Westport (Connecticut) Integrated Transit System

This project (*18*) provides an example of expanded transit coverage through a unique combination of transit vehicles and also illustrates the use of brokerage in providing expanded transportation services. Because the service area expansion included separate communities, this project is included as an illustration of regional transit and paratransit service. Under a demonstration project of UMTA and local sponsorship by the Westport Transit District (WTD), service was initiated on April 16, 1977, through additional vans, a control/dispatch center, and a contract with a local taxi company for operation of the additional service.

Prior to the demonstration, Westport, a city of 28,000 with a high percentage of young transit riders and New York City commuters, was served by a fixed-route mini-bus system. This transit system employed a vehicle fleet of eight diesel mini-buses and two small transit coaches. Service consisted of peak-hour commuter service to and from the railroad station and seven fixed routes operating on a 35-min headway during the daytime. Monthly ridership averaged 11,000 on the commuter service and 42,000 on the fixed-route daytime service. The transit system operated with courteous drivers, used extensive marketing, and employed annual passes for both commuter and daytime service. Coverage was not, however, provided to all areas of Westport.

WTD was supported by the local government in expanding transit coverage that would integrate transit and paratransit service. With WTD taking the lead, a local plan was developed for areawide service, and demonstration monies were obtained from UMTA. Goals of the service area expansion were (a) increased transit coverage, (b) increased transit productivity, (c) improved transit service for the transit-dependent, (d) reduction of traffic congestion, and (e) reduction of household auto ownership.

The additional coverage supported the existing transit operation. The expanded operation consisted of 11 raised-roof vans used for shared-ride service, supplemental fixed-route transit, special shuttles, package delivery, and service for the elderly and handicapped. Two of the vehicles were equipped with wheelchair lifts, and service for the elderly and handicapped was fully integrated into the shared-ride taxi service. The normal shared-ride taxi service operated from 6:00 a.m. to 1:00 p.m. Four vans operated during the off-peak, and eight operated during the p.m. peak period from 4:00 p.m. to 7:00 p.m. The shared-ride taxi patrons could pay in cash, in scrip (which discounted the fare by 20 percent), or by use of an annual pass. The annual pass for daytime service was \$40 and for commuter service was \$65. WTD contracted with a local taxi operator to provide the management of the expanded service.

Special note should be taken of the contractual negotiations with local taxicab operators and subsequent litigation. WTD negotiated for more than 3 yr with the two local taxi operators. Buy-out suggestions were put forth by the taxi operators, who contended that the original transit service damaged the taxi business in Westport. As part of the demonstration project, WTD received two bids from taxi joint ventures, one of which involved a Westport taxi company. Upon the award of the contract, suit was filed by the other local taxi operator. The judgment from the U.S. Circuit Court of Appeals ruled that the plaintiffs were not a mass transportation company inasmuch as the taxis could be reserved for selective use. Thus no damages were due. The U.S. Supreme Court refused to hear the case. In 1980 the same operator filed suit in civil court; however, no further legal action is anticipated. (This information is from a phone conversation with Marty Hauhuth, Westport Transit District, October 28, 1980.)

Response to the integrated transit service was good. Ridership averaged between 2,700 and 3,100 riders per week, excluding package deliveries. This may be compared with a total taxi ridership of 1,400 trips per week prior to the expanded service. Gains in ridership were not at the expense of the existing transit service. Response time for riders averaged about 17 min. Vehicle productivity averaged over four trips per vehicle-hour. Public response to the service was very favorable.

Ridership maintained its level after the demonstration project ended in September 1979. Package delivery was dropped in June 1979, and fares were increased in April 1980. The current price for an annual commuter pass is $70. Cash fare remains at $0.50. Operating expenses of the integrated services are covered up to 95 percent from fare-box revenues. The mini-bus has an operating ratio of 20 percent; however, cost allocations between the two services account primarily for the difference. Local, state, and federal funds provide the required subsidy.

The service area has not expanded; however, service expansion to another area is being studied, and some consideration is being given to transfer arrangements with an adjoining community.

EVALUATION AND GUIDELINES FOR IMPLEMENTATION

The region, because of its size, offers an aggregate potential for TSM, but its complexity and fragmentation often hinder the implementation of TSM measures. Reluctance on the part of local agencies to spearhead regional implementation efforts often results in little or no action being taken. Transportation planners, traffic engineers, and transit operators have recognized, in the implementation of other TSM strategies, the need to spread the peak period by adjusting commuter hours, yet few can devote the necessary resources to the time-consuming task of employer contact and program promotion. The problem is similar in many TSM measures at the regional scale, although regional transit agencies, such as Tri-MET in Portland, have often provided invaluable service as the focal point for regional TSM.

As the regional agency created to improve transportation decision making in an urban area, the MPO is in a position to assist in regional TSM. Analytical work by the MPO in determining regional impacts of TSM actions might result in the priority determination for TSM measures and the lead responsibility for their implementation. As a regional broker, for example, is designated, implementation of TSM is fostered. The ride-sharing programs in Minneapolis and Knoxville are prime examples of this fact.

Guidelines

The following guidelines have been derived from TSM implementation experiences in the regional operating environment.

Reduced Transit Fares

1. Reduced transit fares result in significant revenue loss but with little additional operating cost.
2. Free fares appear to encourage vandalism, and steps should be taken to provide additional police protection.
3. Free fares can result in ridership increases to the extent that adherence to a route schedule is difficult. Steps should be taken to maintain driver morale and schedule adherence.

Ride-Sharing

1. Telephone contact with potential ride-sharers is an effective means of marketing and maintaining updated records. A carefully designed program of telephone marketing should be included in the ride-sharing program.
2. Minimum one-way travel distance for an effective van pool appears to be about 15 miles (24 km).
3. Van pools are fostered by congested freeway access and unavailable fixed-route transit. Regional application of ride-sharing should look first to those areas of poor access to work locations.
4. Multiemployer van pools appear to be more difficult to develop than single employer van pools, principally because of hesitancy on the part of both employers and employees. Third-party van pool agencies can assist in multiemployer locations.
5. Ride-sharing programs should recognize the need for a "critical mass" for program success.

Brokerage

1. Often institutional barriers exist to discourage regional brokerage. Barriers such as state statutes, difficulties in financing, and lack of available insurance should be addressed early in a brokerage effort.
2. Brokerage responsibility should be centered in an agency that has the breadth of authority and the geographic scope to provide regional brokerage services.
3. Computer programs and up-to-date employee/employer files are necessary for a regional brokerage activity.
4. Telephone marketing should be part of a regional brokerage effort to overcome people's apprehension to contact strangers.

Coordinated Transit and Paratransit Services

1. Implementation of coordinated transit and paratransit service should be based on a strong transit foundation in the region. Integrated service should extend existing transit service instead of substituting for it.

2. Legislation, regulatory agencies, and local ordinances should be carefully consulted before integrated services are implemented.

3. Care should be taken to involve the private sector in the operation where possible.

4. Vehicle selection should balance the maintenance savings from a uniform vehicle fleet with the compatibility between vehicle design and supply for varying service requirements.

5. In integrated services, each solid achievement leads to more sophisticated measures and stronger attempts to provide better transit and paratransit service.

Support Activities

Most TSM measures for regional application tend to be mutually supportive. Obviously, brokerage is closely linked to ride-sharing and coordinated transit and paratransit service. Staggered work hours can, however, be counterproductive when accomplished independent of transit and ride-sharing operations. In general, brokerage can effectively coordinate all regional TSM measures into a single, goal-oriented effort.

Certain support activities can complement most TSM measures implemented regionally:

1. *Integrated fare and pass program.* Coordinated transit and paratransit is dependent on an integrated pass program, equitable fare structures, and transfer privileges.

2. *Extensive marketing.* All regional TSM measures depend on an extensive marketing program for public response.

3. *Public information services.* Public information services are an important part of regional TSM to overcome the hesitancy of mode changes, work schedules, and so forth.

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CHAPTER SIX

NEIGHBORHOODS

Neighborhoods can be defined as identifiable areas of residential development with which residents have a feeling of identity. The boundaries of neighborhoods in American cities are most often defined by transportation facilities (such as major arterial streets) and topographical features (such as rivers and hills). In the more dense urban areas, neighborhoods are not limited totally to residential land use but also include land uses for such support services as grocery stores, doctors' offices, schools, and other related activities. In newer neighborhoods built around the auto, land use is devoted primarily to the single-family residence, with only elementary schools and parks included to support the residential life-style. Regardless of the neighborhood design, increasing emphasis in recent years has been placed on preserving the neighborhood, its life-style, and its ethnic and cultural characteristics. Jacobs (*1*), early in the freeway era of American cities, argued for the preservation of the neighborhood and against its desecration by transportation facilities.

Automobile traffic has been identified by Appleyard as a concern of most people living in city neighborhoods (*2*). Traffic variables include traffic volume, speed, and composition. The impact on residential neighborhoods is determined by the street width, landscaping, parking spaces, street maintenance, and neighborhood topography. Reaction by the neighborhood residents is dependent upon the number of children and old people in the neighborhood, available play space, walking and bicycling areas, and the social interaction within the neighborhood. Appleyard suggests that environment capacities be established from such neighborhood characteristics and that traffic be confined to capacity standards by residential traffic management.

The residential neighborhood and its preservation from the negative impacts of traffic offer a unique opportunity for transportation system management (TSM), albeit with different objectives from those normally identified with improved traffic flow. Thus, neighborhoods are identified as a separate and distinct operating environment for TSM—an environment in which local residents are keenly interested and more intimately involved in the TSM decision-making process.

CHARACTERISTICS

Opportunities for TSM in neighborhoods can be related to the characteristics of neighborhoods and generally to the era in which the particular neighborhood was developed. Quite obviously, neighborhoods that developed prior to the auto did not build in the protection from disruptive auto traffic. At the other extreme, recently developed planned communities often limit use of the auto within the neighborhood and in some instances prohibit auto traffic. In between are residential developments designed to limit auto traffic to trips with origins or destinations within the neighborhood. Thus, three different types of neighborhoods can be identified, each with different characteristics affecting the utility of TSM: older, pre-auto neighborhoods; newer, conventional neighborhoods; and planned communities.

Older, pre-auto neighborhoods are characterized by a grid street pattern with no hierarchy of streets and street purpose. Traffic through the neighborhood is not prohibited by its physical design, and traffic is not "managed" by physical features. Considerable conflict may exist between vehicular traffic and neighborhood activities. Quite often no off-street parking is provided. As a result these older neighborhoods offer perhaps the most significant opportunity for improvement through TSM.

Newer, conventional neighborhoods reflect the influence of the auto in their design and the attempt to integrate the auto as a personal means of transportation into good residential development. Street classification systems are identifiable in the neighborhoods, with arterial streets circumventing and bounding the neighborhoods, collector streets providing access to the arterials from within the neighborhoods, and local streets providing access to individual tracts. The neighborhood design uses discontinuous local streets and curvilinear collector streets to divert through traffic to a street system readily identifiable to the auto driver.

In planned communities, traffic management is built into the design. As a result, they offer the least opportunity for improved traffic management by TSM.

A common characteristic of all neighborhoods is the need for residents' involvement in decisions affecting their life-style or the manner in which traffic patterns will be modified. With no single administrative focal point available within a neighborhood, consensus on alternative TSM measures is gained through citizen involvement and participatory decision making.

TSM OPTIONS

Several TSM tactics related to neighborhoods have been implemented to achieve neighborhood objectives. These include:

- Parking constraints, permit parking, and other means of limiting all-day, nonresident parking.
- Traffic management plans to restrain through traffic and to artificially create a hierarchical street system for older neighborhoods. Included are such traffic restraint devices as stop signs, traffic circles, and median barriers.

- Ride-sharing including car pool, van pool, and subscription bus. Emphasis is placed here on the impetus for the service at the neighborhood end of the home-to-work trip rather than at the employment site.
- Bikeways for bicycle transportation within the neighborhood and for bicycle trips outside the neighborhood for work, shopping, recreation, and the like.
- Improvements to the capacity of arterial streets bordering the neighborhood. Often problems of through traffic in a neighborhood occur as a result of poor travel conditions on nearby arterial streets. Improving traffic flow on the arterial street through widening or other TSM measures often improves traffic conditions within the neighborhood.

MOTIVATION FOR ACTION

Motivation for TSM actions in neighborhoods is generally derived from neighborhood residents in response to observed traffic or environmental problems in the neighborhood itself. The problem more often than not is directly related to a specific TSM measure. Parking problems, for example, provide the motivation for a permit parking program. The neighborhood problems most frequently identified as the impetus for TSM actions are:

- Parking problems caused by the use of on-street space by vehicles from outside the neighborhood. This problem most often occurs when a major trip attractor does not have sufficient off-street parking. As a result on-street spaces in the neighborhood are occupied by nonresidents to the extent that neighborhood services, travel, and resident parking are interrupted. This is particularly true when the major attractor operates during the evening hours, when most residents are at home and also need a parking space. The problem is exacerbated by all-day parking and long-term evening parking characteristic of a modal transfer point near or within the neighborhood.
- Environmental impacts identified with nonresident parkers, such as the safety of children, free social contact, and too many autos in the neighborhood.
- High volumes of traffic passing through the neighborhood, thereby creating safety hazards and environmental problems because of negative noise, air, and visual impacts. Such problems are common in older neighborhoods.
- Expense involved in long home-to-work trips from the neighborhood to a major employment site that is the common employer of several neighborhood residents. Although most ride-sharing is organized by the employer or a broker on the destination end of the home-to-work trip, a common area of employment and recognition of the benefits from a shared ride have in some instances provided the motivation for neighborhood action in organizing a ride-sharing program.
- Inadequate facilities for pedestrian and/or bicycle travel. Often the lack of such facilities motivates a neighborhood to seek assistance in the provision of bikeways and

TABLE 5

GOALS, OBJECTIVES, AND MOEs FOR THE NEIGHBORHOOD ENVIRONMENT

Goal	Objective	MOE	TSM Measures for Each Goal
Maintain a Safe Street Environment	• Maximize Safety	• Accidents	Parking Programs Traffic Management Plans Bikeways
	• Reduce Vehicular Speed	• Speed	
	• Preserve Parking for Neighborhood Residents	• Number of Non-Resident Vehicles	
Reduce Neighborhood Disruption	• Minimize Through Traffic	• Vehicles	Traffic Management Plans Parking Programs Traffic Engineering Improvements to Adjacent Arterials
	• Reduce Vehicular Speed	• Speed	
	• Preserve Parking for Neighborhood Residents	• Number of Non-Resident Vehicles	
Maintain a Healthy, Livable Environment	• Minimize Noise Impacts	• Noise Levels	Traffic Management Plans
	• Minimize Air Pollution	• Concentration of Pollutants • Tons of Emissions	
Maintain or Improve Quality of Transportation Service	• Minimize Travel Time	• Point-to-Point Travel Time	Traffic Management Plans Ridesharing Traffic Engineering Improvements to Adjacent Arterials
	• Minimize Travel Cost	• Point-to-Point Out-of-Pocket Travel Costs	
	• Maximize Comfort and Convenience	• Transit Load Factor	

pedestrian facilities within the neighborhood and to nearby activity centers.

GOALS, OBJECTIVES, AND PLANNING ANALYSIS

Goals relating to TSM and the neighborhood generally deal with improving or maintaining the quality of life within the neighborhood and, as such, have the potential for conflicting with TSM goals in other operating environments. Neighborhood goals for TSM primarily call for reduced auto travel and lower vehicular speeds within the neighborhood and therefore can conflict with mobility goals of arterial corridors when the neighborhood is involved. Goal conflicts must be recognized, and care must be exercised to resolve the goal conflicts prior to selection of the appropriate TSM strategies.

Paramount among goal conflicts is the neighborhood's desire to reduce traffic and parking (forcing long-term parkers and drivers making through trips to use an adjacent arterial facility) and the desire of the arterial user and the merchant along the arterial to avoid the diverted traffic and parking. Another goal conflict is the desire of service businesses for additional traffic and parking capacity and the desire of neighborhood residents to reduce the use of the same facilities. Many neighborhood parking permit programs have protected the street and parking facilities of the small neighborhood business, thus minimizing the conflict between these two goals.

Neighborhood TSM goals most frequently specify certain optimum or desirable street conditions. Appleyard (*2*) suggests that neighborhood streets should provide (a) safe sanctuary for play (some state statutes prohibit play within the street); (b) a livable, healthy environment; (c) a neighborly territory that residents feel belongs to them; and (d) a community to be kept clean and enjoyable.

Such desirable street characteristics may be translated into the following neighborhood TSM goals: (a) maintain safe street conditions, (b) reduce neighborhood disruption, (c) maintain a healthy, livable environment, and (d) achieve adequate mobility and neighborhood accessibility. Table 5 expands those neighborhood goals into objectives and measures of effectiveness (MOEs).

Planning analysis of TSM alternatives accomplished prior to their implementation has been limited. Most neighborhood TSM strategies have been implemented with little prior evaluation of impacts on either neighborhood MOEs or exogenous areas or facilities. This lack of analytical evaluation primarily is due to a lack of familiarity with available techniques as well as the relatively low cost of neighborhood TSM measures. Techniques are available, however, and have been used to evaluate neighborhood TSM alternatives in Palo Alto, California. The Palo Alto evaluations concluded that, in the case of the College Terrace neighborhood, improvements to adjacent arterial streets (widening and/or construction of a grade separation) did more to achieve neighborhood goals than did traffic management strategies within the neighborhood itself (*3*). This type of planning analysis, when used, will minimize the negative impacts of TSM measures on adjacent areas and facilities and will maximize the neighborhood benefit in relation to the project cost.

IMPLEMENTATION EXPERIENCES

Washington, D.C., Residential Parking Permit

The District of Columbia has developed a residential parking permit program that may be implemented by neighborhood action (*4–7*). The significance of this program is that it was one of the first extensive efforts by a major city to control parking in residential neighborhoods on a citywide basis.

The residential parking program began in the District through legislation passed in October 1974, and it grew from 4 areas in the summer of 1976 to 24 in 1978 and to the current estimate of from 12 to 15 percent of all residential streets (1,400 blocks). Under the program a neighborhood wishing to implement a parking permit restriction may send a petition (signed by a minimum of 51 percent of the residents of as small an area as one block) to the mayor and city council for action. After an analysis by the District Department of Transportation (DOT) to determine the need, and after a public hearing is held, the program is implemented through the issue of a parking sticker (at an annual cost of $5) to residents in the area. Persons without a permit may park for no longer than 2 hr on a restricted street. Fifteen-day permits and 1-day permits may be issued to residents. The basic objectives of the program are to reduce traffic congestion, eliminate illegal parking, and alleviate related health and safety hazards.

In an impact evaluation in one residential area in the District (Friendship Heights), it was reported that total vehicles parked on the streets decreased by 56 percent, from 1,140 to 501, after the program was implemented. A high degree of enforcement was not reported, but resident response to the amount of enforcement was satisfactory. The report also indicates that businesses in the neighborhood were not adversely affected. In another impact study in 1978 for the Georgetown area, it was found that total vehicles parked on the streets decreased by 29 percent, from 3,689 to 2,609, after implementation of the program. An important beneficial impact in the Georgetown area was the reduction of illegally parked vehicles.

Parking regulations initially were enforced by the police department, and the amount of enforcement varied from district to district depending upon priority given to it by the district police officer. In October 1978 responsibility for enforcement was placed under the newly created Bureau of Parking and Enforcement within the D.C. DOT, and civilian parking patrol aides, or parking control agents (PCAs), were employed. PCAs are enpowered to ticket illegally parked vehicles and to identify vehicles that have committed towable parking violations. As of February 1979, 48 PCAs were patrolling arterial streets and residential neighborhoods. During the 1979 fiscal year each PCA issued an average of 96 parking tickets per day.

Cambridge Residential Parking Permit Program

The significance of the Cambridge program (*6*) is that it is citywide. The program was initiated in 1972 in the Cambridge port area to discourage commuting Boston University students from parking in the area and walking over the bridge to classes in Boston. Enforcement began in January 1973, and violations decreased from 132 to 29 after 2½ weeks.

After the success in the Cambridge port area, the program was expanded to other areas, and parking permits ($1 each) were issued to residents of the area. In 1974 a county district court judge in a court case on the parking program ruled that to be valid the parking permits had to be issued to all Cambridge residents and not just residents of the restricted areas. Permit stickers were subsequently made available to all Cambridge residents; however, guest stickers remained valid for only the area of residence. With the citywide use of permits, a resident of one part of Cambridge could park legally in another residential area. Subsequent reports have concluded, however, that, because Cambridge is small in comparison to the total metropolitan area, the neighborhood program has not been rendered ineffective by the citywide permit system.

In 1975 another court decision upheld the Cambridge program against a discrimination suit by a nonresident of Cambridge. By 1979, 90 percent of eligible streets had been posted under the program, and parking had been restricted.

Arlington County (Virginia) Residential Parking Permit Program

This project (7) is significant in that the Arlington County program was tested in the courts and in 1977 the U.S. Supreme Court upheld it. The program was designed to protect parking space in residential neighborhoods from auto commuters and all-day parking. In its decision *(County Board of Arlington County, Virginia, et al.* v. *Rudolph A. Richards et al.),* the Supreme Court stated that the Arlington program was intended "to reduce hazardous traffic conditions resulting from the use of streets within residential [areas] . . . for the parking of vehicles by persons using districts zoned for commercial or industrial uses . . .; to protect those districts from polluted air, excessive noise, and trash and refuse caused by the entry of such vehicles . . .; [and] to preserve the character of those districts as residential districts."

The Supreme Court concluded that reducing air pollution and other detrimental environmental impacts are legitimate goals and that "a community reasonably may restrict on-street parking available to commuters."

Berkeley Traffic Management Plan

The significance of this project (*6, 8–10*) lies in the extensive use of traffic barriers in local neighborhood streets to divert through traffic to collectors and arterial facilities. Since its implementation in August 1975, the Berkeley traffic management plan has been tested as to legality in the courts and has involved final appellate court rulings. Lessons learned in Berkeley's traffic management plan are applicable elsewhere.

The major portion of the city has a grid street system, and only neighborhoods in the northeastern hills have curvilinear street patterns to discourage through traffic. The city is served by I-80 on its western boundary adjacent to San Francisco Bay; however, access to the freeway is limited to three interchanges in Berkeley. The University of California at Berkeley, a major traffic generator, is located in the eastern portion of Berkeley. The city is served by two Bay Area Rapid Transit (BART) stations and numerous fixed bus routes of the AC Transit System. As a result of the grid street system and topographic limitation to travel dispersement, neighborhoods in the older portions of Berkeley were penetrated by through travel on local residential streets. (This information is from a phone conversation with Herman Sinemus, Traffic Engineer, City of Berkeley, California, July 14, 1980.)

The City of Berkeley implemented its traffic management plan in August 1975. The plan called for installation of 74 traffic diverters, 179 stop signs, 10 chokers, and other signs, signals, and pavement markings to divert traffic to collector and arterial streets. Most of the traffic diverters were concrete stanchions supporting a wooden beam.

In a report that was dated May 1976 and evaluated the results of the management plan, the following significant results were reported:

1. Traffic on most local streets decreased or remained unchanged; however, volumes increased on some local streets due to the diversion patterns. Traffic on some arterial and collector streets increased, primarily those of nonresidential character or mixed land use.
2. Overall travel times in Berkeley along the designated circulation system did not change significantly.
3. Traffic increases on arterial and collector streets did not result in serious increases in congestion. Traffic operations improvements absorbed traffic shifts at key intersections.
4. Considerable disobedience of all traffic management devices was reported. Stop controls, where no need was observed, bred driver contempt and hazardous disregard for the device.
5. Little discernible effect was noted on local transit ridership.
6. Air quality was not meaningfully affected by the traffic management plan, and the data available were insufficient to draw conclusions in regard to impacts on energy consumption.

On June 30, 1980, an appeals court decision permitted the traffic diverters and control devices to remain in place. The court based its decision on the legal findings that the diverters are "official traffic control devices" and that the statutory provision allows local government to "close" any highway to vehicular traffic.

Seattle Neighborhood Traffic Control Program

In 1968, in response to voter approval of a bond issue for neighborhood improvement funds, the City of Seattle developed procedures by which neighborhood residents could petition and work with city professionals in developing a neighborhood traffic management plan. The program is significant in that it continues to be funded by the City of Seattle and has proven to be popular with neighborhood residents (*6, 11–14*).

Under the procedures established by the city, a request for traffic management must be approved by a majority of the neighborhood property owners. Following a traffic study by the city and a survey of all neighborhood residents, temporary control devices are installed for a demonstration period. Following the demonstration period and a second neighborhood survey, an evaluation is made and the city council determines whether or not to make the installation permanent.

The first installation of neighborhood traffic management devices came in response to a petition from the 12-block Stevens neighborhood. Initial installation consisted of four temporary diagonal diverters made of sand-filled 50-gal (190-L) drums connected by reflectorized wooden rails. Following the demonstration period, the plan was modified to include two traffic circles, a diagonal diverter, a partial diverter, and two traffic "bulges" as semidiverters. Subsequent to the final installation in 1973 an evaluation reported the following results:

1. Traffic in the neighborhood was reduced between 25 and 50 percent.
2. Accidents fell from 12 per year to 0.5 per year.
3. Neither traffic volumes nor accidents changed on adjacent arterial streets.
4. The neighborhood was quieter after the installation, and residents developed a stronger identity.

Detrimental impacts were related to driver confusion with the control devices and slightly longer travel routes for residents and emergency vehicles.

Until 1978 neighborhood traffic control plans were available to those neighborhoods eligible for community development block grant funds. In 1978 the City of Seattle formalized a neighborhood traffic control program, named a program manager, and established an annual budget of $200,000 for the program. This amount permits the construction of traffic control devices for four neighborhoods each year. The city is currently considering reducing design landscaping to lower the cost and thus permit more installation annually to overcome a backlog of requests for management plans. Temporary control devices were changed from the 50-gal (190-L) drum and reflectorized wooden rails to temporary asphalt curbs and backfill to reduce vandalism and to improve the appearance of temporary control devices, which frequently have to remain in place over a period of time.

Concurrently with the traffic control program, in July 1979 Seattle established a program to restrict commuter parking in residential neighborhoods. In a residential area adjacent to a large medical facilities complex, the program succeeded in reducing on-street parking from 79 to 47 percent. Unrestricted neighborhoods adjacent to the project were unaffected, having only a minor increase in parking.

Reston (Virginia) Commuter Bus Service

This project is a primary example of ride-sharing and subscription bus initiated through actions of neighborhood volunteer organizations (*15–18*). Ride-sharing and subscription bus are TSM measures normally implemented through agency matching programs at the place of work. The Reston Commuter Bus, however, was initiated through efforts of the neighborhood to minimize traffic cost and inconvenience. Although the subscription bus service at Reston has evolved from a neighborhood TSM strategy to part of the areawide transit operation, it nevertheless illustrates a TSM measure implemented within an identifiable neighborhood. Although the Reston Commuter Bus is one of the oldest and best-known commuter bus clubs in the United States, other examples of neighborhood-oriented commuter clubs, such as those in Columbia, Maryland, may be cited.

In March 1968 a group of Reston volunteers chartered a 51-seat bus from the local franchised bus operator for home-to-work travel to and from Washington, D.C. In the initial effort, the costs to individual riders were based on 35 passengers and were designed to cover the cost of charter operation. Within 6 weeks the single bus operation passed the break-even point financially, and at the end of 2 months a second bus was added to leave 30 min later than the first. Buses operated nonstop from Reston to Washington, D.C., and modified the daily route as necessary to minimize travel time. Late in 1971 the organizers incorporated in Virginia as Reston Commuter Bus, Inc. (RCB), a nonprofit corporation. Service has continued to expand on a step-by-step basis, and by February 1974 RCB was operating 25 runs into Washington each day and 24 runs out, with service to between 800 and 900 subscribers. In September 1979, after the service level had risen to 39 runs in and 36 out each day, with 2,500–3,000 subscribers, the board of directors voted to find another carrier to provide the transit service, because the current operator had difficulties in maintaining adequate equipment. After considerable effort in attempting to find an operator with sufficient equipment to provide the service, RCB bus service was incorporated, but without success, with that of the Washington Metropolitan Area Transit Authority (WMATA). (This information is from a phone conversation with Britt Hedd, Manager, Reston Commuter Bus, Inc., October 21, 1980.)

RCB still functions and operates eight mini-vans to other urban locations. It also provides the service of buying tickets from Metro and selling the tickets on the bus. Service levels remain basically the same, although some ridership loss was experienced as a result of increased costs and fares under WMATA. Currently the one-way fare is $1.95. RCB personnel report that exact ridership figures are unavailable because volunteer "busmeisters," who formerly collected fares, provided ticket sales, and counted passengers, are no longer provided free transportation for their services and are not part of the operation. Passenger collection service in Reston is provided by five basic routes, with approximately 20 stops per route. Collection time in Reston averages approximately 20 min. Similar distribution service exists in Washington to several employment locations. Approximately 15 percent of the ridership comes from oustide Reston, but parking facilities are provided within Reston by RCB.

Reston's location, size, and demographic characteristics were major factors in the success of the commuter bus service. Located approximately 25 miles (40 km) west of the central area of Washington, D.C., Reston's population was approximately 3,000 in 1968 at the start of the commuter bus service. Its 1980 population was approximately 35,000, and less than one-third of the residents were federal government employees. Of the workers who live in Reston and work in Washington, almost 23 percent currently patronize the RCB service.

Initial objectives of RCB in providing the commuter service were to provide transit service where none existed, reduce travel time below that required by the automobile, reduce the necessity of auto ownership for the home-to-work trip. In an evaluation study in 1977, it was found that transit travel time between Reston and Washington was competitive with auto travel time—60 min for transit and 50 min for autos. Transit was also made attractive by the securing of preferential access for the buses to the Dulles Airport limited access highway. Bus productivity was characterized by actual load factors maintained equal to or greater than the break-even load factor.

The Reston bus service initially provided transit service where none existed. Other surveys reported that 21 percent of the riders claimed that they had reduced the number of autos in the household, and 49 percent said that they would be required to increase the number of autos in their household if RCB were abandoned.

Major factors contributing to the success of RCB were (a) gross route involvement of the users of the bus service, (b) service operations and reduced travel times, (c) growth of the community and responsiveness to ridership growth by good management and service characteristics, and (d) cost-control measures and financial solvency.

Eugene (Oregon) Greenway Bicycle Bridge

Neighborhood TSM bicycle measures can relate to bicycle use for recreational purposes within the neighborhood as well as for work or shop trips outside the neighborhood. This project (*19*) provides an example of a connecting bicycle link between a residential neighborhood and a major commercial center.

The Greenway Bicycle Bridge crossing the Willamette River in Eugene was constructed in 1976–77 under the National Bikeway Demonstration Program (Section 119 of the Federal-Aid Highway Amendments of 1974). The project was part of the Eugene Bikeway Master Plan, under which the City of Eugene has committed $50,000 annually plus state gasoline tax funds for bikeway construction. The Greenway Bridge connects a residential area on the southwest side of the Willamette River with the Valley River shopping center on the northeast side of the river. As a requirement under the demonstration grant, extensive before and after surveys were conducted to evaluate the effectiveness of the project. The purpose of the project was to encourage bicycle travel and reduce vehicle trips.

Use of the bicycle bridge was sufficient for the evaluation report to conclude that "the bicycle is no longer a child's toy." The bridge was used by adults of all age groups and income levels for utilitarian trips. Purposes of the bicycle bridge trips included 30–40 percent of all weekday trips for work, 15–20 percent for school, and 20–35 percent for recreational activity. Approximately 50 percent of those crossing the bridge would not have made the trip by bicycle had the bridge not existed. It was estimated that 500 auto trips per week have been eliminated as a result of the bicycle bridge.

EVALUATION AND GUIDELINES FOR IMPLEMENTATION

Neighborhoods provide a different approach to the customary objectives of TSM measures in that, for neighborhoods, traffic is to be discouraged, parking is to be restricted, and auto speeds are to be reduced. Auto traffic is encouraged to use arterial facilities, thereby increasing the possibilities of congestion on the arterials. Although goals for neighborhood TSM strategies are significantly different from goals for freeway and arterial corridors, TSM strategies for neighborhoods can be integrated with TSM actions in these other environments to minimize goal conflict and simultaneously achieve the objectives in several environments.

TSM strategies in neighborhoods can produce conflict between neighborhood residents and commuters who use the neighborhood for parking or for a shortcut. Implementation of neighborhood TSM must recognize this potential for conflict at an early stage of planning so that proper community involvement is obtained and citizens are aware of the measures prior to their implementation. It should be noted that arterial facilities and high-activity centers can be negatively affected by extensive use of restricted neighborhood parking, and the total areawide impact should be considered prior to implementation.

Implementation of TSM measures in the neighborhood environment is clearly the role of the municipal traffic engineer. This individual possesses the skills and technology to design and properly evaluate alternative TSM actions, plus the responsibility and authority for implementation. Coordination is required with operators of emergency vehicles when a traffic management scheme is being considered. Joint development of TSM strategies with major activity centers adjacent to the neighborhood is necessary to provide both the restriction and ample supply in parking control. Outside of these coordination responsibilities, the municipal traffic engineer plays an almost undiminished lead role in implementing neighborhood TSM strategies.

A unique feature of the neighborhood TSM environment is the importance of citizen involvement in suggesting, evaluating, and approving TSM strategies for the neighborhood. Almost without exception, successful projects of parking permit programs and traffic management actions have relied upon direct citizen involvement in testing temporary measures before final installation. Prior analysis consisted primarily of problem determination and suggestion of standard solutions. Final analysis was based on citizen response to temporary TSM installations.

Guidelines

From the TSM examples discussed, guidelines may be suggested for the TSM options in the neighborhood operating environment. These guidelines are structured below under each TSM measure applicable to the neighborhood. A broad overall guideline should be highlighted for each TSM measure—the necessity of meeting the requirements of Title

VI of the Civil Rights Act, especially when the project is receiving federal assistance. Persons responsible for implementing TSM should become familiar with requirements of the Civil Rights Act. Other guidelines are listed below.

Parking Permit Program

1. Enforcement is a major element in a parking permit program and should be designed as part of the total effort.
2. Because much of the nonresident parking demand is often generated by a major activity center, implementation strategies should include simultaneous TSM actions by the activity center. Such TSM actions are described elsewhere in this synthesis.
3. Analysis prior to implementation should cover an area much bigger than the neighborhood in question to ensure that the problem is solved and not relocated.
4. The area of implementation of the permit parking should be flexible to permit expansion in response to a shifting problem but should be clearly defined to facilitate adequate enforcement.

Traffic Management Plans

1. A trial run of suggested barriers and control devices through the use of inexpensive temporary substitutes is extremely important for proper neighborhood evaluation. Successful programs have used 50-gal (190-L) drums and reflectorized timber barriers or, for more aesthetic installation, asphalt curbs and diverters.
2. Aesthetics through landscaping and proper design of traffic control measures is a major consideration in the permanent installation.
3. Traffic management plans should be implemented in a neighborhood as a package and not as staged construction. This was emphasized by several successful programs.
4. Citizen participation is a must in the initiation, evaluation, and acceptance of the traffic management effort.
5. Evaluation of traffic management alternatives should include TSM measures for adjacent arterial streets. Often TSM strategies on arterials (discussed in Chapter 3) can be effective in meeting neighborhood goals. Likewise, neighborhood TSM measures can negatively affect flow on arterials. Thus proper analysis should be accomplished prior to implementing TSM actions.

Ride-Sharing and Subscription Bus

1. Potential riders should have commonality of residential area, employment location, and, if possible, both.
2. Subscription bus services are better suited to larger trips between 10 and 50 miles (16 and 80 km), where conventional transit is less likely to be available and where access time is a small percentage of the total travel time.
3. Transit service should be favored by preferential treatment at freeways and arterial intersections and with disincentives to private auto use.
4. High service standards such as schedule reliability, travel times, convenient access, and guaranteed seating should be maintained.

Bikeways

Recent work on guidelines for bicycle facilities has been reported by the Institute of Transportation Engineers (*20*), the American Society of Civil Engineers (*21*), and the Federal Highway Administration in proposed rule making (*22*). The following guidelines are general conclusions drawn from the examples cited in these studies.

1. Adequate parking for bicycles must be provided if travel is to be attractive to the bicycle rider.
2. Proper signing should provide guidance for the bicyclist to major activity centers or other points of travel.
3. Bicycle paths and bridges can provide recreational opportunities as well as facilities for home-to-work travel.
4. Sidewalks are generally not acceptable for bicycle travel.

Support Activities

Several support measures have been identified as contributing to the success of TSM in residential neighborhoods:

1. *Enforcement*. Although not yet considered strictly a TSM activity, enforcement is a vital support effort for neighborhood TSM measures. Because these measures are restrictive in nature, enforcement is necessary to ensure compliance.
2. *Arterial TSM measures*. Prohibition of through traffic in a residential neighborhood diverts that traffic to arterial facilities, and therefore arterial TSM strategies are necessary to support neighborhood measures.
3. *Major activity center TSM measures*. Because major activity centers often contribute to the parking problem in residential neighborhoods, TSM measures under that environment are significantly supportive of neighborhood TSM activities.
4. *Improved transit alternatives*. Implementation of a neighborhood parking permit program provides an excellent opportunity to coordinate transit service with parking constraint. TSM actions that provide an acceptable transit alternative to the auto trip also support the neighborhood parking strategy.

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CHAPTER SEVEN

MAJOR EMPLOYMENT SITES OUTSIDE THE CENTRAL BUSINESS DISTRICT

Major employment sites outside the central business district (CBD) provide opportunities for implementation of transportation system management (TSM) actions sufficient for the employment centers to be considered as an operating environment in themselves. In this synthesis an operating environment for major employment sites is specifically contrasted with a CBD. Although CBDs, particularly those in major urban areas, are no doubt the focal point of major employment activities, major employment centers outside the CBD have different characteristics and offer different opportunities for TSM.

CHARACTERISTICS

Major employment centers generally consist of industrial, research, and/or office facilities grouped into a single geographic location. Often a single industrial firm is dominant in the total employment of a center, and frequently a single firm is of sufficient size to be classified as a major employment site in itself. In this synthesis no specific effort has been made to rigidly define a major employment site in terms of total number of employees because the TSM activities discussed herein are applicable to most industrial sites regardless of size.

Major employment centers more often than not developed during the urban expansion that occurred after World War II and therefore were designed and developed with the automobile in mind for both home/work travel and business interaction. Quite frequently such centers are not served by transit, and in most cases they have excellent access to the urban freeway system. Certain identifiable characteristics, which are listed below, are common to most major employment centers.

New, Planned Development. Most major employment centers represent a planned facility. Often density of development has been considered as well as a proper grouping of related activities.

Homogeneous Land Use. Closely related land uses and development densities are characteristic of planned employment centers.

Access to Freeway System. Employment and industrial centers developed during the interstate highway era recognized the importance of freeway access and, in contrast with the CBD (which was located at the confluence of radial freeways), these newer industrial centers were often placed adjacent to radial and/or circumferential freeways in outlying areas away from the CBD. Older employment centers that existed prior to the development of freeways often provided sufficient travel demand to influence the location and planning of the freeway system.

Balanced Traffic Flow. Major employment centers, particularly those on circumferential freeways, often, with other suburban development, influence the characteristics of freeway travel such that the directional traffic volumes are balanced during the peak periods, thus restricting the use of reversible lanes.

Limited Transit Service. Major employment centers often have no transit service or limited transit service. In many cases, if transit service is available, it is CBD-oriented and provides little direct movement to the employment center. Such centers thus represent a problem of access by central city residents with limited auto ownership.

Work-Oriented Travel. Concentration of the work place in major employment centers results in a heavy orientation of travel in the drive-to-work category.

Concentrated Peak Period for Travel. Lower auto occupancy for home-to-work travel and homogeneous land uses result in a shorter but highly concentrated peak period. A midday peak is often also observed, particularly at adjacent commercial land uses.

Ample Parking. Special parking is often provided for each industry, and employees are not forced to compete with other auto drivers for parking space. Inadequate parking is seldom the reason or motivation for improved transportation to major employment centers; however, older employment centers with increased employment face demands for additional parking or for other modes of transportation.

Employee Working Conditions Include the Journey to Work. Job dissatisfaction among employees is often blamed on poor conditions in travel to work, and, in contrast to the CBD, the major employer is expected to respond and assist in improving travel conditions.

TSM OPTIONS

Several TSM strategies have been implemented in various employment centers. These include:

- Ride-sharing, consisting of car pools and van pools, with preferential parking for high-occupancy vehicles (HOVs).
- Subscription bus or prearranged travel for either door-to-door or park-and-ride service.
- Express bus or nonstop bus service to the place of employment from neighborhood locations without prearrangement for service.
- Brokerage, consisting of a transportation coordinator to match car pools and van pools and to make arrangements for public or private suppliers of transportation to meet the particular needs of the major employment site.
- Alternative work schedules, consisting of staggered work hours, flex-time, and so on.

Obviously, TSM options are not limited to the specific tactics identified above. In fact, most of the implementation experiences in major employment centers have combined some or all of the above actions with such support activities as employee incentives, park-and-ride lots, employee matching services, and preferential parking.

MOTIVATION FOR ACTION

Impetus for TSM strategies in major employment centers has generally come from management in the major employers; however, employee and neighborhood groups, such as those in Knoxville, Tennessee, have in some instances provided the motivation for action. Although state and local governments have successfully provided major employers with materials on the benefits of van pools, it has generally been the decision and emphasis by upper management in major employment centers that have successfully implemented TSM.

The factors foremost in the decision by employers to implement TSM measures have been identified as follows:

1. Employee satisfaction, primarily to alleviate employee dissatisfaction with the travel-to-work conditions, including poor transit service and rising gasoline prices.
2. Employee productivity and the loss of productivity due to tardiness and absenteeism and long employee commuting time.
3. Corporate pride, particularly as reflected in the creativity and innovation of unique operating programs.
4. Employee recruitment and the corporate environment related to employee life-style.
5. Profit/land values and the costs associated with employee access and parking.

Many of the corporate firms that have been instrumental in implementing TSM measures identified one or more of the above factors as providing the motivation for involvement in TSM. The 3M Company in St. Paul, for example, cited employee satisfaction and the cost of providing additional access and parking facilities as a primary motivation for its initial van pool program in 1973. Conoco of Houston cited the nonavailability of transit and long commuter travel distances as the impetus for implementing such TSM measures as car pools, van pools, and flex-time.

GOALS, OBJECTIVES, AND PLANNING ANALYSIS

Because goals and objectives generally center on the groups to be affected by the TSM strategies, conflict among competing goals of diverse groups is to be expected. In the major employment center environment, however, constituency groups generally consist of only the employees, and, as a result, goal conflict is reduced to a minimum. In other words, although other travelers will benefit from reduced auto travel on freeways and arterials because of van pools, subscription bus, and flex-time, it is the employees and managers within the major employment center who will be the primary recipients of benefits from TSM and around whom goals and objectives are generally developed.

Measures of effectiveness (MOEs) can be identified for each objective to provide an evaluation of implementation results. Goals, objectives, and MOEs for the major employment center environment are shown in Table 6. Recommended MOEs build upon previous work by Abrams and DiRenzo (*1*). MOEs are particularly important in this environment because of the interaction between the public and private sectors. Because the private sector must emphasize MOEs in its "bottom line" approach, they are significant to a greater degree than in those environments that look primarily to the public sector for solutions. Common MOEs for both the public and private sectors can provide the catalyst for an exchange of creative solutions. It should be emphasized, however, that not all TSM tactics provide measurable impacts and that these TSM measures should not be rejected for solely that reason.

What planning analysis is required to project the impact of TSM strategies in a major employment site, and what technical tools are available for this purpose? In many instances little technical analysis has been accomplished (or

TABLE 6

GOALS, OBJECTIVES, AND MOEs FOR THE MAJOR EMPLOYMENT SITE ENVIRONMENT

Goal	Objective	MOE	TSM Measures for Each Goal
Improve Profit Margin (Employer)	• Minimize Parking Requirement (Minimize Auto Usage)	• Parking Space Requirement & Parking Cost	Ridesharing Alternative Work Schedule
		• Number of Vanpools	
		• Number of Single-Occupant Autos	
	• Minimize Capital & Operating Costs	• Capital & Operating Costs	
		• Reduced Tardiness and Absenteeism	
Improve Employee Satisfaction (Employer/Employee)	• Minimize Travel Time	• Point-to-Point Travel Time	Ridesharing Express Bus Brokerage Alternative Work Schedule
	• Minimize Travel Costs	• Point-to-Point Out-of-Pocket Travel Costs	

considered) prior to implementation of TSM strategies. Any prior analysis has consisted generally of locating the home address of employees, conducting surveys of potential response, and estimating the cost of operation. Network planning tools could be used to project and compare point-to-point travel times before and after TSM implementation, but they generally have not been used due to cost and the low capital investment at risk in applicable TSM strategies. Currently in considering TSM in major employment centers, prior analysis is primarily limited to an evaluation of employee responses plus capital and operating costs. Experimental implementation permits a "go slow and see" approach and reduces the need for extensive prior analysis and projection of impacts; however, sound analysis prior to actual implementation can lead to better and more implementable strategies.

IMPLEMENTATION EXPERIENCES

3M Company Commute-a-Van

This van pool program is the oldest and one of the largest company-sponsored van service pools in this country. The program was initiated in April 1973, when 3M began operation of six vans as a pilot project to provide service to its headquarters in St. Paul, Minnesota. The program is unique in operational techniques and management strategies (*2–4*).

The 3M Company employs in excess of 10,000 persons in a large suburban complex on a 400-acre (160 hm^2) site east of St. Paul. Parking facilities are provided to accommodate 8,000 vehicles at 17 buildings within the complex. Home-to-work travel is primarily by automobile; and in 1973 the company, with increases in employment, faced peak-hour congestion problems as well as the necessity for large investments in additional parking facilities. As part of the pilot project, the company organized an ad hoc committee with representatives from each of the affected six departments to produce an operations guide for the program. The primary objectives of the commute-a-van program were to reduce the total number of vehicles at the site, thus alleviating congestion, and to reduce the demand for parking. Secondary objectives were to reduce air pollution and increase energy savings.

In the pilot project, 3M supplied standard 12-passenger vans to employees who were willing to participate. The vehicles were purchased by the company, and fares were set to meet operating costs. Pool coordinators (drivers) and assistant drivers were selected. Throughout the program, from 1973 to the present, the pool coordinators have been responsible for choosing their routes and their passengers from a list of potential riders furnished by the company. Fares are based on 8 passengers (not including the driver), and if the pool coordinator opts to include up to 11 passengers, their fares go to the pool coordinator as extra income. Pool coordinators also are permitted to use the company-owned van for their private use at a charge of $0.08 per mile ($0.05/km). Pool coordinators are responsible for submitting an expense form and mileage report each month and a list of passengers for the upcoming month. Riders pay at the beginning of each month and pay the full fare whether they ride every day or not.

The commute-a-van was immediately successful. Waiting lists developed for van pools, and the management of the company approved expansion of the program. By September 1975, 75 vans were in operation with a total of 780 riders, representing almost 8 percent of the total number of employees. By January 1977 the number of vans had increased to 86. As of July 1980, 3M was operating a total of 135 vans with a ridership of 1,500.

The van pool program covers a seven-county area. Round-trip distances range from 5 to 150 miles (8 to 240 km) with an average of 50 miles (80 km). Approximately 90 percent of the van trips are door-to-door, and the longer trips originate from a common pickup point. Vans park free in company lots, and private autos are charged for parking.

Surveys in 1973 revealed that 53 percent of the van riders earned $15,000 (1973 dollars) or more; 37 percent had incomes between $8,000 and $14,000; and only 10 percent made less than $8,000. Eighty percent of van poolers found the van service more convenient than their previous mode. Forty-nine percent of the van riders had previously driven an auto in a driver-only mode, and 46 percent had previously participated in a car pool.

Measured against the objectives of the program, the van pool effort has resulted in less congestion, and the need for 700 additional parking spaces has been negated. Van users report commuting cost savings, reduced driver tension, lower insurance fees, less wear and tear on private autos, and freedom of the family car for other uses. The 3M Company reports that $3 million was saved in parking facility costs and by 1980 the average annual savings had increased to over 297,000 gal (1 124 000 L) of gasoline and 3.7 million vehicle-miles (6 million km) of travel.

Three factors contributed to the success of the 3M commute-a-van program. First, company management took the lead in forming van pools and provided unique incentives to encourage ridership. Second, responsibility for the van pool operation was delegated to the pool coordinators, and financial incentives were built in to encourage full vans. Third, continued professional support and monitoring of the program were centered in a management professional.

TVA Express Bus and Van Pool

This major TSM effort illustrates the importance of company and city administration response to opportunities highlighted by citizen inquiries and employee concerns (*5–9*).

The Tennessee Valley Authority (TVA) is the largest employer in downtown Knoxville, Tennessee, the major urbanized area in east Tennessee. Because the TVA is the major employer in the CBD and primarily because the employer took a lead role in implementing the TSM strategy, this example is included in this operating environment rather than in the CBD environment. Then, too, with a total urbanized area population of less than 300,000 in the Knoxville area, it was felt that this example was more illustrative of a TSM activity successfully implemented through the efforts of a major employer than it was of TSM in a CBD operating environment.

Express bus service to the TVA and the Knoxville CBD from west Knox County was initiated in December 1973 in response to concerns expressed by a homeowners' council and a union-management organization within the TVA about the increasing traffic congestion on I-40. Subscription bus service had been proposed by the Knoxville Transit Authority but was rejected because the proposal called for five-day-a-week prearranged travel, and many of the possible users indicated a need for less than five-day service. This was particularly true for students of the University of Tennessee, which is located just west of the CBD and would be served by the express bus service. The goals of the express bus service included the provision of a viable alternative to auto use, reduced congestion on I-40, reduced parking demand at the TVA and in the Knoxville CBD, and reduced travel time from west Knox County.

Concurrent with the express bus service, the TVA initiated van pool service to its employees through six vans purchased by the organization's credit union. Prior to initiating van pool service, the TVA agreed that the van pools would not be used to compete with the transit authority's express bus service. Van pools were used in outlying areas without any bus service.

Both TSM strategies were supported through the efforts of a transportation broker, or coordinator, funded by a demonstration grant from the Urban Mass Transportation Administration. The transportation broker was initially part of the Knoxville city administration, then a part of the University of Tennessee, and later under the city's Department of Transportation Services. Because the broker operates in a regional environment, the activities are covered in Chapter 5. Obviously the transportation broker has provided a continuing impetus toward an ongoing program.

The express bus service (at a one-way fare of 50 cents, compared to 30 cents for local one-way transit fare) enjoyed initial success. By the spring of 1974 seven express buses were in operation. Surveys conducted in 1974 revealed that more than 99 percent of the express bus riders had annual family incomes greater than $10,000 (1974 dollars) and over 11 percent had annual family incomes in excess of $25,000. Similar surveys in 1975 on reasons for express bus use found that almost 40 percent used the bus because it provided a less expensive means of travel; 27 percent rode because of freedom from the tensions of driving an auto; and 22 percent rode the bus for gasoline conservation. Only 1.9 percent, however, reported that they used the express bus because it provided them with a faster means of travel. Modal split and parking demand resulting from the express bus (expressed as a percentage of the total Knoxville TVA work force) are shown in the following table.

	November 1973	January 1976	May 1976	May 1980
Mode of Transportation to Work	%	%	%	%
Drive alone	65	19	—	15
Ride bus	4	31	—	26
Car pool	30	43	—	37
Van, bike, walk	2	7	—	24[a]
	No.	*No.*	*No.*	*No.*
Work Force	2,950	3,200	3,450	4,200
Parking Space demand	1,900	—	1,050	—

[a] Van—22 percent; bike and walk—2 percent.

Operational difficulties were encountered by the transit authority in the practical economics of express bus operation. In the initial success the transit authority had been able to rearrange driver schedules and divert buses to express runs. With the success of the express bus operation and its expansion to 22 routes, difficulties were encountered in employing drivers on a split-shift basis or paying drivers for 8 hours for the two daily peak-period runs. Assistance was provided by private bus companies that operated one-third of the express routes.

As of the summer of 1980 approximately 85 percent of the 4,200 employees at the Knoxville office of the TVA participated in ride-sharing. This illustrates the success of the program. Average occupancy in the 300 vans operated at the Knoxville location is 12.8 persons. Average bus occupancy is 39. In its total program at three locations, the TVA operates 600 vans and 88 buses in which 8,000 employees participate in ride-sharing.

The following significant factors in the TVA express bus and van pool program can be identified:

1. Several TSM strategies were used in a supportive fashion. The strategies included express bus, car pool, van pool, park-and-ride, and transit marketing.
2. TSM actions were coordinated and supported through the efforts of a transportation broker.
3. Employee incentives for van pools were provided by the employer, and the express bus service was strongly supported by TVA management. An example of management support was a revenue guarantee for the operation of "overtime" buses to offset the impact of employee overtime on regular express bus schedules.
4. TVA payroll by home address provided a marketing tool for both express bus and van pool operation.
5. Revenue guarantees for express bus operations were provided by the TVA for service expansion by private bus operators.
6. Expansion of the express bus service to the University of Tennessee and other major employers met with limited success because of irregular travel patterns at the university and the wide physical separation of employees at other industrial firms.

Texas Van Pool/Car Pool Program

Van pool programs have been encouraged and fostered in recent years through state energy programs funded in part by the U.S. Department of Energy. The largest and one of the most successful state programs (*10–12*) has been operated in Texas by the Texas Energy and Natural Resources Advisory Council (TENRAC). The basic strategy of the program is to sell the state's largest employers on the van pool concept and to provide technical assistance during implementation. TENRAC has served as a statewide focal point for inquiries and dissemination of information on employer van pool programs.

The first employer van pool in Texas was the Texas Instruments program in Dallas in March 1974. Starting with a nine-van program, Texas Instruments now has 16 vans in Dallas and has also initiated van pool programs at most of its other plant sites in Texas. Conoco, in Houston, began the second van pool effort in Texas in March 1975 with 15 vans. In March 1980 Conoco had 80 vans in Texas, 74 in Houston, and 6 in other locations. In addition, Conoco operates 107 vans at other U.S. sites.

TENRAC has developed guidelines and concepts for employee van pool operation and provides to the employer advice and technical assistance in implementing the van pool program. TENRAC also provides a means of assisting implementation of employer van pools through placing potential employers in contact with existing successful programs. To foster this effort TENRAC conducts a quarterly census of van pool operations in Texas. The April 1980 survey reports that 80 programs at 92 sites are providing 1,393 vans and that another 92 vans are currently committed, all at an investment in excess of $13 million. The census estimates that the 1,393 vans now in service conserve 522,000 gal (1 990 000 L) of gasoline and provide 9,250,000 passenger-miles (14 900 000 km) of service per month.

An example of the support provided to the state van pool effort by major employers is the Conoco program (*13*). Conoco provides a detailed report of its van pooling approach to any major employer requesting it. This report provides vehicle specifications, employee questionnaire, policy and procedures guide, estimates of operating expenses, cooperative agreements, and detailed results of the Conoco program. Results are compared to single-occupant auto travel and report an annual reduction of 81,460 vehicle-miles (131 000 km) of travel for one van over eight cars, plus an annual savings of over 8,000 gal (30 000 L) of fuel, 5.23 tons of air pollution, and seven parking spaces.

In an effort coordinated with TENRAC, the City of Dallas developed an extensive *Rideshare Coordinator's Handbook* for major employers. This manual includes a description of management's role in van pools and such topics as legal aspects of ride-sharing, parking considerations, costs, vehicle selection, and vehicle maintenance service schedule. In 1980 the City of Dallas sponsored a 1-day van pool exposition for which letters of invitation were sent to the management of all firms employing more than 100 persons. At the exposition, van manufacturers demonstrated van products and stressed design features for van pool operations (*14*).

Seattle/King County Commuter Pool

The Seattle/King County Commuter Pool (*15-17*) is an excellent example of transportation brokerage that provides major employment sites with van pools, subscription bus, ride matching, flexible work hours expertise, and parking management. This publicly sponsored program is the largest and broadest (in terms of services rendered) brokerage operation in the country.

The Seattle/King County Commuter Pool is administered by the City of Seattle and is directed by a steering committee of professional transportation staff from local and state governments. Although the commuter pool receives funds from the Federal Highway Administration Urban Systems program and the Washington State Energy Office, the participants in the van pool/subscription bus programs pay all costs. No public subsidy is provided to the commuter operations. The van pool program, which began service in May 1979 to major employers, currently operates 132 vans, including backups. Drivers are qualified through selection criteria and are responsible for collecting fares from all passengers. Drivers ride free for 11-passenger van loads and receive a bonus for the 12th, 13th, and 14th passenger. The van is provided through the commuter pool, and routes are developed in response to employer interest. The average daily round trip is 66 miles (106 km). The average monthly personal use by the driver is 115 miles (185 km)—drivers may use the van for personal use at a cost of $0.16/mile ($0.10/km), and 3,000 miles (4800 km) per year are allowed. Riders in the van pool program reported the following breakdown on the former mode of travel: drive alone—46 percent; car pool—44 percent; bus—6 percent; other—4 percent.

The Honeywell Corporation serves as an example of the use of a transportation broker by a major employment site. Honeywell, located on the shores of the Ship Canal in Ballard, was not conveniently served by transit in 1977 and, with limited parking for its 1,000 plus employees, began negotiation with the Seattle/King County Commuter Pool. As of June 1980 Honeywell was served by six commuter vans, two subscription buses, and a car pool ride-match system, and it offered flexible work hours to employee groups.

Vallco Park Traffic Reduction

The significance of the Vallco Park TSM effort (*18,19*) lies in the fact that traffic reduction in the form of traffic-mitigating actions was required by the City of Cupertino, California, prior to the issuance of a construction permit for portions of the 1-mile^2 (2.6-km^2) development complex.

Vallco Park is a planned, mixed-use development in Cupertino, a suburban community in the San Jose metropolitan area. In 1975 the park contained nine industrial firms (primarily electronics research and development), a community shopping center, and a department store. Prior to issuance of a building permit for a major regional shopping center within the development, the City of Cupertino required that (a) study be initiated with the goal of reducing Vallco Park auto traffic by 25 percent during the peak hour and by 10 percent over the entire day, (b) 46 acres (19 hm^2) of Vallco park remain undeveloped pending success of the traffic-reduction methods, and (c) the developer contribute $67,000 annually to a 20-year fund to enhance the city's environmental quality.

The study revealed that almost 82 percent of the work trips of Vallco Park were drive-alone auto trips. The study concluded that "at the most" a 5 to 13 percent reduction in peak-hour automobile traffic could be obtained and recommended the five following TSM strategies: ride-sharing program (reduction of 3.6–7.2 percent), noontime shuttle, local commuter bus (reduction of 0.7–2.5 percent), bicycle provision (reduction of 0.1–1.3 percent), and local shopper bus (reduction of 0.4–1.6 percent).

The City of Cupertino, as part of the program, arranged for the employment of an implementation coordinator; as of June 1980, however, the position had not been filled and had been removed from the annual budget. (This information is from a phone conversation with Glenn Grigg, Traffic Engineer, City of Cupertino, June 23, 1980.)

The program was not implemented to the degree envisioned in the report. Ride-sharing efforts were relegated to the state ride-sharing program. No implementation coordinator of the total effort was provided locally. In 1980 Vallco Park reported that there was a 3–5 percent reduction in the total number of existing trips to the industrial park through car pooling and van pooling and that the number of actual trips had been significantly lower than the study projection. In addition to TSM measures, a transit terminal to serve Vallco Park was under construction using accumulated funds from the annual $67,000 payment. (This information is from a phone conversation with Walter Ward, Vallco Park Development, July 1, 1980.)

Conclusions reached by the study for Vallco Park highlighted four key factors in this approach to traffic reduction.

- TSM plans for employment and activity centers must be site-specific; that is, they must respond to the needs and opportunities of the particular center.
- Certain TSM strategies, such as park-and-ride and traffic management measures, require implementation on a regionwide basis to avoid seriously hurting the competitive position of private development.
- With parking in ample supply, little opportunity is provided to ameliorate peak-period traffic congestion.
- Strategies such as ride-sharing or shuttle bus can best be implemented and marketed by a developer; however, TSM measures such as HOV preferential lanes or express bus/park-and-ride cannot be implemented by a developer.

Cupertino's policies requiring traffic-mitigation efforts by private development remain in effect (*20*). Similar policies have been adopted by the City of Irvine, California (*21,22*). No recent applications of the policy have been reported as of July 1980.

EVALUATION AND GUIDELINES FOR IMPLEMENTATION

Major employment sites offer perhaps their greatest potential for TSM through ride-sharing. If proper incentives can be provided to both employer and employee, a successful van pool program can result largely through nonpublic efforts. Indeed, success stories abound of major employers who are operating van pool programs. In most instances these programs are developed at the initiative of the employers, although in some instances the program is developed in response to local government requirements for a transportation management plan. Van pool programs have proven their worth in reducing vehicular traffic, and packaged programs are available from central locations. The Texas Vanpool Program, for example, has done an excellent job of making known to major employers the advantages of van pooling. Similarly, the National Association of Vanpool Operators has rendered a unique service in assisting the operators in both initiating and managing van pools.

The size of the employer determines to a great extent the way the program is managed. For large employers (greater than 2,000 employees) the company operates the van pool program and designates a van pool manager to administer the effort. In the case of smaller employers, however, a broker is often needed to initiate service. This has been effectively done by the TVA and the Knoxville brokerage program on a regional basis.

Responsibility for TSM measures at major employer sites does not fit neatly into any one category. Obviously the city traffic engineer is in an excellent position to respond to inquiries and problems of the employer. Similarly, areawide programs can be supported by informational programs by the state and/or the metropolitan planning organization. Regional transit authorities can provide the brokerage mechanism required for several small employers, or a special municipal department can be designated to act as a broker for the van pool service. Obviously cities can require ride-sharing for development permits and traffic management plans, although the programs of Cupertino and Irvine have yet to be universally adopted. The most successful efforts, however, have seemed to come from the initiative of a major employer, with little or no governmental action.

Guidelines

The following guidelines primarily address TSM measures implemented by the major employer. Guidelines for the areawide brokerage concept are described in Chapter 5. The following guidelines are principally suggested for van pools.

1. Van pool programs should provide incentives to the driver of the van through a free ride to work, close-in parking, and possibly a financial return from "incentive fares" above a certain number of passengers.
2. Incentives should also be provided to the van pool riders, who must be attracted to ride-sharing if the program is to be a success. These incentives should be primarily financial in nature (i.e., reduced travel costs).
3. Company incentives for van pooling should include reduced parking costs, more available space for company expansion, satisfied zoning and traffic management requirements, and reduced congestion.
4. Company management should also be made aware of tax-shelter incentives through company ownership and depreciation of the vans.
5. Minimum one-way distance for van pool operations appears to be about 10 miles (16 km); however, programs initially attract longer trips and then prove attractive to the 10-mile trips after the program catches on.
6. Van pools can be successfully operated by either employers, employees, or a third party (e.g., a local credit union owning or leasing the vans).
7. A broker can best be used to provide the vans and the liability insurance for multiemployer car pools.

Support Activities

Van pool programs can be made to operate under most conditions, provided the proper incentives are available. Two support activities are beneficial:

1. *Preferential treatment for HOVs.* Special lanes, ramps, access drives, and close-in parking are effective preferential treatment measures for HOVs. These are discussed in more detail in Chapter 2.

2. *Auto pricing schemes.* Reduced tolls for van pools on existing tollways are support measures beneficial to van pools.

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CHAPTER EIGHT

OUTLYING COMMERCIAL CENTERS

Outlying commercial centers concentrate retail merchandising in locations other than a central business district (CBD). The shopping center is the most common outlying commercial center; however, careful attention must be given to the appropriate definition of a shopping center for it to be classified in this kind of work as an outlying commercial center. The Urban Land Institute (*1*) defines a shopping center as "a group of architecturally unified commercial establishments built on a site which is *planned, developed, owned, and managed as an operating unit* related in its location, size, and type of shops to the trade area that the unit serves. The unit provides on-site parking in definite relationship to the types and total size of the stores." [Emphasis added.]

Shopping centers are classified by the Urban Land Institute as either neighborhood, community, or regional centers. The determination is principally based on the major tenant classification, but size in square feet of gross leasable area is often used in discussing the type of shopping center. The term *outlying commercial center* as used here refers to either community or regional centers and thus permits this work to focus on larger commercial concentrations under a single leaseholder who is responsible for overall management of the physical plant. It excludes both neighborhood shopping centers and miscellaneous collections of retail businesses along major streets or clustered in a shopping district. Also excluded are CBDs of small suburban communities, which are discussed in Chapter 4.

The outlying commercial center is generally a product of increased dependence on the automobile and suburban growth. It has historically catered to auto trips, and perhaps the most distinguishing feature is the provision of free parking. Since the 1960s, shopping centers have more often been developed as malls with enclosed, air-conditioned walkways.

The outlying commercial center offers a unique challenge for transportation system management (TSM), particularly those measures involving a mode shift to transit, inasmuch as transit service to centers is generally limited or nonexistent. An opportunity for TSM is provided, however, through the single management head of the center, who is interested primarily in marketing the center and maintaining or improving access to it. Such a focal point provides a good starting point for TSM strategy discussions.

CHARACTERISTICS

Several characteristics distinguish the outlying commercial center from decentralized shopping districts or the CBD.

Unified Site, Architecture, and Merchandizing. The center has been located in response to market demand and the retail units assembled to maximize retail merchandizing in a common structure of unified architecture.

Single Management Structure. Inasmuch as the center is developed as a unit and functions as such for a profit, a single management structure provides coordination among individual retail units. There is then a focal point for decisions on parking, transportation access to the center, time of operation, amenities, and so forth.

On-Site Parking. On-site parking is considered an integral part of the total center design and must carefully take into account the parking demand, entrance and exit, and acceptable walking distance. Parking demand criteria have become less restrictive than the one space per 200 ft^2 (19 m^2) of gross leasable area that was the standard in the early 1970s (*2*). Parking layout design generally requires a maximum walking distance between the parking space and the center entrance of 400 ft (120 m) (*3*). These standards have in most instances been met as a marketing demand, but many centers have lacked good traffic engineering in the layout design.

Separate Facilities for Goods Delivery. The delivery of goods to the center has also been designed into the total operation and uniquely separated from consumer traffic.

Ancillary Activities. Many centers provide facilities for activities ancillary to the merchandising effort. This includes service professionals such as doctors, dentists, notaries, and so on, plus public support facilities such as auditoriums, meeting rooms, and public auctions (*4*).

TSM OPTIONS

Two different approaches to TSM in outlying commercial centers can be identified from implementation experiences to date. These approaches are (a) the measures that provide some form of transit service to the center and (b) the measures that use the parking facilities of the center for modal transfer for express transit service to another location. The center ostensibly benefits from both measures through increased exposure to the public. Specifically, these TSM measures include:

1. Fixed-route transit service to the center from distant locations within the market area.
2. Shoppers' bus shuttle from adjacent neighborhood locations.
3. Dial-a-ride service within the marketing area.
4. Park-and-ride/express bus service terminals at the center's on-site parking.
5. Special transportation (primarily for the elderly) to the center on a charter or prearranged basis.
6. Traditional but highly effective traffic engineering measures, including increased turn radii, protected left turns, adequate lane widths, proper signs and pavement markings, and well-designed signal systems. (It will be noted that these features apply equally to auto and transit access.)

Most outlying commercial centers were developed around the auto, so most have incorporated good traffic engineering principles in access routes and parking lot design. Obviously, if such principles have not been followed, their review and use are of first concern in implementing low-cost improvements. These accepted practices are not reviewed here in favor of giving preference to the more creative and less recognized TSM measures.

MOTIVATION FOR ACTION

No single source can be identified as the impetus to implement TSM measures at outlying commercial centers. The motivation has often been in response to regulatory requirements and, at the other extreme, as a result of ingenuity in search of solutions to problems apparently unrelated to transportation. Following are the most frequently identified reasons for implementing TSM at outlying commercial centers.

1. A response to requirements from local or state environmental control agencies as a condition for a building permit for the center.
2. An effort on the part of the center to provide greater access to the center to improve its merchandising capability.
3. An effort to emulate measures at other centers and to remain competitive in the commercial sales market.
4. A program of public agencies responding to demands of transit-dependent citizens for improved transit access to the commercial centers and other high-activity locations.
5. A response to congestion problems caused by traffic to the outlying commercial center.
6. An opportunity to use the on-site parking facility as a park-and-ride/express bus service to other high-activity locations—the CBD, for example. The commercial center is often approached with the idea that improved exposure from the park-and-ride users will benefit sales at the center.

GOALS, OBJECTIVES, AND PLANNING ANALYSIS

Conflicting goals and objectives are often apparent in implementing TSM measures at outlying commercial centers, and resolution of the conflicts is necessary for implementation to occur. For example, the primary goal of the commercial center is profit, and the center's management is often unsympathetic to off-site traffic problems that do not affect the center. Conversely, the center's management will be supportive of goals that seek to provide access to the center at minimal cost. Broader goals involving environmental quality must also be integrated with economic goals and will often be in the form of compromise.

The following goals have been identified in the implementation of TSM:

1. To promote economic impacts of existing transportation and services.
2. To increase the efficiency of the existing transportation system.
3. To minimize the undesirable environmental impacts of the existing transportation system.
4. To maintain and/or improve the quality of the existing transportation system.
5. To improve accessibility to the commercial center through all transportation modes.

Table 7 provides a list of the goals, objectives, measures of effectiveness (MOEs), and the appropriate TSM measures for each goal.

Of the TSM measures appropriate for an outlying commercial center, only one or two might require planning analysis prior to developing the details for implementation. Most, in reality, should be implemented and evaluated under actual conditions, inasmuch as little methodology is available to project impacts prior to implementation. Because low cost and minimum disruption characterize the TSM measures related to outlying commercial centers, actual testing is perhaps the most efficient means of evaluation. Some planning evaluation may, however, be devoted to projecting the probable ridership on a park-and-ride/express bus combination from off-site parking at a commercial center. If extensive express bus improvements are considered, or if consideration is given to possible controversial actions (e.g., taking a freeway lane for express bus), planning analysis may be necessary to justify the project. Most of the TSM measures, however, require only design and coordination prior to implementation.

IMPLEMENTATION EXPERIENCES

Portland (Oregon)—Washington Square

This project represents an example of TSM strategies employed by a major regional shopping center in response to requirements of the State Department of Environmental Quality (*5,6*). The Washington Square Shopping Center in southwest Portland opened in April 1974 and, with over 1,000,000 ft^2 of (93 000 m^2) of leasable floor space, is one of the largest shopping centers in Oregon. It has excellent access via a freeway and primary arterials and is served by a parking lot with over 7,200 free parking spaces.

In 1972, after construction had begun on the center, the Washington Square owners applied to the Oregon Environmental Quality Commission for permission to build a 5,200-space parking lot for the center. The commission, acting on staff recommendations, prohibited the construction of the parking facility but did permit the facility under the condition that the owners submit a detailed public transit plan and implementation schedule to maximize transit use at the center. The plan was to include transit service from the surrounding residential areas and express bus from the Portland CBD. The goal of the transit plan was to minimize degradation of air quality by auto trips to Washington Square. In response, the owners developed a transit plan and implemented transit in order to proceed with the parking facilities.

The transit program for Washington Square consisted of two elements. First, five double-deck, "London" buses operated on three routes from major residential areas to the center. The decision to use London buses came from a recommendation from the marketing firm employed by Washington Square to promote the transit service. Second, the routes of four regularly scheduled buses of Tri-MET, the

TABLE 7

GOALS, OBJECTIVES, AND MOEs FOR THE OUTLYING COMMERCIAL CENTER OPERATING ENVIRONMENT

Goal	Objective	MOE	TSM Measure for Each Goal
Promote desirable impacts of transportation facilities	• Promote desirable economic impacts	• Dollar Sales • Employment	Shopper's Bus Shuttle Dial-a-Ride Service Park-and-Ride/Express Bus Terminals
Increase the efficiency of the existing transportation system	• Increase transit patronage	• Transit Passengers	Park-and-Ride/Express Bus Terminals
	• Increase transportation system productivity	• Operating Cost per passenger trip	
Minimize undesirable environmental impact of the existing transportation system	• Reduce transportation system air quality impacts	• Tons of Emissions	Fixed Route Transit Service Dial-a-Ride Service
Maintain or improve the quality of transportation services on the existing system	• Reduce travel time for the movement of people and goods	• Point-to-Point Travel Time	Park-and-Ride/Express Bus Terminals
	• Reduce travel costs for the movement of people and goods	• Point-to-Point Travel Costs	
	• Improve comfort and convenience on the existing system	• Comfort and Convenience	
Improve accessibility to the commercial center	• Increase transit patronage	• Transit Passengers	Fixed Route Transit Shopper's Bus Shuttle Special Transportation

areawide transit operator in the Portland area, were extended.

The London bus service began in April 1974 with the opening of Washington Square, but only after route inspections to change the routes from streets with a poor riding surface or with low, overhanging trees. Average length of the routes was 11 miles (18 km), and one bus served each route continuously between 10:00 a.m. and 6:00 p.m. each weekday. No fare was charged for service to the center, but $0.25 was charged for outbound service. No weekend service was provided. The marketing program began 3 months prior to initiation of the service with a ribbon-cutting and cannon-firing ceremony. Fliers were distributed, and press stories were provided on rider interviews. An active promotional campaign was fostered through free bus tickets, radio shows, and the like. The promotional campaign was not based on the convenience of the system but rather on the suggestion that riders were contributing to cleaner air.

Ridership on the three London bus routes was less than expected. Operating costs to the center were estimated to be $120,000 from April 1974 to April 1975. The number of passengers per month increased from 2,200 in April 1974 to 9,400 in August 1974. In September 1974 the ridership dropped to 2,300 after school started. Washington Square estimated that the majority of summer passengers were joyriders who did not exit at the center. In February 1975 ridership per month dropped to 1,600. The London bus service was discontinued on May 15, 1975, after it was successfully argued before the Oregon Environmental Quality Commission that the ridership did not justify the expense.

Three bus lines of Tri-MET were extended to the center in April 1974 under the condition that Washington Square pay Tri-MET the sum of $25,000 per year to finance the operating costs. Ridership increased rapidly during the first months, and early in 1975 Tri-MET extended a crosstown route to serve the center. By April 1975 the Tri-MET buses carried approximately 4 percent of Washington Square shoppers, and the ridership had increased by 67 percent over the first month's operation, from 3,000 to 5,000 passengers per week. In April 1975 Washington Square and Tri-MET signed a 2-yr agreement in which Tri-MET agreed to extend the hours of service and the center agreed to (a) provide two shelters at the entrance to Washington Square, (b) pay all promotional costs, and (c) pay $33,030 a year to subsidize operation. After the term of the 2-yr agreement, ridership on the Washington Square routes had increased to the extent that Tri-MET no longer required direct route subsidization. In 1980 Tri-MET continued to provide transit service to Washington Square, the center's management providng free transit marketing.

Although Tri-MET was brought into the negotiations for transit service to Washington Square after the center had been designed and was under construction, the experience nevertheless proved beneficial in a later development. Tri-MET became an active participant in the planning of Clackamas Town Center (1.4 million ft^2 [130 000 m^2]) in east Portland in the summer of 1978 and worked with the developer to include transit in the center's design. Opting for physical improvements for transit facilities in lieu of annual subsidy payments (which were onerous for both parties), Tri-MET secured, with assistance from the Urban Mass Transportation Administration (UMTA), two transit passenger waiting areas. One will be a transit center with eight loading bays, and the other will be a park-and-ride facility with 400 parking spaces. The transit facilities were incorporated in the initial design of the center and permitted Tri-MET to develop a pulsed schedule system for timed transfer between regional and local routes, with all area routes centering on the major commercial center. Tri-MET staff expressed the opinion that the commercial center permitted the acquisition of some desirable opportunities for transit development (*7*). (This information is from an interview with Michael Kyte, Manager of Service Planning, Tri-MET, February 4, 1981.)

Bergen County (New Jersey) Shopper's Shuttle

This project is significant in that it provides bus transportation between shopping centers during the Christmas shopping season (*8–10*). Four shopping centers with a combined retail floor space in excess of 3.7 million ft^2 (340 000 m^2) are located within 3 miles (5 km) of the major interchange of Route 4 and Route 17 (major state highways). Each center is separately owned and operated and serves a large population base beyond the confines of the borough of Paramus, in which all four are located.

Impetus for transit service was provided by congestion during the holiday season, when traffic volumes increased to 20 percent over the average weekday volume. The average weekday volume for the interchange of Route 4 and Route 17 was 185,000 vehicles, as a result of which the New Jersey Commission of Transportation had designated the interchange as the most critical in the state for congestion and accident experience. Congestion was aggravated during the holiday season, as the approaches to the shopping centers sometimes queued traffic through the interchange and on the major routes for as much as 3 miles in all directions.

In November 1977 the Bergen County Board of Transportation implemented a "Shopper's Shuttle" for the holiday season, in addition to maintaining the eight regularly scheduled transit routes of the Bergen County system. Existing routes serve each center during the day on headways of 30 to 90 min, but with reduced service on Saturdays and no service on Sundays. During the holiday rush, buses on these regular routes were delayed by the congestion surrounding all four centers. The Shopper's Shuttle operated between the four malls with the objective of reducing traffic congestion.

Because the service was line haul only between the centers' bus terminals, a fixed route was unnecessary; therefore, the bus operators, through the cooperation of the local police, ingeniously found the fastest routes between centers, whether the route was on major arterials or local streets. Using traffic reports, radio-equipped dispatchers at each center terminal directed each shuttle to the least congested center entrance. In this manner the shuttles remained on schedule.

The shuttle service is provided with regular buses operated by a private carrier under contract to the county. Headways of 15 min on weekdays and 10 min on Saturdays are provided during the daily period of shopping center operation. The one-way fare is $0.25, and a single ticket is good for any number of rides on the date of its purchase. For a comparison, the one-way fare on the regularly scheduled route is $0.50. Shuttles are uniquely marked for clarity, and arrangements have been made for transfer privileges to other franchised routes serving the centers. All necessary subsidy (about 90 percent of the total cost) is provided by Bergen County. The shopping centers provide the advanced publicity for the shuttle service but do not participate in the cost of operations.

Ridership for 34 shopping days in 1977 amounted to 10,600, or about 310 riders per day. The Shopper's Shuttle operated again during the 1978 holiday season, and ridership for 31 days was 11,300, or 360 riders per day. For the 1979 season the fare was changed, making a one-ride limit per $0.25 fare. This increase, plus unseasonably cold temperature in early December, reduced total ridership for 31 days to 10,400, or 340 riders per day. In 1980 the season was expanded, the first shuttle running on Saturday, November 15. Daily service (except Sundays) began on November 28 and continued through December 31. Ridership figures are not available for 1980.

Staff personnel report that any improvement in congestion on Route 4 and Route 17 as a result of the shuttle is imperceptible due to the high total volumes on the highways. Very positive comments from consumers have been received, however, and its repeated use is expected each year.

Connecticut Express Commuter Bus Service

The Connecticut Department of Transportation (DOT) has been operating a program of park-and-ride/express bus service on 25 routes from 99 lots, carrying over 50,000 persons weekly to major Connecticut cities. This program (*11–15*) provides an excellent example of private/public cooperation in its use of private parking facilities at major shopping centers and publicly provided express buses for commuter trips.

The program began January 17, 1972, with service from Corbins Corner in West Hartford to the Hartford CBD. Corbins Corner is a shopping center in a high-density suburban area adjacent to I-84 west of Hartford. The shopping center is located approximately 7 miles (11 km) from the Hartford CBD.

The primary purpose of the project was to reduce peak-hour congestion on I-84 and improve traffic flow and parking in downtown Hartford. The Connecticut DOT, as sponsor of the project, obtained agreement from the owners of Corbins Corner to provide 250 parking spaces free of charge. The Connecticut DOT agreed to maintain the parking area and build a small commuter shelter for passengers. A contract was executed between the Connecticut DOT and a private transit company to provide and operate four 45-passenger buses for a trial period of 3 months at no cost to the state.

Service was initiated with 10-min headways between 7:00 a.m. and 9:00 a.m. Similar return service was provided during the afternoon peak. Buses received no preferential treatment and operated in mixed flow on the freeway. Travel time on the bus route was between 13 and 18 min during the morning peak. The initial one-way fare was $0.35. At the end of 3 months, 250 passengers were using the service daily, with more than 150 autos parked at the shopping center. With 280 passengers per day needed to break even, the fare was increased after 6 months to $0.45 one way to pay the total cost of the operation.

Surveys conducted during the 3-month trial period revealed that most people chose the service to avoid driving in congested traffic. A large number said the service saved them time. Most of the time savings resulted from not having to park in downtown Hartford. No studies were conducted on traffic flows on I-84, and reduced congestion was only assumed based on the removal of 150 autos that would have used the freeway.

An extensive survey of Corbins Corner express bus passengers was conducted in August 1977. The one-way fare remained at $0.45, but one-way ridership averaged more than 370 persons daily. Of the 304 passengers returning the questionnaire, 301 reported that the trip purpose was work. A total of 206 drove alone to Corbins Corner, and 84 others arrived as auto passengers (the remainder rode a bicycle, took a bus, or walked); 256 reported a frequency of use of every day, and 32 others said 3 to 4 days per week; 190 were female, and 85 were male (no response to this question from 29). In response to the question of the trip mode prior to the park-and-ride system, 93 people said they had driven alone, 29 had been part of a car pool, 32 had been passengers in a car, 31 had taken the bus, and 104 had not made the trip. (Fifteen people did not respond to this question.)

The second park-and-ride/express bus project was initiated in July 1972 from Burr Corner east of Hartford in Manchester County. This remains the most heavily used express bus route, with daily inbound ridership averaging over 550 in October 1980.

Two additional routes to Hartford and one to New Haven were added in 1973; two more to Hartford and one to Bridgeport in 1974 (the Bridgeport route was dropped after 6 months due to lack of ridership); and two more to Hartford and one to New Haven in 1975. System expansion continued to the present program of 22 routes to Hartford and 3 to New Haven. Bus service is provided by private transit operators under contract to the Connecticut DOT and/or by Connecticut Transit, depending upon existing franchise agreements. Fare-box revenues provide just over 50 percent of the operating costs of Connecticut Transit. Private operators are guaranteed a base operating cost by the Connecticut DOT; however, total subsidies to the private operators are not available. Subsidies to the publicly owned transit are provided by the state with UMTA Section 5 operating assistance. All buses operate in mixed flow on freeways, and no preferential treatment is provided; however, high-occupancy vehicle (HOV) lanes are currently under construction on I-84 east of Hartford to Burr Corner.

In early 1981, one-way fares for Corbins Corner to Hartford were $0.75, with an unlimited monthly pass available for $25. The longest route is from Old Saybrook County to Hartford, with a travel time of 1 hr and 10 min. The one-way fare from Old Saybrook is $2.10, with a 10-trip packet available for $16. Eleven departure times are available from Corbins Corner at a 10- to 15-min headway from 6:50 a.m. to 9:00 a.m., and three departure times are available from Old Saybrook from 6:15 a.m. to 7:15 a.m. (This information is from a phone conversation with John D. Miles, Transportation Planner, Connecticut Department of Transportation, February 19, 1981.)

Shirley Highway-Springfield Plaza Park-and-Ride/Express Bus

The significance of this project (*16,17*) lies in a combination of park-and-ride service from the parking lot of a major shopping center and express bus to a major CBD via exclusive bus lanes on a freeway. The project has provided a special roadway for directional flow of buses within the Shirley Highway, linking northern Virginia with the CBD of Washington, D.C. Approximately 30 percent of bus commuters in the Shirley corridor are park-and-riders. Although there are many park-and-ride lots in the Shirley corridor, only three have been designated as official park-and-ride locations. Of these three, two are in major shopping centers. Impetus for park-and-ride at the major shopping centers is derived from the overall purpose of the Shirley corridor project to reduce congestion and travel time on the Shirley Highway.

Springfield Plaza is a major shopping center adjacent to the Shirley Highway (I-95) and is approximately 15 miles (24 km) from downtown Washington. Bus headways average about 15 min, and the average trip time to Farragut Square in downtown Washington is 32 min. For the majority of park-and-ride users of Springfield Plaza, the distance between their home and the park-and-ride lot is greater than 2 miles (3 km), and more than 20 percent reported distances as great as 5 miles (8 km). The average access time (from the residence to the park-and-ride lot) is about 25 percent of the total door-to-door time and illustrates how auto access can extend bus service over large areas with little loss of travel time.

In February 1973 a study was conducted to determine the influence of various park-and-ride factors on the decision to commute by bus. In relating the important features that caused them to use park-and-ride, 80 percent of the users rated the same three factors highly: (a) reduced stress and frustration of commuting, (b) schedule reliability, and (c) convenience of arrival and departure. Other positive features included the perceived travel time savings through park-and-ride/express bus and the free parking at the shopping center (compared with parking costs in the CBD). More than 60 percent of the park-and-riders were former auto users, and 30 percent had car pooled before using the express bus. It was concluded that the coordinated development of park-and-ride with express bus increased transit ridership significantly within the corridor.

An important feature of the park-and-ride/express bus service is the preferential treatment provided HOVs on the Shirley Highway. The freeway consists of a maximum of three directional lanes (one-way) plus two reversible lanes in the median that are reserved for buses and car pools (four or more persons). The most recent volume counts (in 1980) report 9,053 autos per hour inbound on the freeway at the maximum load point near the Pentagon during the a.m. peak hour (7:00–8:00) and 2,372 HOVs in the reserved lanes. The total for inbound vehicles during a 13-hr count for freeway and HOV lanes was reported as 60,400 vehicles. During the peak hour the two HOV lanes carried 58 percent of the total inbound commuters, as compared with 42 percent carried by the three freeway lanes. (This information is from a phone conversation with Ronald Sarros, Assistant Director of Transportation Planning, Metropolitan Washington Council of Governments, February 19, 1981.)

Greece (New York) Dial-a-Ride

The Rochester-Genesee Regional Transportation Authority (RGRTA) began dial-a-ride service in the town of Greece in August 1973. In two different surveys conducted in 1974, it was found that between 43 and 48 percent of all trips on the dial-a-ride system were to three shopping centers in Greece. The significance of this project lies in the feasibility of dial-a-ride as a means of providing transit access to major commercial centers (*18–21*).

The original service area of the dial-a-ride system contained 9.6 miles^2 (25 km^2) of a low-density residential area in Greece, a suburban community northwest of Rochester. Population of the service area was approximately 51,000. The dial-a-ride operated from 8:15 a.m. to 5:30 p.m. with a fleet of seven 25-passenger buses. Fare for the service was $1.00 per person, and the system operated with a response time of about 25 min. By 1975 ridership had risen to 490 passengers per day at a cost of $3.50 per passenger. Discounts to groups lowered the average fare to $0.70, which meant that the fare covered only 20 percent of the operating cost, somewhat below the 55 to 70 percent estimated before service began. Subsidy was provided by the local community, assisted by UMTA funds.

The 1974 surveys found that 36 percent of all trips on dial-a-ride were made for the purpose of shopping, with the work trip accounting for 38 percent. The three shopping centers that attracted about half the dial-a-ride trips were the Greece Towne Center, the Longridge Mall, and the Ridgemont Plaza, all of which were located close to each other in the southwest corner of the service area. The total combined floor area for all three centers was almost 1.5 million ft^2 (140 000 m^2).

The objectives of the service included the provision of transit service to low-density areas, the replacement of costly fixed-route transit, and the development of increased transit ridership. Unfortunately, the system encountered organizational problems, computer dispatching difficulties, and vehicle breakdowns to the extent that ridership declined, service was cut in order to reduce costs, ridership declined further, and operating costs were increased. During 1977, ridership averaged around 150 passengers per day at a cost of $6.00 per passenger.

At the end of the demonstration period and the termination of UMTA demonstration funds, the town of Greece was given the option of providing the local 50 percent of operating costs (50 percent provided by UMTA Section 5 funds) or of terminating the dial-a-ride operation. Because subsidy costs to the community would have been approximately $40,000 annually, the service was terminated in late 1979. All dial-a-ride operations of RGRTA ceased in January 1980.

The financial benefit of dial-a-ride to shopping centers was not significant. Shopping center management was not heartbroken by termination of the service, but disappointment was expressed by many riders of the system, particularly the elderly and those not owning cars. (This information is from a phone conversation with David Sharfarz, Planning and Program Manager, Rochester-Genesee Regional Transportation Authority, October 23, 1980.)

La Habra (California) Dial-a-Ride

The La Habra Fashion Square is the major node of retail activity in La Habra, California, a community of approximately 50,000. The shopping center is located at the intersection of two major highways and has 566,000 ft^2 (53 000 m^2) of gross leasable floor area. Although the center had provided 3,000 parking spaces and was served by fixed-route transit, other modes of travel were needed to meet the demands of the socioeconomically mixed population. Hence, dial-a-ride service was initiated in February 1973 by the Orange County Transit District (OCTD) with the objective of providing a transit service to meet shoppers' demands and needs. This project (*20,22*) illustrates a successful dial-a-ride operation for a major commercial center.

Ridership of the system over the service area of 7 miles^2 (18 km^2) rose from 5,900 in the first month to 13,000 per month after about 1 yr. The initial fare was $0.50 but has since been increased in increments to a 1980 fare of $1.00. On December 1, 1980, the service was expanded to include all of Orange County, subdivided into 34 zones of about 10 miles^2 (26 km^2) each. Zones were designed to be small to minimize dial-a-ride trip length. Cost per rider of dial-a-ride in 1980 was $4.50. As a part of the total transit operation of OCTD, the dial-a-ride system is subsidized through UMTA Section 5 monies and the total budget of OCTD. A total of 95 15-passenger mini-buses served Orange County with dial-a-ride in 1980, and 28 are equipped with wheelchair lifts. Transportation for the elderly and handicapped is integrated into the countywide system, and a totally accessible operation is planned.

Shopping trips account for more than one-third of all trips made on dial-a-ride, and all mini-buses are equipped with overhead racks for storage of packages and personal belongings. Although no studies have been conducted to determine the economic impact of the dial-a-ride system on Fashion Square, it has been reported that between 20 and 30 percent of the total dial-a-ride system is associated with Fashion Square, which is the origin or destination of more than 25 percent of all dial-a-ride trips on Saturdays.

Response time for pickup is normally 15 to 30 min, and the average trip time is 11 min. Subscription service was terminated in 1980 to allow more vehicle-hours. Same-day call is required for all trips except those for the handicapped, for which advanced reservations can be made.

Although Fashion Square is one of the smallest shopping centers in Orange County, it is the focal point of the dial-a-ride operations, and it is Fashion Square's support of dial-a-ride that accomplished the mutual effort.

Denver Regional Transit District Shopper's Service for the Elderly

Since 1976 the Denver Regional Transit District (RTD) has operated a transit service from areas with high concentrations of elderly persons to outlying commercial centers (*20*). Forty-four such locations are provided with prearranged bus service to five major shopping centers in the Denver region.

Service in 48-passsenger buses is usually provided 1 day each week to the shopping center selected by a majority of the elderly at each location. Buses leave the residential location at 10:00 a.m. and return by 2:00 p.m. Several locations may be combined to obtain a full bus load. All service is prearranged by location and destination. The fare is $0.50 for the two-way trip, with a per-passenger cost of approximately $1.00 to RTD, which operates the service as a part of its total system.

The service has been very popular with the passengers, and about 6,000 persons per month have used the service during the summer months. Ridership is higher during periods of good weather. Many riders have no other means of regular transportation. The operators of the shopping centers generally welcome the elderly passengers; however, no shopping centers provide financial support for the service. Some centers provide attendants to the elderly persons needing assistance.

EVALUATION AND GUIDELINES FOR IMPLEMENTATION

The unique feature of outlying commercial centers is the single management structure within the center. This single administration minimizes the coordination required to implement a TSM strategy; however, the administration is subject to the demands of leaseholders and will seek transportation measures compatible with their wishes.

Because most centers are less than 30 yr old, they have not been subjected to a changing concept of urban transportation and thus reflect a design and operation that is compatible with the auto/freeway system prevalent in most urban areas today. Inasmuch as the center is dependent on automobile access, most centers have incorporated good traffic engineering in their design. Thus the TSM measures that appear to have the most promise in outlying commercial centers are those involving some form of transit operation. However, traffic engineering principles should be investigated and evaluated as the first TSM opportunity.

The responsibility for implementing TSM measures at outlying commercial centers is not clearly delineated. Often action comes about after the administrator of a center gets the local traffic engineer and transit operator to investigate suggested improvements. More often than not, however, TSM ideas have come from the alert traffic engineer at the local level or the highway engineer at the state level who has recognized a potential for combining the center's on-site parking facilities with park-and-ride/express bus operation. Some responsibility problems can be identified where the centers are in different municipalities from the CBD or other express bus destinations. In this frequent case the responsibility is assumed by the state highway engineer, who must in turn coordinate or contract with a transit operator. It can be envisioned that a metropolitan planning organization could evaluate outlying commercial centers from a TSM perspective; however, few examples of this have been reported.

Guidelines

The guidelines listed below are suggested for TSM implementation at outlying commercial centers.

1. Special fixed-route transit from adjacent residential areas to outlying commercial centers has not proven to be successful due to the level of service provided by the automobile.
2. Fixed-route transit service, as part of the total transit system, has been successful when coupled with extensive marketing of the service by the center plus, at least in the initial phases, a direct subsidy from the center. Fixed-route service should consider the market area of the center.
3. A shoppers' shuttle requires loading points of highly concentrated activity. Successful shuttles (with subsidies) have been provided *between* centers during the holiday season.
4. Dial-a-ride services to an outlying commercial center appear to require unique circumstances for successful operation, even with costly public and private subsidies. The requirements include a short travel time for those who have little accessibility to an auto or to fixed-route transit.
5. On site parking of outlying commercial centers has been successfully used for park-and-ride lots. Lot location must be convenient; lot location and transit service must provide a competitive edge over the auto trip; and lots should be served by high-quality bus service. Preliminary neighborhood surveys are helpful in determining the feasibility of a park-and-ride lot for express bus service.

Support Activities

Many of the TSM measures relating to outlying shopping centers require support actions or other facilities for successful operation.

1. *Transit terminal facilities.* Shoppers' shuttles and other transit services to centers are facilitated through the provision of terminal shelters and informational facilities at the center.
2. *Transit marketing.* Marketing of the transit service is of primary importance to its success and to the center. Many centers have willingly accepted the responsibility of transit marketing for center-oriented transit.
3. *Park-and-ride and express bus.* These measures should be seen as mutually supportive; the success of either is highly dependent on the availability of the other. Both should be designed as part of a total subsystem.

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CHAPTER NINE

MAJOR ACTIVITY CENTERS

Major activity centers are generally classified as institutional land uses either publicly or privately owned. Included in major activity centers are universities, hospitals, sports stadia, and, in some instances, major governmental installations. A common characteristic of most activity center categories is a single focal point of administration. This characteristic provides excellent opportunities for transportation system management (TSM) measures that require close coordination with other modes or support actions in the form of management emphasis and provision of incentives.

CHARACTERISTICS

Transportation characteristics of major activity centers differ sharply depending upon the type of institution. The differences significantly influence the range of appropriate TSM measures, and thus the characteristics must be reviewed for each institution type.

Universities

Universities have very large student populations whose daily schedules show considerable variation from day to day and from semester to semester. Turnover in the student population is rapid. Depending on the circumstances at the university, student housing facilities are often available within walking distance of the campus. Campus faculty schedules also vary. Usually only nonprofessional campus employees have a routine schedule conducive to ride-sharing or a similar TSM measure.

Travel patterns at universities and colleges can be significantly different depending on the type of educational program offered. Specialized and graduate programs tend to support in-residence attendance, close-in housing, and travel patterns reflecting the shorter trips. Urban junior colleges and universities with minimal on-campus housing depend upon most of the student body commuting to class and therefore often exhibit high traffic generation and peaking characteristics similar to those of the urban area itself.

Hospitals

A significant characteristic of hospital travel is the shift work necessary for operation of the hospital. Most hospitals operate three work shifts per day, 7 days per week. This shift work is particularly characteristic of nurses and support personnel.

Sports Stadia

Facilities for major sporting events are unique special traffic generators and have peaking characteristics related to the event. There is usually fee parking adjacent to or near the stadium, and, because parking revenues are often built into the bonded indebtedness structure for the stadium complex, the management has little interest in reducing auto travel to a level below that necessary to fill all parking spaces. Unloading facilities and parking areas, however, often are identified for express buses to serve the special events.

Major Govenmental Installations

Included under this activity are all army posts, naval installations, air force bases, and the like. Daily schedules at these facilities are often quite fixed and have high peaking characteristics similar to those of major employment centers. Parking facilities are generally adequate in on-post locations. Because many such installations are some distance from residential areas, particularly for civilian employees, ride-sharing opportunities are increased for those employees.

TSM OPTIONS

Various TSM measures have been successfully implemented at major activity centers. The following measures have been implemented individually or in combination:

- Parking constraints, parking fees, and fringe parking.
- Alternative work schedules, consisting of staggered work hours, flex-time, and so forth.
- Transportation brokers for the activity center to coordinate and market TSM strategies.
- Ride-sharing, consisting of car pools and van pools.
- Subscription bus or other prearranged travel for either door-to-door or park-and-ride service.
- Scheduling of events to minimize travel conflicts and to permit sequential use of transportation and parking facilities.

MOTIVATION FOR ACTION

Most of the TSM measures that have been implemented at major activity centers have been motivated by a recognized traffic problem, usually a parking problem. In some instances this parking problem was the source of conflict between neighborhood associations and the activity center in the use of on-street neighborhood parking spaces by institutional drivers. Parking problems have also been experienced within activity centers, and lack of parking space has motivated TSM actions.

Poor transit service also has prompted the management of major activity centers to improve transportation through TSM. As well, local government requirements for traffic mitigation, plus a desire to reduce travel costs and improve travel service to employees, have provided the impetus for TSM implementation. One generally finds, too, in the institutional environment, a stronger desire to conform to such national goals as energy conservation and reduced air pollution. In many instances this alone has provided motivation for TSM measures.

In sum, the primary factors for TSM implementation decisions have been:

- Employee/student/patient/client dissatisfaction with parking supply and/or location.
- Conflicts with local neighborhood groups in regard to on-street parking and traffic congestion.
- Employee/student absenteeism and tardiness resulting from poor or nonexistent transit schedules.
- Budgetary conflicts between parking facility capital costs and other budget items.
- Employee/student/patient/client dissatisfaction with increasing travel costs (gasoline prices) and fuel nonavailability.
- Statutory demands from state and federal agencies for reduced auto travel and improved air quality.

GOALS, OBJECTIVES, AND PLANNING ANALYSIS

As one might expect from the motivation factors listed above, major activity centers, particularly those falling in the institutional category and located in a residential neighborhood, establish goals of minimizing conflicts with neighborhood groups and owners of adjacent properties. Because most TSM activities in this environment are developed and implemented by the institution or activity center, the goals quite naturally relate to the institution itself—its reputation, its employees, its students, its patients, and so on. Table 8 provides the most common goals, objectives, and measures of effectiveness (MOEs) for the major activity center environment.

Transportation brokers in the institutional settings provide an excellent mechanism for planning analysis prior to implementation of TSM measures. It is quite common to find transportation brokers establishing goals, objectives, and MOEs and conducting an analysis in order to project the probable quantifiable success of various combinations of

TABLE 8

GOALS, OBJECTIVES, AND MOEs FOR THE MAJOR ACTIVITY CENTER ENVIRONMENT

Goal	Objective	MOE	TSM Measures for Each Goal
Minimize Conflicts with Citizens' Groups and Local Governments	• Minimize Auto Usage	• Vehicle Miles of Travel • Person Trips • Number of Carpools, Vanpools	Transportation Broker Alternative Work Schedules Ridesharing Subscription Bus Restricted Parking Rescheduling of Events
	• Maximize Pedestrian and Bicycle Travel	• Bicycle Counts • Pedestrian Counts	
Improve Employee/Student/ Patient Satisfaction	• Minimize Travel Time	• Point-to-Point Travel Time	Subscription Bus Improved Transit Service Rescheduling of Events
	• Minimize Travel Costs	• Point-to-Point Out-of-Pocket Travel Costs	
Improve Budgetary Efficiency	• Minimize Parking Requirement (Minimize Auto Usage)	• Parking Space Requirement and Parking Costs	Ridesharing Subscription Bus Improved Transit Service
	• Maximize Tranit Usage	• Transit Passengers	
	• Minimize Capital and Operating Costs	• Capital and Operating Costs	
Reduce Energy Consumption	• Minimize Energy Consumption	• Energy Consumption	Ridesharing Subscription Bus
Improve Air Quality	• Minimize Air Pollution	• Concentration of Pollutants • Tons of Emissions	Ridesharing Subscription Bus Alternative Work Schedules

TSM measures. Such analysis considers the trade-offs between various TSM measures, such as the trade-off between reduced parking requirements (savings in dollars) and improved transit with more subsidy (expenditures in dollars). This analysis is more often than not a normal process, but it permits good evaluative decision making by institutional management and results in a careful monitoring process by the transportation broker.

IMPLEMENTATION EXPERIENCES

University of Massachusetts Fare-Free Bus and Restricted Parking

The significance of this project lies in the relationship between TSM strategies in transit operations and in restricting parking through increased parking costs and limited parking permits (*1*). Through an Urban Mass Transportation Administration (UMTA) research and demonstration grant, the University of Massachusetts evaluated the relationship between fare-free transit and restricted parking and the impact of both on congestion and parking demand.

The University of Massachusetts is located in Amherst, Massachusetts, a college community with a 1980 population of 33,900. In 1973, at the time of the project implementation, Amherst had a population of 32,228. Also located within Amherst are Amherst College and Hampshire College. Enrollment at the University of Massachusetts had grown during the 1960–70 decade from 7,000 to more than 22,000 students in 1973. This growth had resulted in increased congestion on the Amherst street system and had created a parking overload on the university campus. In February 1973, prior to initiation of the demonstration project, the campus was served by three campus buses operating as an on-campus shuttle with a daily ridership of from 2,000 to 2,500 passengers. Access to the campus was gained primarily by the automobile. Parking spaces were assigned at a fee of $5 per academic year. The parking system was overloaded and overassigned (1.7 autos per campus core parking space), and parking restrictions were poorly enforced.

In February 1973 the campus bus sytem was expanded from 3 to 13 31-passenger buses, and service was extended to three of the four high-density housing developments in the Amherst area. No fares were charged for use of the transit service. In September 1973 parking policies that were initiated (a) increased the parking fee from $5 to $17 and $55 per year, depending upon parking lot location; (b) reduced the number of available parking spaces (limited number of permits); and (c) increased the number of peripheral parking spaces served by the transit system. The stated objectives of the TSM strategies were to reduce on-street congestion on the college campus and in Amherst, reduce on-campus parking demand, provide an attractive transit option for campus travel, and transform the campus core into an auto-free zone.

Staged implementation of the TSM strategies permitted an evaluation of impacts resulting from improved transit operation without more stringent parking policies and the impact of both strategies combined. MOEs included travel time, traffic volumes, and transit passengers.

After the fare-free bus system expansion was implemented, the following results were noted: (a) bus ridership increased from 2,500 passengers per day to 6,500 passengers per day; (b) traffic volumes *increased* but at a rate slightly below that estimated on the basis of past trends; and (c) travel times were reduced slightly but were insignificant.

After the fare-free bus system expansion plus restricted core-area parking and increased parking fees were implemented, the following results were noted: (a) bus ridership increased from 6,500 passengers per day to 13,500 passengers per day; (b) traffic volumes *decreased* significantly, and improvements in traffic congestion were reported; (c) no significant changes in travel times were recorded; and (d) parking registration demand decreased by 8 percent from that of the previous year.

A unique capability to balance costs with revenues as well as to travel between transportation modes is provided by the joint operation of transit and parking. Annual (1976–77) revenues to the university from parking fees, meter income, and violation revenues amounted to $1,156,000, and transit system costs plus the security and parking staff cost amounted to $1,472,000. The university administration supported transit through its physical plant budget for the difference.

It is significant that authority for both transit and parking operations is vested in the university administration. This was reported to be a positive factor in achieving the objectives of the TSM strategies. Subsequent to the demonstration project, both transit and parking operations were placed under a single individual, the director of transportation and parking. With the creation of the Lower Pioneer Valley Transit Authority in 1975–76, the University of Massachusetts ceased to operate the on-campus bus system and currently contracts with the authority to provide the campus transit service. The subsidy for the fare-free campus operation is provided by the university through the local governments.

In the implementation of the combined strategies, opposition was encountered from the nonprofessional university employees (approximately two-thirds of the total university work force). They had been the main beneficiaries of the existing parking policy, primarily because of their morning arrival time in relation to that of the students and faculty. The conflict was resolved by lowering the parking fees and eliminating a $120 special reserve option, but the final evaluation report concludes that "rationing parking space strictly by price may not be the best approach."

By July 1980 the transit service had been expanded to 30 buses with an average daily ridership of 22,000 passengers. All transit operations are still fare-free. Parking policies remain basically unchanged; however, parking fees have been increased once since the initial change in 1973. (This information is from a phone conversation with William Barrett, Director of Transportation and Parking, University of Massachusetts, July 2, 1980.)

University of California San Francisco Transportation Program

Since 1974 the University of California San Francisco (UCSF) has had an active program of TSM actions and has successfully implemented, monitored, and evaluated mutually supportive TSM tactics (*2,3*). The significance of this experience is that it showed the improvements in parking and auto trip reduction that can result from an active institutional program.

UCSF is located about 4 miles west of downtown San Francisco. In 1977 the average daily population at the university and teaching hospital was estimated to be 12,100: approximately 20 percent students, 12 percent academic staff, 35 percent nonacademic staff, and 33 percent other (visitors, patients, etc.). Due to the location of UCSF, transportation access has long presented problems to the area. Adjacent residential neighborhoods have experienced a disruptive impact as a result of auto trips generated by UCSF. University patrons, neighborhood residents, Golden Gate Park visitors, and others compete for the limited number of parking spaces in the area. Transit service to UCSF is inconvenient due to UCSF's separation from the downtown focal point for traffic.

In 1974, in response to community concerns, UCSF implemented a series of TSM measures, the primary objective being to reduce auto traffic generated by the campus. These TSM actions included car pool incentives (matching program and priority parking), employee van pool program, support for a commuter bus club, shuttle bus services, and promotional efforts. Significantly, UCSF also adopted a policy not to increase campus parking supply.

In May 1977 a study was completed on the impacts of the UCSF Transportation program. The following table (*3*) summarizes the results of that study.

Element	Number of Services	Daily Ridership (Two-Way)	Percent of Traffic Reduction[a]
Car pools	40 pools	200	0.5
Van pools	6 pools	120	0.8
Bus pools	6 pools	400	2.9
Shuttle bus service	4 routes	500	3.4
Total		1,220	7.6

[a] Measured relative to levels that would have occurred without the program.

As of June 1980 all program elements remain in effect and continue to expand. Parking decals sell for $8 monthly for car pools and $18 for private vehicles (these decals are limited in supply). UCSF has designated a manager of transportation to monitor and direct an ongoing program. This transportation broker has successfully negotiated work hour schedule changes with department heads to facilitate car pool and van pool programs. (This information is from a phone conversation with Jim Wood, Transportation Officer, University of California San Francisco, June 23, 1980.)

University of California at Berkeley Fringe Parking and Van Pool Program

This program includes fringe parking, with shuttle service and peak-hour van pools to the campus interior and "fringe-pools" operating as van pools from residences to the fringe parking lot. The project is significant in that it provides a combination of services for long-distance trips to the University of California at Berkeley campus, walk-on transit service to local areas unserved by fixed-route transit, and traditional van pool service, all within the same program (*4–6*). The goal of the project is to reduce vehicle miles of travel to and from the campus each day.

Van pool service consists of 50 van pools, primarily serving faculty and staff of the university. Managed by the transportation services office of the university, the van pools operate an average of 50 miles (80 km) daily. In a survey conducted in May 1980, the majority of van poolers were identified as former auto drive-alones who changed because of the "high cost of driving" (65 percent) and because they were "tired of coping with peak hour traffic" (49 percent).

In addition to the van pool program, the university's transportation services office opened two fringe parking lots in September 1977. These fringe lots, the Gateway lot and the Harrison lot, provided parking facilities at locations away from the campus, with shuttle bus service operating on a 1-hr headway to the campus. The Harrison lot was closed in June 1979, after evaluation studies indicated that it was attracting riders from the conventional van pool program. Additionally, the Harrison lot was already served by good fixed-route transit to the campus, which reduced demand for the shuttle service. In its place, the Fruitvale lot under the MacArthur Freeway (I-580) in Oakland was opened.

Both the Fruitvale and Gateway lots were served with shuttle service from 7:30 a.m. to 6:30 p.m. In addition, the lots were served by three van pools during the peak hours. In this service the van pool drivers operated on a strict schedule once each peak period between the fringe lot and the campus. This service proved to be more popular than the shuttle because of passenger familiarity and reduced wait time at the fringe lots. After the first year the program was modified to permit fringe van pool operators to collect passengers at their door prior to completing the load at the fringe lot.

Peak-hour fringe van pool ridership in October and November (high ridership periods) had exceeded 1,000 each month at Fruitvale and 700 each month at Gateway. Shuttle ridership during the same month was just over 350 for both Fruitvale and Gateway. Average ridership on the shuttle was less than one passenger per shuttle trip. Users of fringe lots traveled about 11 miles (18 km) from home to the Gateway lot and less than 1 mile (1.6 km) to the Fruitvale lot. On June 30, 1980, the Gateway lot was closed due to poor use and low ridership on the shuttle.

Comparisons were made between the Gateway and Fruitvale lots. The Gateway lot was located too close to the campus and too far from residential areas, leading to the conclusion that unless campus parking costs were extraordinarily high, drivers would not stop at a fringe lot to transfer. Fruitvale, however, serves an area close to a residential concentration that is poorly served by fixed-route transit.

The operating deficit of the fringe parking program increased during four evaluation periods of 6 months each. Although it was estimated that the program reduced the campus parking demand by 39 spaces daily, the benefit of the shuttle service was questionable.

San Francisco Joint Institutional TSM Program

Implementation of TSM measures through the collective actions of institutions has been accomplished in San Francisco by a management group of transportation brokers. This unique example (*7,8*) provides experiences in joint operation of transportation broker training, joint broker employment, shuttle bus, and so on. Its significance lies in the potential for similar joint efforts in other metropolitan areas.

In 1977 the City of San Francisco passed Ordinance No. 174-76, which required any private institution located in a residential area to prepare an institutional master plan that included impacts of proposed development and possible mitigation measures, including TSM. Subsequently the city planning department worked with 14 major institutions in San Francisco to organize a joint institutional TSM program. Objectives of the program were to reduce auto parking and traffic impacts at each institution and to foster economy of operations through cooperative efforts. Under the program, funded partially by UMTA, transportation brokers were designated and TSM programs were developed for each institution. Of the 14 institutions, 9 were medical centers, 3 were universities, 1 was a combined medical center and university, and 1 was a major insurance complex. Although 6 of the institutions did not fall under the city ordinance requiring an institutional master plan because they were privately owned, all 14 participated equally in the joint TSM program. Under the program, transportation brokers were trained in a 40-hr course covering all aspects of TSM.

As of June 1980 most of the institutions were implementing the institutional TSM strategies recommended from the joint effort. (This information is from a phone conversation with Cliff Chambers, Transportation Manager, Children's Hospital of San Francisco, June 23, 1980.) Joint activities recommended for the consortium included (a) grouping employees from more than one institution in bus pools, van pools, and shuttle buses; (b) supporting the transit expansion plan of the local transit operator and acting as a group to influence transit decisions; and (c) sharing experiences in implementing TSM strategies. Subsequently the Joint Institutional Transportation Brokers Association (JITBA) was formed to facilitate the continued joint effort.

The TSM program of Children's Hospital should be cited as an example of the individual and joint efforts resulting from the joint institutional effort. Since 1978 Children's Hospital has:

1. Joined with Marshal Hale Memorial Hospital in employing a transportation broker;
2. Developed a ride-sharing program that expanded the number of car pools from 13 in 1978 to 55 in 1980;
3. Joined with Marshal Hale Memorial Hospital and St. Mary's Hospital in providing bus shuttle service for an interim crosstown route;
4. Implemented a preferential parking program in the surrounding neighborhood and an off-street parking management program; and
5. Pooled resources with other JITBA members to conduct a marketing/training program on TSM for new employees.

Studies conducted for Children's Hospital in April 1980 revealed a large decrease since 1978 in the percentage of hospital employees driving alone as a result of the TSM actions. On the two most important shifts, the day and evening shifts, the shared-ride mode increased from 41 to 55 percent of the total work trips to the hospital. With the parking program, the number of unregulated spaces was reduced from 1,440 to 40, the unregulated spaces being replaced with 2- or 3-hr restricted spaces. The number of hospital employees parking in adjacent neighborhoods was reduced from 60 percent of the parked vehicles in 1978 to only 26 percent in 1980.

Norfolk Van Pool and Contract Hauler

This project focuses on van pool operations to serve employees of five major naval installations at Norfolk, Virginia (*9,10*). It illustrates the unique features of military installations as activity centers and the influences that military departments provide through matching efforts and program promotion. The objectives of the program are to reduce auto travel and congestion in the tidewater area.

Van pool service to the naval installations at Norfolk began in September 1977 as a joint effort between the U.S. Navy and UMTA, through a demonstrations grant from the Service and Methods Demonstration Program of UMTA. A contract was awarded to the Tidewater Transportation District Commision (TTDC), which serves as the regional transit operator for the tidewater area. The U.S. Navy provides the ride-matching programs from extensive employee records and markets the program through the individual naval commands.

Under the contractual agreements, the TTDC purchases vans and leases them to drivers who are U.S. Navy employees and who have met all qualifications for operation of a van pool. The TTDC carries all responsibility for financing the purchase of the vans. It is also responsible for insurance coverage, vehicle maintenance, and general promotion.

The van pool program staff at the TTDC consists of two full-time employees and one half-time employee. The full-time employees are the program manager and the traffic services representative; the latter works closely with the U.S. Navy on operational matters. Clerical support is provided on a half-time basis to maintain records. The program is supported by other administrative divisions of the TTDC, such as financial, legal, and operational.

Van maintenance is performed by the TTDC when garage space is available; otherwise it is contracted out to private garages. All minor maintenance (e.g., fan belts and light bulbs) is to be provided by the driver. A preventive maintenance schedule is provided by the TTDC, and the driver agrees to follow the schedule and maintain the van in top condition. All vans are of the same make and are 12-passenger, bench-seat type.

Drivers must be U.S. Navy employees, be at least 25 years old, have a valid chauffeur's license, and have had no at-fault accidents during the last 3 yr. Prior to executing an agreement as a van pool operator, the driver is required to complete a defensive driving course. Prospective drivers are assisted by the TTDC in forming a van pool from the matching program. The van is leased to the driver for a fixed monthly charge plus a unit cost per mile. A minimum of eight passengers is required to form and maintain a van pool. The driver sets the charge, but the TTDC provides suggested rates for eight-passenger and nine-passenger pools.

The TTDC attempts not to compete with private vanpoolers, but supports their formation and has supported private haulers by providing loan sources for van purchase and insurance.

The TTDC has provided 50 vans for the van pool operation, which serves a total employment of 86,000 at the five installations.

Dallas Stadium Transit

The significance of this project (*11*) lies in the provision of special transit service to major athletic events in an urban area where overall transit ridership is quite low. Special transit service is provided by the Dallas Transit System (DTS) to Texas Stadium in Irving, Texas, for all home football games of the Dallas Cowboys and the Southern Methodist University (SMU) Mustangs. The goal of the effort is to reduce congestion to the stadium by handling 10 percent of all person-trips by transit service.

The special service is provided through charter service to special groups and express "Cowboy Flyers" on 13 routes serving 39 locations with nonstop transit. Similarly, "Mustang Mania Flyers" on five routes serve 18 locations. Collection points are generally located at shopping center parking lots by prearranged agreement with the management. Current round-trip fare is $5.00 for the average round trip of 37 miles (60 km).

During the 1979 season the DTS served approximately 15 percent of all persons attending Cowboy games by transit and 7 percent of those attending SMU games. An average of 204 buses were used per Cowboy game for 12 events and 83 buses per SMU game for 5 events. For comparative purposes, it should be noted that the total bus fleet of the DTS consists of approximately 450 buses.

Excellent parking locations and preferential treatment for buses provide an incentive for transit ridership. With strict police enforcement, DTS buses are permitted to pass long queues for stadium access. High auto parking costs, long walking distances, and long delays for autos in entering and leaving the stadium area also contribute to transit ridership. Program marketing is accomplished through brochures and media coverage.

Steamboat Springs Ski Area Parking Plan

Recreational activity centers for special events or for seasonal activities offer unique challenges in transportation management because of the high cost of improvements, such as parking facilities, and their limited use on an annual basis. The use of TSM measures to reduce parking requirements in the Mt. Werner (Steamboat Springs) Ski Area offers insights on TSM potential (*12*).

The Mt. Werner Ski Area in Colorado has experienced a growth in skier-days from 100,000 in 1968–69 to an anticipated 900,000 skier-days in the 1981–82 season. Skier parking demand in 1979 was 1,114 spaces, which exceeded the skier parking capacity of 1,030 spaces. High costs associated with the provision of additional parking facilities to meet a peak demand that is realized only 15 days out of a 140-day season were the motivation to evaluate other means of traffic management. Limited transit service existed in 1979; however, studies indicated that, although the transit system was fare-free, walking distances to bus stops and limited hours of operation reduced ridership by local residents. Employees at the ski lift area, studies showed, used prime parking spaces, because transit service was unavailable at the time they reported to work. Thirty-nine percent of the cars that were parked in the most desirable area for the ski lift were registered to local residents.

The TSM program developed to increase parking efficiency contained five major elements:

1. Increased transit availability to local residents and expanded hours of operation.
2. Expanded transit marketing efforts for both residents and skiers.
3. Establishment of congestion pricing for the base area, where shops and lodging facilities are located and where on-street parking is permitted.
4. Establishment of preferential parking for high-occupancy vehicles.
5. Expanded promotional efforts to induce skiers to travel to Steamboat Springs in a mode other than private auto. (This marketing must be directed at skiers before they leave for the ski area.)

EVALUATION AND GUIDELINES FOR IMPLEMENTATION

The potential for TSM at major activity centers depends on the characteristics unique to each type of activity center and each specific center itself. It is often the single administrative head of the major activity center who permits the creative approach necessary to adapt TSM to a specific location.

This single administrative head, however, often serves a broad constituency capable of mounting a concentrated campaign for improvement of travel conditions. Therefore, a single administrative head provides not only a good opportunity for management of the transportation system, but also a focal point for special interest groups to bring pressure on issues both within and exogenous to the activity center. These issues often originate from conflicting goals and objectives—for example, between two traffic-free neighborhoods adjacent to a community hospital that has limited funds for on-site parking. Low-cost TSM actions might provide the administrative head with that middle ground needed to improve travel to the activity center and simultaneously negate the requirement for restrictive parking measures in surrounding neighborhoods.

The individual responsibility for TSM to serve major activity centers is difficult to identify consistently. Often it lies outside the governmental sector and is assumed by an alert administrator or traffic head at the activity center. The joint broker concept at the Children's Hospital in San Francisco is an excellent example of this assumed role for TSM leadership. Local governments would do well to encourage transportation brokerage among the major activity centers within their jurisdictions.

Guidelines

The following guidelines are suggested for implementation of TSM strategies at major activity centers.

Parking Constraints, Parking Fees, and Fringe Parking

1. Parking fees should be set at a scale necessary to discourage parking at undesirable locations and provide the optimum turnover rate and should be recognized as a means to offset other transportation program costs, such as administration and transit service.
2. Parking constraints should be rigidly enforced to ensure compliance.
3. A single administrative head over both parking and transit service at a major activity center is highly desirable.
4. At major sports and related events, location and cost of parking can be used as an incentive for transit ridership.
5. Location of fringe lots at major activity centers should consider the length of the auto trip to the fringe lot as a percentage of the total trip. Previous work has suggested that the residential travel time (from home to the fringe lot) should be less than 45 percent of the total travel time (*13*). Other work has concluded that the trip origin, fringe lot, and final destination should lie along a relatively straight line (*14*).
6. Fringe lots should be located so as not to compete with fixed-route transit or institutional van pools.

Brokerage

1. Major activity centers should consider a joint brokerage arrangement to provide qualified professionals to implement TSM.
2. Associations of brokers of related major activity centers provide an opportunity for information sharing and brainstorming.

Subscription and Charter Bus for Special Service

Preferential treatment of transit should be used to attract riders for special events.

Ride-Sharing

1. Van pool programs should provide incentives to the driver of the van through a free ride to work, close-in parking, and possibly a financial return from incentive fares above a certain number of passengers.
2. Incentives should also be provided to the van pool riders, who must be attracted to ride-sharing if the program is to be a success. These incentives should be primarily financial in nature (i.e., reduced travel costs).
3. Van pools can be successfully operated by either employers, employees, or a third party (e.g., a local credit union).

Support Activities

Well-coordinated TSM measures at major activity centers can provide mutual support. Many actions are involved, however, in a successful TSM program for such centers, and almost total support and coordination are necessary to achieve success. Such coordination requires tenacity and also needs the full-time direction provided by a designated broker. This perhaps provides insight into the success of brokerage operations.

Another significant support activity for major activity center TSM is that of enforcement. Successfully implemented TSM programs have included enforcement personnel in the coordinated effort beginning in the design stages. It is strongly suggested that implementors of TSM measures at major activity centers include appropriate highway patrol, city police, and private security agents in the initial deliberations on TSM. Enforcement is a strong support activity that deserves proper consideration in TSM development at major activity centers.

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CHAPTER TEN

MODAL TRANSFER POINTS

Modal transfer points provide the means of transferring from one mode of travel to another or of changing routes within the same mode. Interest in passenger transfer has lagged behind other aspects of urban transportation in recent years, and modal shift has often been overlooked; yet modal transfer points are ubiquitous in urban areas and are an important part of the total urban transportation system. In any community with more than one bus route, passengers transfer from one route to the other, although in many cities modal transfer points are no more than sidewalk locations in the downtown area where bus routes converge. Such transfer points, however, are candidates for improved efficiency through TSM.

Transportation professionals have traditionally attempted to minimize necessary transfers in the urban transportation system instead of concentrating on increasing the efficiency of existing and proposed modal transfer points. The obvious purpose of the modal transfer point, and hence the transportation system management (TSM) measures that support it, is to improve the overall efficiency of the total urban transportation system. A broad view of modal transfer does not just consider the transfer between bus routes but rather expands the concept to include, for example, the shift from the pedestrian to the transit mode (including bus shelters); the shift from auto to car pool at a park-and-pool lot; and the storage of bicycles to permit the shift from that mode to express bus routes. With this broad view of modal transfer, the role of TSM becomes more evident. More efficient transfer between or among modes results in increased efficiency in all systems and thus encourages use of more efficient modes of travel. Modal transfer points, then, as operating environments for TSM, offer an opportunity for the application of TSM measures to increase the efficiency of the transfer while at the same time providing amenities for passenger convenience.

CHARACTERISTICS

Seven modes of travel use a modal transfer facility: the walk mode, bicycle, automobile, car pool/van pool, bus, rail, and air. The modal transfer points between each pair of modes are shown in Table 9.

Certain transfer points are not applicable to normal urban travel, and these are so indicated in the matrix (e.g., bicycle/bicycle transfer). Bicycle and auto modes normally involve private ownership and require storage facilities at a transfer point. (This ignores, for the sake of simplicity, the private ownership of general aviation aircraft, for which storage is normally provided at air terminals.) Required storage facilities are identified in Table 9 by parentheses. The provision of these storage facilities and rapid access to them are major considerations in the design of modal transfer points.

Eight different types of modal transfer points can be iden-

TABLE 9

MODAL TRANSFER POINTS

ORIGINAL MODE (Origin)	FINAL MODE (Destination)						
	Walk	Bicycle	Auto	Carpool Vanpool	Bus	Rail	Air Travel
Walk	N/A	(Bicycle Storage)	(Parking Facility)	Private Location	Bus Shelter Station	Rail Terminal	N/A
Bicycle	(Bicycle Storage)	N/A	N/A	(Bicycle Storage) Park-and-Pool Lot	(Bicycle Storage) Park-and-Ride Lot	(Bicycle Storage) Rail Terminal	(Bicycle Storage) Air Terminal
Auto	(Parking Facility)	N/A	(Parking Facility)	(Parking Facility) Park-and-Pool Lot	(Parking Facility) Park-and-Ride Lot	(Parking Facility) Rail Terminal	(Parking Facility) Air Terminal
Car/Van Pool	N/A	N/A	(Parking Facility) Park-and-Pool Lot	N/A	(Parking Facility) Park-and-Ride Lot Station	(Parking Facility) Rail Terminal	(Parking Facility) Air Terminal
Bus	Station	(Bicycle Storage) Station	(Parking Facility) Park-and-Ride Lot	(Parking Facility) Park-and-Ride Lot Station	Bus Shelter Station	Rail Terminal	Air Terminal
Rail	Rail Terminal	(Bicycle Storage) Rail Terminal	N/A	(Parking Facility) Rail Terminal	Rail Terminal	Rail Terminal	Air Terminal
Air Travel	N/A	(Bicycle Storage) Air Terminal	(Parking Facility) Air Terminal	(Parking Facility) Air Terminal	Air Terminal	Air Terminal	Air Terminal

tified: bicycle storage, parking facility, park-and-pool lot, park-and-ride lot, bus shelter, bus station, rail terminal, and air terminal. The five primary modal transfer points for TSM opportunities are discussed below.

Park-and-pool lots. (auto to car pool/van pool). This modal transfer point ranges from roadside parking in rural areas to private parking at outlying commercial centers and church lots. TSM opportunities include the provision of park-and-pool lots adjacent to major intersections. (See the Kansas City program described in Chapter 5.)

Park-and-ride lots (walk to bus and auto to bus). Park-and-ride and kiss-and-ride lots are common TSM-related facilities. Lots may be small and are located where they will provide easy access to residential neighborhoods.

Bus shelters and bus stations (walk to bus and bus to bus). This modal transfer point ranges from the simple bus stop in a residential neighborhood to bus terminals in the central business district (CBD). Outlying bus stops with high use are often furnished with shelters. TSM opportunities are most frequently identified with central bus terminals; however, bus shelters at neighborhood bus stops could also be considered.

Rail terminals (walk to rail, auto to rail, bus to rail, and rail to rail). The rail terminal is, with the air terminal, the most complicated of modal transfer points. It must provide interface between rail travel and the pedestrian, the auto, the bus, and other rail facilities. It often is designed so that modes operate at different platform levels, and it must provide easy and rapid transfer between levels.

Air terminals (auto to air, bus to air, rail to air, and air to air). Air terminals range from general aviation airports, which normally provide parking for both the aircraft and the auto, to major hubs for air carriers, which frequently interface with rail, bus, and auto modes.

TSM OPTIONS

TSM measures to increase the efficiency of existing modal transfer points are related to the design of the facility. The operation of the modal transfer point should be considered in the design of the facility to provide a smooth interface between the modes. Good design of the modal transfer is an important TSM element in itself.

Operational TSM measures include timed transfer between neighborhood bus routes and line-haul facilities, simplified fare collection procedures, pedestrian islands in bus transit centers for easier bus loading, passenger amenities such as information displays and newspaper racks, and joint use of facilities (parking, roadways, amenities, etc.) with outlying commercial centers.

Guidelines included in this chapter for TSM measures are more closely related to facility design and system operation than to feasibility determinations.

MOTIVATION FOR ACTION

Impetus for modification of modal transfer facilities has generally come from a desire of transit management to operate the transfer more efficiently and minimize delays to line-haul equipment. Amenities at transfer points, however, have come in response to rider complaints, as have projects to expand parking, kiss-and-ride operations, and security for outlying park-and-ride lots. In general, the TSM measures for modal transfer points are reactions to problems for which the solution is readily identifiable.

GOALS, OBJECTIVES, AND PLANNING ANALYSIS

Goals and objectives for TSM measures at modal transfer points relate primarily to the objective of the terminal or station itself, which is to permit the safe and efficient transfer of persons between modes of travel. Little conflict between goals of different groups can be expected because most relate to efficient transfer. Some goal conflicts may be encountered with adjacent neighborhoods if insufficient parking is provided. Table 10 includes some of the more common goals and objectives associated with modal transfer TSM strategies and the measures of effectiveness (MOEs) for their evaluation.

TSM measures at modal transfer points generally relate to design guidelines for the transfer facility. Good design of a terminal or station will incorporate applicable TSM measures with little need for analytical transportation planning in advance. Planning is required, of course, to minimize the need for transfers and optimize the location of transfer points. Locations can be translated into terminal design through accepted standards and guidelines.

IMPLEMENTATION EXPERIENCES

Washington, D.C., Metro Silver Spring Station

The Silver Spring station of the Washington Metropolitan Area Transit Authority (Metro) is located in Silver Spring, Maryland, and provides an example of a new station that has incorporated TSM measures to reinforce rail, bus, auto, and pedestrian interchange (*1*). Its significance lies in its ability to serve large volumes of feeder bus traffic.

The Silver Spring station was planned and designed to serve the rapidly growing commercial and office development of downtown Silver Spring and the adjacent medium- to high-density residential areas. Access to the station is provided by Colesville Road, a principal arterial facility. A 600-ft (180-m) platform extending over Colesville Road provides direct access to the Metro trains. Escalators serve the platform and fare collection facilities are located at street level and are entered directly from the bus unloading areas.

Bus service to the station, which is one of the high-volume stations of Metro, is provided through the Metrobus lines and the "Ride-On" buses of Montgomery County. Fifteen bus bays were constructed for unloading the 70 Metrobuses and 59 Ride-On buses serving the station daily between the hours of 7:00 a.m. and 8:00 a.m. and loading the 132 buses serving the station during the p.m. peak (5:00–6:30 p.m.).

Parking at the station site is provided by Montgomery County. A kiss-and-ride facility with 47 short-term parking spaces and two stop locations is included in the station area. No enclosed shelter is provided for persons arriving by bus or auto, but all facilities are located adjacent to the rail platform, and thus easy access is provided to the station.

As of May 1980, 5,178 (31.5 percent) rail passengers for the Silver Spring station arrived by Metrobus; 3,144 (19.2 percent) by Ride-On bus; 2,262 (13.8 percent) as auto drivers; and 1,796 (10.9 percent) as auto passengers. A total of 3,791 (23.1 percent) are "walk-on" passengers.

Toronto Subway Terminals

The rail system serving Toronto, Ontario, Canada, provides significant designs and experiences in modal transfer centers (*2*). The 32-mile (51-km) system has 57 stations, the majority of which provide intermodal transfer, primarily between bus and rail and between private auto and rail. The Toronto Transit Commission (TTC) operates 120 surface routes of buses and light-rail vehicles that interface with the rail system at 158 connections. Evaluation of the terminal design in Toronto provides insight into significant design features of modal transfer points.

The metropolitan area of Toronto covers 244 miles^2 (632 km^2) and has a population in excess of 2 million. The population of the area served by the TTC within a 30-mile (48-km) radius of the Toronto CBD has a population of approximately 3.3 million. With the major growth occurring in the fringe areas, and with Toronto remaining the major employment center, the rail system has increased in importance. The TTC has provided rail terminals with park-and-ride and kiss-and-ride facilities to capture trips to the Toronto CBD. Partially

TABLE 10

GOALS, OBJECTIVES, AND MOEs FOR THE MODAL TRANSFER POINT OPERATING ENVIRONMENT

Goal	Objective	MOE	TSM Measures for Each Goal
Maintain and/or improve the quality of transportation services on the existing transportation system	• Minimize Travel time • Maximize Security • Maximize Comfort and Convenience	• Person Hours of Travel • Crimes • Transit Transfer Time • Trip Distance	Adequate design through standards and guidelines Increased security and illumination Simplified fare collection Timed transfer of bus schedule Passenger amenities
Increase the efficiency of the existing transportation system	• Maximize Transit Usage	• Transit Passengers	Adequate design through standards and guidelines Timed transfer of bus schedules

as a result of this policy toward improved terminals, the TTC now carries 70 percent of the peak-hour commuters to the downtown core.

In addition to providing over 10,000 parking spaces for park-and-ride in the system, the TTC has also pioneered the development and design of kiss-and-ride facilities as part of a total concept for modal transfer points. Separate roadways for a specific drop-off and pick-up area where auto passengers could easily connect with the subway system were first constructed in 1968 in the Islington and Warden terminals. Operation of the terminals was closely monitored, and improved designs were incorporated in later terminals.

The initial kiss-and-ride facilities at Islington and Warden were very popular, and the initial volume of 3,000 to 4,000 users made up approximately 10 percent of the total terminal users. A separate kiss-and-ride roadway with entry from intersecting arterial streets was provided to the subway entrance. No traffic control measures were provided at the entrance or exit. The a.m. peak flow in the kiss-and-ride roadway was smooth, but the p.m. peak flow was congested on both the special roadway and the arterial street because of a queue for the train arrival. An orbiting pattern was noted: auto drivers circulated on approach arterials and local streets while waiting for the subway's arrival. This orbiting pattern resulted in additional arterial congestion. To ameliorate the problem, 18 layover parking spaces and special entrance ramps off the arterial were provided for vehicle storage. Enforcement of the short-term layover spaces proved difficult. Uniformed police officers were added to keep traffic moving during the peak hour.

In 1976 the pedestrian platform at the Islington subway entrance was extended approximately 110 ft (34 m) with a 60-ft (18-m) glass enclosure. Although this added no capacity to the kiss-and-ride operation, it added to commuter convenience and reduced delays because passengers could observe their approaching car from a protected area. Thus pick-up times were reduced.

Close monitoring of the kiss-and-ride operation resulted in a carousel design for two new terminals constructed after 1974. Two new stations, the Finch and Wilson terminals, provided for passenger pickup from an enclosed, circular terminal with glass frontage that provided a full view (360°) of arrivng vehicles. Automobiles circulate in two concentric lanes around the terminal and wait for a vacant head-in parking space between the circulating lanes and the pick-up lane adjacent to the terminal. Upon the arrival of the passenger, the driver of the waiting vehicle moves directly into the pick-up lane, picks up the passenger, and exits through the circulating lanes.

In 1978 traffic studies it was found that buses provided 75 to 80 percent of the subway passengers, park-and-ride furnished 7 to 9 percent, and kiss-and-ride furnished 5 to 7 percent. Pedestrian arrivals varied considerably among the four stations, from 1 percent to as high as 12 percent of the total subway riders. Comparison between the old terminal design (Islington terminal) and the carousel design (Finch terminal) noted that fewer kiss-and-ride vehicles (only half as many) entered the roadway at the Finch terminal than at the Islington terminal to pick up almost the same number of passengers, illustrating less orbiting and consequently less congestion. Studies of the carousel facility estimated the capacity of the kiss-and-ride roadway to be 325 vehicles per hour; however, a peak-hour load of 379 vehicles for 1 hour had been observed. The carousel design continues to be the preferred design for kiss-and-ride operation at TTC modal transfer facilities.

Portsmouth (Virginia) Park-and-Ride

The Greenwood Drive park-and-ride lot in Portsmouth, Virginia, provides an example of an underused facility and illustrates the need for adequate planning in feasibility determinations and transit travel (*3*).

The park-and-ride lot was located at the interchange of I-264 and Greenwood Drive in southwest Portsmouth. Designed for 335 free parking spaces, kiss-and-ride services, an enclosed passenger shelter, bicycle racks, lighting, and landscaping, the lot was developed jointly by the Federal Highway Administration, the Virginia Department of Highways and Transportation, the Tidewater Transportation District Commission, and the City of Portsmouth. Bus service began on May 17, 1976, with six buses providing service to the naval installations in Norfolk and the Norfolk CBD. Buses from the Greenwood Drive lot to the U.S. Naval Operations Base and the U.S. Naval Air Station also served a shopping center and stopped on demand at a local university and hospital.

The use of the park-and-ride lot was limited from the outset. After 1 yr, service to the Norfolk CBD was discontinued due to insufficient passenger demand. Daily parking at the lot ranged from 15 to 20 cars, and an average of only 30 passengers a day used the transit service to the naval installations. An evaluation was conducted in 1977/78 to determine the reasons for poor use of the facility, and an attempt was made to develop demand models for park-and-ride service. Total trips from the surrounding single-family homes and town houses to the naval installations amounted to approximately 750 daily person-trips. Easy access to the freeway in the travel corridor from the lot was provided. Negative features of the lot design and location included a lack of directional signs for new users of the facility, a low level of maintenance, and a lack of security.

Perhaps the most significant reason identified for the attraction of less than 5 percent of the potential work trips was the existence of a subscription bus service prior to the opening of the lot. Nine 65-passsenger buses operated within the same market area as the Greenwood Drive lot and provided transportation to the naval installations. Privately owned by employees of the naval bases, the buses operated on a subscription basis and picked up riders at their homes for 60 to 75 cents per trip. Thus, the subscription bus clearly dominated the transit market in the corridor. The lack of continuous advertising for the park-and-ride service was also identified as a reason for underuse of the lot.

Garland (Texas) Park-and-Ride Lot

Garland is a suburban city in the Dallas urban area with a population of approximately 150,000. No fixed-route public transportation service is available. At the initiative of the

City of Garland, a contract was executed in 1975 with the Dallas Transit System to provide express bus service from the Dallas CBD to two park-and-ride facilities in Garland. Average freeway distance from Garland to the Dallas CBD is 16 miles (26 km). No direct freeway movement is possible. This project illustrates the success of park-and-ride when adequate modal transfer facilities are provided (*4*).

Express bus service was initiated in November 1975 to the temporary park-and-ride lots in Garland, which consisted of unpaved but improved parking lots with temporary shelters. Average daily ridership for the first year was 837; the average one-way fare was $0.65, and the average deficit per passenger was $0.28.

In January 1979 improvements were completed at the south terminal for a permanent facility. With assistance from an Urban Mass Transportation Administration grant, the new $1,000,000 facility provided 440 paved parking spaces and a 1,500-ft^2 (140-m^2) enclosed passenger terminal. An additional 106 paved parking spaces were to be completed in early 1981.

During the 1979–80 operating year, the average one-way daily ridership was 1,824 passengers. Average fare was $1.13, and the average deficit per passenger was $0.24. Thus, even with increased passenger fares, the ridership has risen with the addition of permanent transfer facilities.

Portland (Oregon) Clackamas Town Center Modal Transfer

The Clackamas Town center southeast of Portland is a shopping mall with 1.2 million ft^2 (110 000 m^2) of retail space serving a developing area. In the design and construction of the town center, the developer worked closely with Tri-MET, the regional transit operator, in designing a transit station as part of the center's operation. This project illustrates the design and operation of a modal transfer station in conjunction with a major retail center (*5*).

Four basic transit elements were included in the design of the shopping center: a transit station at a major mall entrance, a park-and-ride facility at a corner of the parking lot, on-site roadways reserved for transit circulation, and special transit access at the center.

Tri-MET uses the transit station as a modal transfer point and coordinates local and regional trunk routes on a pulsed schedule (timed transfer) to facilitate bus transfer. The location of transit transfer stations adjacent to major activity centers increases the ridership on local routes, which then serve the dual function of providing transit service to the shopping mall and feeder service to regional routes. This service concept had been shown by Tri-MET and others to be a very efficient way of providing a fairly high level of off-peak transit service in areas of low to medium densities of development. (This information is from a personal interview with Michael Kyte, Manager of Service Planning, Tri-MET, February 4, 1981.)

The transit station is virtually built into the shopping center adjacent to a main entrance to the mall. The passenger loading area (a single contraflow platform) enhances its function as a transfer point and as an access to the shopping center. A large, sheltered waiting area with amenities (rest rooms, schedules, newspapers) provides easy access to buses and to the shopping mall entrance. Exclusive transit access is provided to the center. The community-related facilities in the shopping mall (library, meeting rooms, day care center, ice rink) are major attractions for transit trips.

Tri-MET officials participated in discussions with the developer in the mall's initial planning. The transit program was formalized in a written agreement in which a long-term lease secures the transit operator's interest in the transit station.

EVALUATION AND GUIDELINES FOR IMPLEMENTATION

Efficient operation of modal transfer points through TSM measures provides an opportunity to increase the efficiency of the total transportation system. TSM measures in modal transfer points are built into a well-designed facility, but they can also improve the operation of the modal transfer.

Responsibility for TSM in modal transfer points is less fragmented than in other operating environments. Because most transfers involve a public transportation mode, the transit authority has a basic responsibility for improved efficiency at transfer points. Coordination is required, of course, with operators of feeder bus service and with local traffic engineers for arterial access. Municipal traffic engineers, highway engineers, regional transportation planners, and transit operators should be aware of the need for efficient modal transfer in all functions of the urban transportation system, even though not all of them are involved in the transfer point design and operation.

Guidelines

The following guidelines (*6–8*) may be considered in the application of TSM to the modal transfer point design and operation.

Pedestrian-to-Bus Transfer

1. Amenities are often not provided, although shelters are desirable in the higher traffic locations.
2. Shelters should provide 360° visibility.
3. Bus stops should be located so as to provide easy access from residential areas.

Auto-to-Bus Transfer

1. Transfer facilities or lots should be located for maximum access through the local street system.
2. Adequate parking is necessary, with 400 to 700 spaces being an optimum range. A desirable maximum size is 1,200 spaces (*9*).
3. Amenities should be provided at each terminal.
4. Design of the lot should be developed according to the following priority: (a) bus loading and unloading; (b) taxi loading and unloading, (c) passenger car unloading (dropoff), (d) passenger car loading (pickup), (e) short-term parking, and (f) long-term parking.

5. Park-and-ride lots should be properly advertised and signed for easy recognition and use.

6. Adequate illumination and security should be provided.

Bus-to-Bus Transfer

1. Downtown terminals should be located at points of optimum efficiency where express buses have lost freedom of high-speed movement.

2. Local-express bus terminals should be of simple design with relatively few bus bays.

3. Joint-use facilities and pulse scheduling are appropriate for suburban modal transfer centers.

4. Ancillary facilities should be kept to a minimum.

Pedestrian-, Bicycle-, Auto-, Bus-to-Rail Transfer

1. Transfer facility should be located for easy access through the local street system.

2. Maximum possible separation should be provided for pedestrians and motor vehicles.

3. Distance between access modes and the station platform should be minimized.

4. Design of the parking facilities should consider the different characteristics of commuter rail travel and Amtrak trips if both are accommodated at the same terminal.

5. For commuter rail, 0.32 parking space per daily boarding passenger is recommended. For Amtrak, 0.28 parking space per boarding passenger is recommended (*10*).

6. Off-street kiss-and-ride facilities should be provided at all suburban terminal locations.

7. Amenities should be provided at each terminal.

8. Parking lots should be adequately illuminated.

9. Enforcement of vehicular travel regulations is often required.

Rail-to-Rail Transfer

1. Safe and efficient movement for transferring passengers should be provided between separated levels of rail facilities.

2. Facility should be attractive with amenities.

3. Parking facilities should consider the different characteristics of the rail travel served.

4. Parking at rail-to-rail transfer is usually minimal because of adjacent land costs.

Support Activities

Efficient operation of modal transfer points is supported by enforcement of parking and traffic restrictions, adequate security for passengers and parked vehicles, and proper signing for easy access and departure.

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CHAPTER ELEVEN

SUMMARY AND CONCLUSIONS

The nine operating environments discussed in this synthesis appear to offer a reasonable structure for transportation system management (TSM) in an urban area. They seem to point in each case to the individual or agency that should assume the mantle of leadership for TSM. They also provide proper delineation of a subsystem that is both large enough to encompass impacts of TSM alternatives and yet small enough to be manageable. It may be argued that good engineering practice and astute management in urban transportation permit the operating environments to surface in a natural way. TSM and the operating environments may then truly be something "that we've been doing all the time anyway." Nevertheless, a deliberate effort toward initial delineation of operating environments and recognition of the leader in each case may foster a more enthusiastic approach to better management and more efficient use of the existing transportation system.

Given that, what conclusions can be drawn when these TSM implementation experiences are evaluated from a broad perspective? What silver thread, if any, weaves its way into the fabric of successful TSM measures? Similarly, what characteristics, if any, are common to TSM experiences that were less than successful? Any conclusions must, of course, be subjective, for all of the factors influencing success or failure can never be known. It has been said that success has many fathers but failure is an orphan, and it is true that many failures are buried in the memory of their originator. But so, too, are many successes undocumented and unreported. So maybe the scale is balanced and objective conclusions can offer some insight into the characteristics of both successful and unsuccessful TSM experiences.

SUCCESSFUL TSM EXPERIENCES

The following characteristics seem to be common to most successful TSM experiences.

A strong, innovative personality keenly interested in urban transportation. Even in highly technical issues the strong personality seemed to get results. Almost without exception, all participants in a successful TSM enterprise would point to some individual as being the primary reason for success. In some instances it was an elected official, but in the majority of cases it was a professional staff person who provided the leadership in a particular environment. Although the political structure was important in the approach to the successful TSM, it did not appear to be the determining factor. The innovative personality seemed to be able to work within any political structure and overcome barriers to achieve the end result.

Coordinated teamwork among transportation entities. Very few TSM measures in any operating environment can be implemented without the necessary coordination among individual agencies. However, few entities would ever admit to a lack of coordination, and, in a sense, coordination probably does take place in almost every urban area. The key seems to be more than just coordination; it is rather the kind of teamwork that encourages brainstorming and results in a synergism toward creative management. Each successful TSM experience spoke to this necessary teamwork.

Identifiable problem. TSM appears to develop a constituency only when problems and circumstances demand it. Such was the case in the TSM experiences described herein. The problem was not always traffic congestion but often was economic in nature (declining sales, higher driving costs, employee dissatisfaction) or was related to personal values (preservation of a neighborhood, cleaner air, reduced conflict between an activity center and surrounding neighborhoods). The problem was often not an immediate one but one that would evolve if current trends continued (loss of jobs, decline of the central business district [CBD], loss of transit service). Often it was the professional staff that responded to the problem, particularly if the problem was transportation-related, but just as often it was the elected official who saw non-transportation-related problems that could be positively affected by TSM.

Adequate planning analysis to determine system impacts. Each successful TSM experience seemed to demand a well-thought-out approach with stated goals, objectives, and measures of effectiveness. This seemed to be particularly important in those TSM strategies that had nontransportation goals and objectives.

Proper packaging of TSM strategies and support measures. The successful experiences seemed to envision a total system or subsystem and consider a myriad of support measures and combinations of strategies within that system. Balancing transit fares with bridge tolls and providing CBD preferential parking in conjunction with high-occupancy vehicle (HOV) lanes are functional elements of a dynamic system that speak to the need for proper packaging of TSM measures and support activities. The support activities noted for each operating environment imply the additional entities that must be involved and the teamwork that is demanded in the proper packaging of TSM measures and support activities. Proper packaging, in spite of its additional demands on staff resources, is one of the keys to successful TSM.

UNSUCCESSFUL TSM EXPERIENCES

It does not necessarily follow that the lack of the above characteristics would result in unsuccessful implementation, although it is true in some cases. Some characteristics that unsuccessful experiences seemed to have in common are given below.

A withdrawal of traveling privileges. Some TSM measures were unsuccessful because they withdrew from the public a transportation convenience that people had come to expect. The primary example of this is the take-a-lane concept for HOV lanes on freeways. The public's response in some of these TSM experiences led one professional to conclude that "you can't take from the public something you gave them to begin with."

Lack of a perceived problem. In many of the TSM experiences, both successful and unsuccessful, the public did not respond negatively to increased inconvenience as long as a problem was perceived to exist and the TSM solution appeared successful. And the public seemed willing to accept a better alternative if it appeared to be needed. However, the lack of a perceived problem limited TSM successes. HOV lanes, for example, have generally been unsuccessful when no freeway congestion existed and when freeway lanes offered a level of service equivalent to that of the HOV lane. Similarly, auto drivers on congested freeways have generally accepted HOV lanes with good voluntary compliance when the lane was adequately used by buses and car pools. Success seems to demand a proper balance between a perceived problem and an observed workable solution.

Imbalance between operating costs and level of service rendered. Some TSM measures were judged successful when evaluated against objectives other than cost but were abandoned because local decision makers judged the operating cost too high for the level of service rendered or the extent of the clientele served. This was the case in several dial-a-ride and fare-free transit projects.

Inadequate enforcement or lack of enforcement. Perhaps the most consistent characteristic of unsuccessful TSM experiences was the lack of enforcement for restrictive TSM actions. In many cases enforcement was not adequately considered in the design process, and effective enforcement was difficult. As in most public restraints, voluntary compliance was necessary for the measure to be effective. However, many TSM experiences reported a very negative public attitude toward voluntary compliance, probably reflecting both the type and design of the TSM measure itself.

NEEDED RESEARCH AND FUTURE DIRECTIONS

- *Long-range impacts of extended application of certain TSM measures.* Most of the TSM measures encourage a modal, spatial, or time-related shift in transportation use. CBD parking policies encourage a shift to the transit mode; neighborhood parking and traffic-control programs shift traffic and parking to arterial facilities; and flex-time spreads the peak hour. All have been successful in limited applications, but research appears to be needed on the long-range impacts of such measures, particularly if they are implemented on a citywide or regional basis.
- *Interrelationships among TSM actions and support measures.* Although some of the TSM experiences have suggested appropriate support measures, additional work appears to be needed in interrelating TSM actions and support measures and in identifying those support measures that should be considered for a successful effort.
- *Enforcement and TSM.* Perhaps the support measure most common to TSM strategies was that of enforcement. As noted previously, lack of enforcement was a major factor in unsuccessful TSM measures in almost all the operating environments. Considerable work has been done by Meyer and others (*1–4*), but more research is needed to determine the proper role of enforcement and to develop TSM design standards that devote adequate attention to enforcement and voluntary compliance.

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