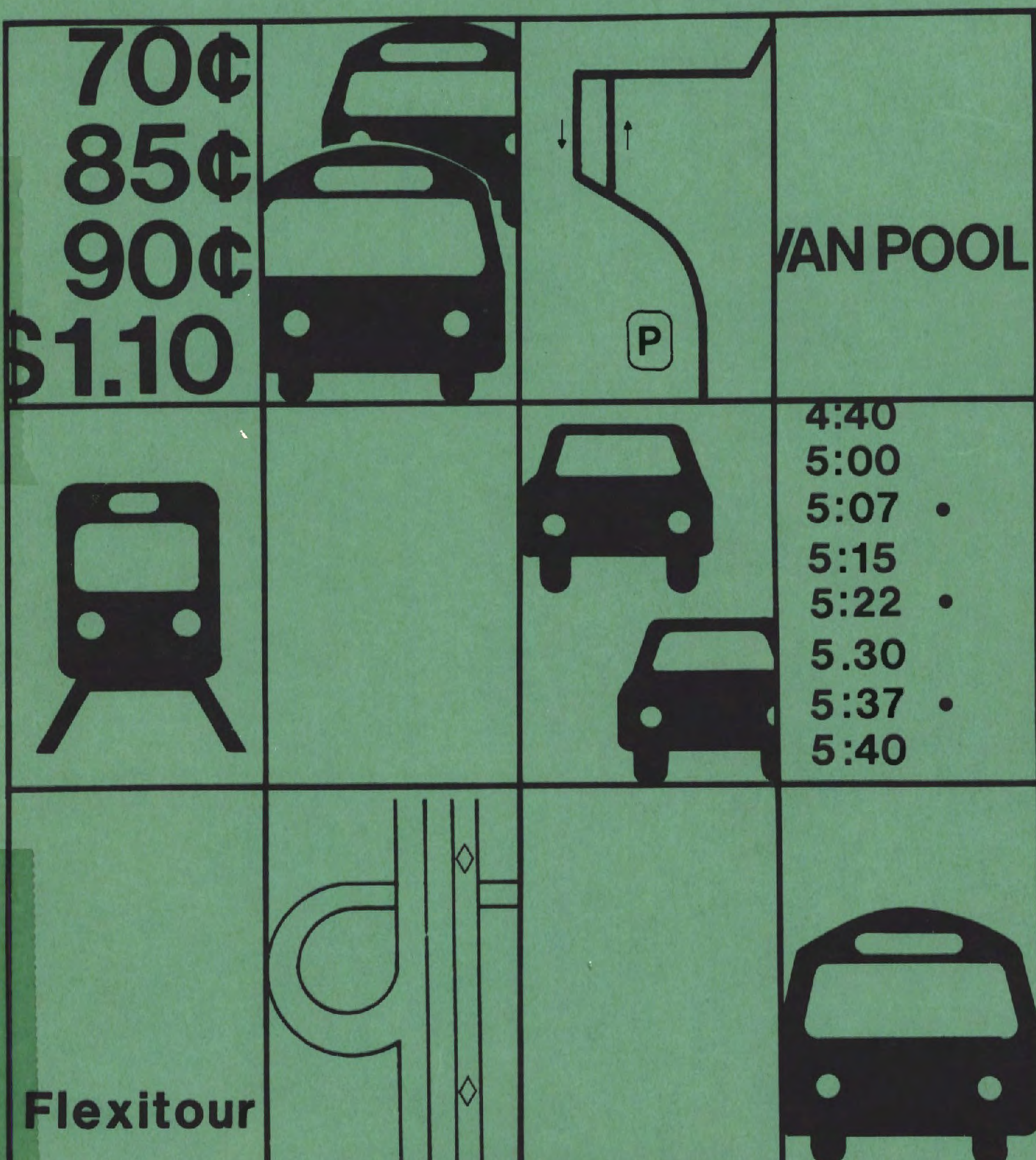
Traveler Response to Transportation System Changes

Second Edition
July, 1981

U.S. Department of Transportation
Federal Highway Administration



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TRAVELER RESPONSE TO TRANSPORTATION SYSTEM CHANGES

SECOND EDITION

Prepared Under Contract

DOT-FH-11-9579

By

Barton-Aschman Associates, Inc.

R.H. Pratt & Co. Division

July 1981

U.S. DEPARTMENT OF TRANSPORTATION

Federal Highway Administration

Office of Highway Planning
Urban Planning Division

ACKNOWLEDGMENTS

This second edition Handbook was prepared at Barton-Aschman Associates, Inc., R.H Pratt & Co. Division, by Richard H. Pratt and John N. Copple for the U.S Department of Transportation, Federal Highway Administration. The authors are particularly grateful for the extensive assistance and suggestions of first and second edition Contract Manager Louise E. Skinner of the Urban Planning Division, Office of Highway Planning, Federal Highway Administration. The authors also wish to acknowledge the continuing use of the contribution of first edition co-authors Neil J. Pedersen and Joseph J. Mather.

Many individuals and organizations developed the original information which has been compiled and interpreted in this Handbook; too many, unfortunately, to acknowledge other than by numerical reference in the text. The authors sincerely appreciate the help of all those persons and organizations who assisted by contributing references, papers, information on reference sources, and special data updates.

The authors of this second edition wish to state that the contents of this Handbook reflect their own views, and they alone are responsible for the facts and accuracy of the material presented. The contents do not necessarily reflect the official views or policy of the Department of Transportation, nor does this Handbook constitute a standard, specification or regulation.

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EXECUTIVE INTRODUCTION

This U.S. Department of Transportation handbook, Traveler Response to Transportation System Changes, is now in its second edition. The purpose of the first edition was to equip members of the transportation profession with a readily accessible, interpretive documentation of how travel demand was being affected by different types of transportation actions. Since the first publication of the Handbook, there has been continued extraordinary growth in emphasis on making more cost effective and energy efficient use of the transportation system through application of Transportation System Management (TSM) options. More than ever, transportation planners, providers and decisionmakers need up to date information on the various results obtained. Accordingly, this second edition of the traveler response handbook builds upon the 1977 edition to provide a contemporary assessment of the experience and insights gained from the application and analysis of various transportation system changes.

A comprehensive, concise digest of the travel behavior findings derived from available literature has been prepared for each of nine transportation system change topic areas chosen for full coverage in this second edition. The topic areas involved are:

- Pool/Bus Priority Facilities
- Variable Work Hours
- Pool/Transit Fringe Parking
- Vanpools/Buspools
- Transit Scheduling/Frequency
- Bus Routing/Coverage
- Express Transit
- Transit Fare Changes
- Transit Marketing/Brokerage

Each topical digest begins with a listing of the types of system change addressed, followed by a "Traveler Response Summary" section, which highlights the traveler response findings for the topic. Next, each digest presents in generalized and example form the nature and sensitivity of reported traveler response to each principal configuration of transportation system change. A discussion of underlying travel behavior mechanisms is provided, along with a sketch of related energy, environmental, social and economic impacts.

To complement each digest, individual papers are reviewed to provide condensed case-specific traveler response information. In addition, the Handbook bibliography covers 16 additional specific system change and research topic areas. Taken together, the 25 topic areas in total are intended to cover the full spectrum of those TSM and capital intensive transportation system changes that directly affect the traveler, plus related areas of investigation.

Chapter I of this Handbook provides a user's guide to its application. Chapter II is comprised of the digests and reviews described above, grouped in nine system change topical summaries. Chapter III consists of an alphabetical bibliography with cross-reference lists covering the 25 types of transportation system change and research areas.

This Handbook is structured for use at several levels of detail. To obtain a quick review of traveler response findings, refer to the first two sections of each digest in Chapter II. For further coverage with respect to a specific transportation system change category, go through the pertinent topical digest. Upon finding relevant information, consult any of the accompanying literature reviews which may apply. For the full breadth and detail of the source material, use the bibliography via the references in the digests or the cross-reference lists to proceed to the appropriate papers, studies, and texts.

CHAPTER I

SCOPE AND USE OF THE HANDBOOK

CHAPTER I

SCOPE AND USE OF THE HANDBOOK

The background, scope and user application of this Traveler Reponse to Transportation System Changes handbook are the subjects of this introductory chapter. The purpose of the Handbook and the approach of the study are briefly reviewed. Then explanations to aid in Handbook use are provided, beginning on page 7. Use of the Chapter II topical digests and reviews is specifically covered on pages 16 through 24. Use of the Chapter III bibliography and cross-reference lists is addressed on pages 25 through 29.

SCOPE OF THE HANDBOOK

Introduction

In February 1977 the U.S. Department of Transportation published the first edition of the Traveler Response to Transportation System Changes handbook. The purpose was to equip members of the transportation profession with a readily accessible, interpretive documentation of the various results obtained across the U.S. and elsewhere from different types of transportation actions. The 1977 Handbook was part of an overall transportation systems and travel demand research effort by the U.S. Department of Transportation. This same effort also included the publication of related handbooks on Characteristics of Urban Transportation Systems (159)[a] and Characteristics of Urban Transportation Demand (356). All three handbooks have received wide distribution and have become standard references in the transportation field.

The first edition of Traveler Response to Transportation System Changes was published at a time of rapid change in the transportation field. Energy and environmental concerns and a shift in emphasis away from capital intensive projects had caused serious consideration of transportation alternatives to increased low occupancy auto usage. In September 1975 the Urban Mass Transportation Administration and the Federal Highway Administration issued a set of joint regulations requiring Transportation System Management (TSM) as part of the planning process in urbanized areas. This action focused on the application of the low capital urban transportation improvements that were the primary focus of the first edition Handbook.

Since the first publication of the Handbook in 1977, there has been continued growth in emphasis on the application of traffic operations improvements, high occupancy vehicle priority techniques, ridesharing, transit service enhancements, variable work hours, and other TSM actions. Shrinking transportation revenues, rising construction costs and energy scarcity have required more effective use of our existing transportation systems. It is safe to say that there has been more experience gained over the past 4 years in the application of those transportation actions now characterized as TSM than in the previous 10 to 20 years.

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[a] The numbers in parentheses throughout the text key to the bibliographic reference listing in Chapter III.

All of these factors underscore the benefit of documenting the response of travelers to the many changes made in our urban transportation systems as the concept of transportation system management has begun to take root. More than ever, transportation planners, providers and decisionmakers need up to date information on how travel demand is affected. Accordingly, this second edition of the traveler response handbook builds upon the 1977 edition to provide a contemporary assessment of the experience and insights gained from the application and analysis of various transportation system changes.

Handbook Objective

The first edition of the Handbook noted the inadequacy of most available travel demand forecasting techniques for projecting traveler response to most transportation options then beginning to receive consideration. Lacking appropriate forecasting tools, it was particularly important that planners at least have reliable information on actual system user response in cases where transportation system and policy changes had been implemented. The state of the art has improved. Nevertheless, travel demand estimation at its best should be used in partnership with first hand experience. Moreover, specific forecasting technique gaps still remain.

Understanding how travelers will respond is essential in designing and evaluating alternative facility, operational, and policy alterations to urban transportation networks and services. Travel projections of the number, characteristics, and vehicular use of travelers for each transportation mode are used to estimate traffic flow and congestion, revenues and costs, travel benefits and disbenefits, economic impacts, energy use, and environmental effects. With improved information, transportation planners can more accurately predict the efficacy of their plans and more effectively formulate responses to transportation needs and policy.

The objective of this second edition Handbook is to update and expand the material in the first edition to provide a comprehensive, accessible consolidation of contemporary experience derived from observation and estimation of traveler responses to transportation system changes. Comprehensive referencing of additional study materials is also provided. This information will aid transportation planners and decision makers by providing insights on transportation results obtained in other communities, and by assisting in the continued improvement of travel demand estimation capabilities.

Study Approach and Scope

The literature search which began the development of this Handbook was designed to identify and obtain bibliographic information on papers and study reports with information on any aspect of traveler response to urban transportation system changes. Although the primary concern was to seek data obtained in actual field studies, significant attention was also given to locating work in which travel demand models or other estimating techniques had been applied so as to give additional insight into potential traveler response.

The literature search for this second edition concentrated on the 1975-1980 period. The major source was a computerized search performed in February 1979 by the Highway Research Information Service (HRIS). In addition, the project staff performed supplementary literature searches and contacted a number of organizations and individuals known to be active in research areas of concern.

With specific exceptions, no documents which came to the attention of the authors after January 1980 were included in the literature compilation. The bibliographic information obtained was categorized and screened. References were selected using criteria such as the timeliness or enduring relevancy of the studies reported on, the degree to which traveler response was measured, the apparent completeness of the work, and the extent of other literature on the same topic or event. Similar criteria were used to choose between retaining and deleting individual references from the first edition Handbook.

A comprehensive but concise digest of the travel behavior findings derived from the literature has been prepared for each of the nine transportation system change topic areas chosen for full coverage in this second edition of the Handbook. The topic areas involved are listed below. Topic areas denoted by an asterisk (*) are updates and expansions of digests from the first edition, and the remainder are new.

Pool/Bus Priority Facilities*
Variable Work Hours*
Pool/Transit Fringe Parking
Vanpools/Buspools*
Transit Scheduling/Frequency*
Bus Routing/Coverage*
Express Transit
Transit Fare Changes*
Transit Marketing/Brokerage*

Each digest distills and interprets the collective observations of the literature reviewed, and presents in generalized and example form the nature and sensitivity of reported traveler response to each principal configuration of transportation system change. The interpretations presented in the digests are the responsibility of the Handbook authors.

Comments are provided to aid the user in assessing the degree of confidence with which the findings presented for each transportation change can be applied to estimate the likely travel demand results. Handbook users should note that the findings presented in each digest are intended only as general guidelines. In practical application, each individual project must be analyzed in terms of the specific site and conditions involved.

To complement each digest, individual papers were selected for preparation of reviews. Each one page review is designed to provide condensed case-specific traveler response information within the context of the system change involved and the data collection and evaluation procedures originally employed. The intent has been to present the original author's descriptions, findings, and interpretations without substantive alteration. The Handbook authors accept full responsibility for the condensation results.

The Handbook bibliography covers 16 additional topic areas. The first 10 are specific system change topics, while the last six delineate related areas of research. Topic areas denoted by a plus sign (+) were subjects for digests and associated reviews which are available in the first edition Handbook (510).

The 16 additional topic areas are:

New Highway Facilities
New Transit Facilities/Equipment
Traffic Operations Improvements
Pedestrian/Bikeway Facilities
Carpooling Encouragement Activities+
Area Auto Restraints+
Auto Facility Pricing+
Auto Facility Supply
Collection/Distribution Transit
Flexible Paratransit
Research Techniques
Travel Demand Modeling
Consumer Preference Analysis
Time/Cost Modeling
Convenience/Comfort/Reliability Analysis
Safety Analysis

Taken together, the 25 topic areas in total are intended to cover the full spectrum of those TSM and capital intensive transportation system changes that directly affect the traveler, plus related areas of research.

USE OF THE HANDBOOK

Handbook Organization

This Handbook is designed and organized to provide:

- Condensed state-of-the-art information on how travelers respond to different types of transportation system changes.
- Sources of additional information on the same subject.

The remainder of this chapter is devoted to instructive material offered to enhance use of the Handbook. Chapter II is comprised of nine topical summaries, each addressing one general type of transportation system change. Each topical summary provides a digest, with references, of information and interpretation relative to how travelers respond to the system change under discussion. Accompanying each digest are the selected reviews of case study literature on the same topic. Chapter III is a cross-referenced bibliography of pertinent articles and reports. Twenty-five system change topics are identified in the bibliography, including the nine for which topical summaries are provided in Chapter II.

The bibliographic references of Chapter III are listed in alphabetical order by author and are numbered sequentially. Topical keywords, one for each of the 25 system change topic areas, are used for cross-referencing and to link the papers listed to the various topical areas and the summaries of Chapter II. Secondary sets of keywords describing the nature of study data sources and the nature of traveler responses examined are used for additional cross-referencing and description of literature content.

Topical Classification System

The transportation system change classification structure of this Handbook encompasses 25 system change topics, each assigned to one of five broad system change categories. Each system change category describes a different purpose for undertaking a change in the transportation system. Topics are grouped within categories based on the type of system change involved. For example, the topic "Variable Work Hours" is placed within the category "Actions to Ensure the Efficient Use of Existing Road Space," while the topic "Pool/Transit Fringe Parking" is placed within the category "Actions to Reduce Vehicle Use in Congested Areas."

The headings of the 25 system change topics form the topical keywords, nine of which uniquely identify the summaries of Chapter II, and all of which are used in the bibliography of Chapter III for cross-classification and as literature theme descriptors. The five system change categories are not translated into keywords or used in the bibliography. They simply serve to order the system change topics.

Table I (page 10) presents an outline of the overall classification system. The system is deliberately designed to conform, to the extent possible, with the taxonomy of Transportation System Management actions published by the U.S. Department of

Transportation as advisory information in connection with regulations governing the urban transportation planning process.[a] Two categories have been added to the U.S. DOT classification system:

- Class (I), Actions to Add Transportation System Elements, which contains topics pertaining primarily to capital intensive transportation system facility additions (or deletions), and

- Class (V), Traveler Response Research, which includes topics covering methodologies employed in traveler response evaluation and forecasting, along with findings derived in generalized (non-system change specific) research on traveler responses.

The U.S. DOT category "Actions to Increase Transit Internal Management Efficiency" has been omitted for lack of relevancy to the subject of this Handbook.

Tables 2 through 6 (pages 11 - 15) provide annotated outlines of each system change category and its subordinate topics. Not all possible topics within each category have been developed; only those needed to encompass the full scope of the second edition Handbook. All of the developed topics have been expanded and modified to conform with the current literature. Parenthetical notes are included in each table to explain the major adaptations vis-a-vis the U.S. DOT classification system.

The Federal Highway Administration and the Urban Mass Transportation Administration have published revised rules to streamline the planning and project development process and clarify TSM. Emphasis is placed on both the short-range and long-range aspects of TSM with a list of tactics included to illustrate these types of actions. This list differs from that in the 1975 regulations. However, the classification system in this second edition remains in conformance with the 1975 regulations. This enables the second edition to be consistent with the first edition and to draw on a taxonomy of actions into which the references in both editions logically fall.

<u>Handbook Application</u>

Applying the material in any handbook which attempts to provide useful generalizations and examples must be done with care, and this Handbook provides no exception. The subject at hand is particularly complicated by the many confounding factors which may influence traveler response, and by the diversity of urban environments served by transportation. Some of these considerations are expanded upon in the next section "Use of the Topical Digests and Reviews," under the headings "State-of-the-Art Implications," "Impact Measurement Considerations," and "Demographic Considerations."

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a/ Federal Register, Volume 40, Number 181, Wednesday, September 17, 1975, pages 42978-42979.

Transportation planners and decisionmakers can use the information in this Handbook as a starting point to consider and evaluate transportation alternatives. Any specific situation must be examined in terms of the particular urban form, population, travel patterns, and transportation systems involved. No transportation system change can properly be considered in isolation from these factors.

This Handbook is primarily structured to point the reader to more detailed studies and texts. Given a specific transportation and travel demand question, start with the pertinent topical digests. Upon finding relevant information, consult any of the accompanying literature reviews which may apply. Proceed from there or directly from the topical digests to the appropriate reference papers, studies, and texts, as only they can provide the breadth and detail of the original work. Finally, study the question at hand within its own particular context and unique environment.

TABLE I. SYSTEM CHANGE CLASSIFICATION SYSTEM OUTLINE

I Actions to Add Transportation System Elements

- New Highway Facilities
- New Transit Facilities/Equipment

II Actions to Ensure the Efficient Use of Existing Road Space

- Traffic Operations Improvements
- Pool/Bus Priority Facilities*
- Pedestrian/Bikeway Facilities
- Variable Work Hours*

III Actions to Reduce Vehicle Use in Congested Areas

- Pool/Transit Fringe Parking**
- Carpooling Encouragement Activities+
- Vanpools/Buspools*
- Area Auto Restraints+
- Auto Facility Pricing+
- Auto Facility Supply

IV Actions to Improve Transit Service

- Collection/Distribution Transit
- Transit Scheduling/Frequency*
- Bus Routing/Coverage*
- Express Transit**
- Flexible Paratransit
- Transit Fare Changes*
- Transit Marketing/Brokerage*

V Traveler Response Research

- Research Techniques
- Travel Demand Modeling
- Consumer Preference Analysis
- Time/Cost Modeling
- Convenience/Comfort/Reliability Analysis
- Safety Analysis

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* Digest and reviews updated and expanded for the second edition and contained in Chapter II.

** Digest and reviews newly prepared for the second edition and contained in Chapter II.

\+ Digest and reviews contained in the first edition Handbook only.

TABLE 2. CATEGORY: ACTIONS TO ADD TRANSPORTATION SYSTEM ELEMENTS

This category includes those transportation system changes accomplished by opening significant new highway or transit facilities or prompted by introduction of new types of traveled ways or vehicles which significantly alter the urban transportation operating environment or market structure.

- New Highway Facilities

  Encompasses introduction of new highways and modification of existing highway facilities, including the opening of freeways, expressways, and major arterial connecting links. Also covers those traffic management changes and transit scheduling or routing alterations necessitated by new highways and highway modifications.

- New Transit Facilities/Equipment

  Includes introduction of new transit facilities and equipment, and facility modifications or additions, which significantly alter the transit operating environment or market structure. Covers station changes and new fixed guideway facilities.

(The principal orientation of the U.S. DOT classification system[1/] is to transportation systems management: the coordination of system elements through operating, regulatory, and service policies. This category of actions expands on the U.S. DOT classification by focusing on new construction and other significant alterations of transportation system facilities. The two topics employed here simply distinguish between highway and transit systems).

1/ Federal Register, Volume 40, Number 181, Wednesday, September 17, 1975, pages 42978-42979.

TABLE 3. CATEGORY: ACTIONS TO ENSURE THE EFFICIENT USE OF EXISTING ROAD SPACE

This category contains system changes designed to improve the person carrying capacity and environment of existing roadways. Improved designs initiated in connection with new facilities and improvements to transit services are not included:

- Traffic Operations Improvements

  Covers roadway and intersection operational improvements designed to better manage and control the flow of vehicular traffic, such as traffic channelization, one-way streets, better signalization, progressive signal timing, computerized traffic control, metered freeway access, and reversible lanes for mixed traffic. (Because of the mass of traffic engineering literature on traffic operations improvements, this Handbook emphasizes reference to pertinent general texts and handbooks.)

- Pool/Bus Priority Facilities[1/]

  Covers those preferential treatments for transit and other high-occupancy vehicles involving use of priority facilities. Embraces freeway and arterial lanes, freeway access/egress ramps, individual lanes on multi-lane ramps, and congestion and toll-plaza bypasses designated for exclusive use of buses and/or other high-occupancy vehicles with the objective of increasing person throughput on existing facilities.

- Pedestrian/Bikeway Facilities

  Covers elevated and subterranean pedestrian walkway systems, pedestrian malls, and other means of separating vehicles and pedestrians. Encompasses bicycle paths and lanes, secure and convenient storage areas for bicycles, and other bicycle facilitation measures. (The automobile exclusion aspects of street coversion to pedestrian or transit malls are covered in the topic "Area Auto Restraints.")

- Variable Work Hours[1/]

  Covers work schedule variations intended to reduce or spread over a larger time interval the peak period travel, thereby evening out the load on transportation facilities and transit services. Includes flexible and staggered work hours, and the compressed work week.

(The U.S. DOT classification[2/] includes in this category reduced off-peak transit fares and facility tolls, and parking management and control. The available literature considers reduced off-peak fares as one element of transit fare policy and this Handbook thus places such measures among actions to improve transit service. Similarly, toll differentials are considered as auto facility pricing changes while parking management and control policies are considered as auto facility pricing or supply changes or carpool/transit fringe parking measures; all of these are placed among actions to reduce vehicle use in congested areas.)

1/ Digest and reviews updated and expanded for the second edition and contained in Chapter II.

2/ Federal Register, op. cit.

TABLE 4. CATEGORY: ACTIONS TO REDUCE VEHICLE USE IN CONGESTED AREAS

This category covers policies intended to reduce private automobile use in congested areas. Included are programs to encourage fringe area change of mode and overall use of high occupancy vehicles, along with actions to discourage congested area auto use.

- Pool/Transit Fringe Parking[1/]

  Encompasses the provision, management, and control of change-of-mode parking facilities facilitating transfer to transit and other high occupancy vehicles in fringe areas, along major transportation corridors, and also peripheral to the CBD. (The management and control of other types of parking facilities are covered in the topics "Auto Facility Pricing" and "Auto Facility Supply.")

- Carpooling Encouragement Activities[2/]

  Embraces policies designed to enhance carpool formation, such as carpool locator systems, promotional campaigns, cost incentives, priority parking, and other preferential treatments exclusive of reserved traffic lanes. Priority carpool lanes are considered in connection with actions to ensure the efficient use of existing road space.

- Vanpools/Buspools[3/]

  Includes employer sponsored, third party and owner-operator vanpooling along with contract bus services. Distinguished from carpooling actions by the greater degree of management and institutional involvement required along with the use of larger vehicles and regularly assigned drivers.

- Area Auto Restraints[2/]

  Encompasses the diversion, exclusion, licensing, and metering of all or selected types of auto and truck access to specific areas or streets. Includes Transportation Control Plans, which typically involve many types of system changes, because of their area-wide application and impact.

- Auto Facility Pricing[2/]

  Includes commuter tolls, charges, or surcharges including those instituted as congestion pricing measures and applied to downtown parking, downtown access routes, bridges, and tunnels. Also covers gasoline taxes, surcharges, and price increases.

- Auto Facility Supply

  Includes programs and involuntary circumstances of nonmonetary supply restrictions on parking facilities, gasoline, and automobile availability. Does not include restraints or charges levied on automobile use; these are considered to be area auto restraint or auto facility pricing measures.

(The U.S. DOT classification[4/] contains fewer topics than are presented here, however there are no essential differences. Some topic elements were split into independent topics as the category was expanded and refined.)

1/ Digest and reviews newly prepared for the second edition and contained in Chapter II.

2/ Digest and Reviews contained in the first edition Handbook only.

3/ Digest and reviews updated and expanded for the second edition and contained in Chapter II.

4/ Federal Register, op. cit.

TABLE 5. CATEGORY: ACTIONS TO IMPROVE TRANSIT SERVICE

This category class covers policies and actions designed to improve public transit and paratransit, either through improvements in existing services or the creation of new services. However, physical improvements or additions which significantly alter the transportation system are considered in the category "Actions to Add Transportation System Elements."

- Collection/Distribution Transit

  Includes transit and paratransit collection, distribution, and internal circulation services, feeder services, and shuttle services.

- Transit Scheduling/Frequency[1/]

  Covers conventional transit scheduling changes including changes in the frequency of service and measures for providing greater flexibility and responsiveness in scheduling.

- Bus Routing/Coverage[1/]

  Covers conventional transit routing alterations and measures for providing greater responsiveness to travel patterns in bus routing. Covers system expansion or retrenchment increasing or decreasing coverage, including new bus systems and transit closures.

- Express Transit[2/]

  Encompasses express bus and rail transit services and their coordination with local service collection and distribution systems. Includes express service from fringe park-and-ride lots.

- Flexible Paratransit

  Covers jitney, shared-ride taxi, and other flexible paratransit services, including their use in serving the handicapped and elderly. Addresses the integration of paratransit with conventional transit operations, but excludes use of paratransit in feeder services (covered in the topic "Collection/Distribution Transit").

- Transit Fare Changes[1/]

  Embraces transit fare increases and decreases, fare system modifications, simplified fare collection procedures (e.g., exact fares, but not including prepaid fare sales), free transit, off-peak fare reductions, and preferential fares for the handicapped and the elderly.

- Transit Marketing/Brokerage[1/]

  Includes transit promotional and informational campaigns, selling of service including prepaid fares, combined service information and paratransit and ridesharing facilitation programs (brokerage), and multimodal systems such as would evolve from brokerage activities.

(In this category the topic "Collection/Distribution Transit" is not limited to low density areas and includes the subject of CBD circulation services. The topic "Express Transit" combines the two topics in the U.S. DOT classification[3/] dealing with express and local service integration and fringe park-and-ride lot express service.)

1/ Digest and reviews updated and expanded for the second edition and contained in Chapter II.

2/ Digest and reviews newly prepared for the second edition and contained in Chapter II.

3/ Federal Register, op. cit.

TABLE 6. CATEGORY: TRAVELER RESPONSE RESEARCH

This final classification performs two special functions. First, it encompasses discussions of current research and analysis techniques used in evaluating and in forecasting traveler response to transportation system changes. These discussions aid in understanding the methodologies underlying findings reported in this Handbook, and are of value in designing future investigations. Second, it covers analysis of generic travel attributes, including extrapolations and mathematical models of observed traveler responses to changes in transportation system supply characteristics such as travel time, cost, convenience, and safety. The findings of such analyses provide insight into the reasons behind traveler response to specific changes, most of which can be broken down into changes in generic attributes.

- Research Techniques

  Covers traveler response research techniques, including study design, sampling, questionnaire format, and evaluation methods used to examine traveler preferences and behavior. Includes also related analysis techniques of special interest.

- Travel Demand Modeling

  Addresses the modeling methods typically used to explain and forecast travel demand given changed transportation systems. Concentrates on modeling based on aggregate or disaggregate travel survey data, as contrasted to data on the preference and perception of individuals. (Since this is a supplemental topic for this Handbook, emphasis is placed on reference to pertinent compendiums and reviews.)

- Consumer Preference Analysis

  Encompasses both the methodologies of consumer preference analysis and available findings of studies designed to isolate and identify traveler preferences for attributes of transportation service. (As with "Travel Demand Modeling," emphasis with respect to methodological questions is placed on pertinent reviews.)

- Time/Cost Modeling

  Covers changes and differences in the travel time and user cost attributes of travel modes.

- Convenience/Comfort/Reliability Analyses

  Covers changes and differences in the travel convenience, comfort, and reliability of travel modes as they relate to traveler decisionmaking.

- Safety Analysis

  Covers changes and differences in safety from crime and accidents involved in the use of travel modes.

(This category is a special purpose addition to the U.S. DOT classification.[1/])

1/ Federal Register, op. cit.

USE OF THE TOPICAL DIGESTS AND REVIEWS

Digest and Review Format

Summaries for each of the 9 topics chosen for review in this second edition Handbook are presented in Chapter II. Each topical summary is comprised of two principal parts:

1. A state-of-the-art digest, with an appended listing of reference numbers.

2. Reviews of pertinent studies.

Together, these components provide a compilation of current knowledge concerning traveler response to the transportation system change in question, sources of further information, and condensations of some noteworthy case studies.

Each digest begins with a listing of the implemented or implementable types of system change included, followed by a "Traveler Response Summary" section which highlights the traveler response findings for the topic. The user can obtain an overview of Chapter II by reading the first two sections of each digest.

The "Traveler Response Summary" of each digest is followed by a survey of observed or estimated traveler responses, a discussion of underlying travel behavior mechanisms, and a sketch of related energy, environmental, social and economic impacts. Other related subject areas pertinent to the particular system change topic are included.

Each digest concludes with a listing of reference numbers which identify the literature addressing the system change topic under scrutiny. In addition, reference numbers within the digest identify the source of data presented and/or literature which expands upon the immediate topic of discussion. Reference numbers followed by an asterisk (*) indicate that a review of the referenced literature is provided within the same topical summary, following the digest. Reference numbers followed by a number sign (#) indicate that a review is provided elsewhere in Chapter II, under another topic heading. Referral to the Chapter III bibliography is required to locate such reviews. Reference numbers followed by a plus sign (+) indicate that a review was provided in the first edition Handbook, but not in this second edition.

The reviews provide one page condensations of relevant papers and reports. They are designed primarily to present case-specific traveler response information, necessarily within the context of the operating system studied and the data collection and evaluation techniques employed by the authoring organization or individual. In structuring the reviews, the intent was to include a description of the system change involved, some indication of the analysis methodology employed, and a highlighting of the principal findings along with related useful information. Table 7 illustrates the general format of each topical summary and its relationship to the general TSM classification system using "Pool/Transit Fringe Parking" as an example.

State-of-the-Art Implications

The confidence which can be placed in the generalizations drawn in the digest concerning impacts of transportation system changes varies among the types of change

Table 7
Topical Summary Format Example

Format	Example
Transportation System Management Category	Actions to Reduce Vehicle Use in Congested Areas
Transportation System Management Topic	Pool/Transit Fringe Parking
Digest	
Types of Programs	Rail Service Fringe Parking Bus Service Fringe Parking Carpool Fringe Parking Peripheral Parking
Traveler Response Summary	Overview of traveler response to programs
Survey of Responses; Discussion of Underlying Behavioral Factors; Related Energy, Environmental, Social and Economic Impacts	Program Objectives Response to Rail Service Fringe Parking Response to Bus Service Fringe Parking Locational and Service Impacts on Fringe Parking Response to Carpool Fringe Parking Response to Peripheral Parking Travel Time and Cost Impacts on Peripheral Parking Underlying Traveler Response Mechanisms Facility Access and Market Shed Prior Mode of Fringe Parkers Impacts on Transit and Carpooling Use Impacts on Volumes, VMT, Energy and Environment Impacts on Bus System Costs
Additional References	One reference highlighted 69 references listed
Article Reviews	Five references reviewed

involved. The appropriate degree of confidence necessarily depends on the number of documented observations of a certain type of change, the confounding factors which may have affected the reported results, the extent to which impacts have been successfully modeled, and the consistency with which findings were obtained and reported. Some transportation system changes examined here have had only limited application, or have been very infrequently subjected to systematic analysis, so that it is difficult to generalize to universal experience. In other instances, confounding factors or unique situations have influenced the results. Even where it has been possible to draw upon and compare numerous study findings, the validity of the inferences drawn is still dependent upon the quality of the data and analysis methods originally employed in deriving the reported conclusions.

Table 8 has been prepared to provide an indication of the confidence with which the authors feel the traveler response findings and related conclusions in this Handbook can be used. In this table the authors' confidence ratings are given with respect to each type of transportation system change addressed. The rating scale is as follows:

A = Strong empirical evidence and theoretical basis exist to support the validity and widespread applicability of the conclusions drawn.

B = Empirical evidence and theoretical basis exist to support the validity and general applicability of the conclusions drawn, but a degree of uncertainty remains.

C = Examples exist to support the conclusions drawn, but their general applicability is largely undemonstrated, or other significant uncertainties remain.

D = Little hard data exists; any conclusions offered are drawn primarily by inference or from very limited experience or theoretical studies.

In general, findings and conclusions provided with respect to impacts on vehicle miles of travel (VMT), energy and environment are relatively more dependent on estimations and modeling applications than the associated traveler response conclusions.

Impact Measurement Considerations

The available observations of traveler response to transportation system changes are typically provided by user surveys, or by before-and-after counts of volume, passengers, or revenue. The analyst who evaluates system change impacts, in addition to exercising normal concern regarding survey or count procedures, must be especially cautious when interpreting results that may have been affected by confounding events or unique circumstances. Such events or circumstances may adversely affect the transferability of results from one location or time period to another (641). For example, two periods of fuel shortage occurred during the 1970's, in 1973-74 and in 1979. The observed traveler responses to ridesharing and transit programs instituted concurrently with these fuel shortages may not be fully applicable to times of normal gasoline supply. In the same way, unique circumstances in a particular city may influence system change results in an atypical manner. For example, it has proven difficult to duplicate the original success of short-haul buspools in Peoria, Illinois, where the employees of a single industrial plant are unusually concentrated in their residential locations.

TABLE 8. CONFIDENCE RATINGS OF TRAVELER RESPONSE CONCLUSIONS

(See text for rating scale definition)

POOL/BUS PRIORITY FACILITIES	
Separate Priority Vehicle Roadways	B
Contra-Flow Freeway Priority Lanes	B
With-Flow Freeway Priority Lanes	C
Priority Freeway and Tollway Entry	B
Arterial Priority Lanes	C
VARIABLE WORK HOURS	
Staggered Work Hours	B
Flexible Work Hours	B
Compressed Work Week	C
POOL/TRANSIT FRINGE PARKING	
Rail Service Fringe Parking	B
Bus Service Fringe Parking	B
Carpool Fringe Parking	C
Peripheral Parking	C
VANPOOLS/BUSPOOLS	
Employer Sponsored Vanpool Programs	B
Third Party Vanpool Programs	C
Owner-Operated Vanpools	D
Short-Haul Industry-Oriented Buspools	B
Short-Haul CBD-Oriented Buspools	B
Long-Haul Commuter Buspools	B
TRANSIT SCHEDULING/FREQUENCY	
Bus Frequency Changes	A
Train Frequency Changes	B
Schedule Regularization	D
Schedule Reliability	D
Frequency Changes With Fare Changes	C
BUS ROUTING/COVERAGE	
Comprehensive Changes	B
New Transit Systems	C
New Coverage	B
Special Routes	B
Service Restructuring	D
Crosstown Routes	C
EXPRESS TRANSIT	
Priority Roadway Service	B
Priority Lane Service on Freeways	B
Mixed Traffic Service on Freeways	B
Priority Lane Service on Surface Streets	C
Mixed Traffic Service on Surface Streets	C
Reverse Commute Service	C
TRANSIT FARE CHANGES	
Fare Increases	A
Fare Reductions	B
Free Transit	C
Off Peak Fares	C
Senior Citizen Fares	B
Paratransit Fares	D
Fare Changes With Service Changes	B
TRANSIT MARKETING/BROKERAGE	
Marketing of Service Changes	D
Information Campaigns	C
Advertising Campaigns	C
Fare Promotions	C
Fare Prepayment	C
Paratransit Service Marketing	D
Transportation Brokerage Programs	C

Frequently, a particular system change is linked with other simultaneous changes which affect the results. For example transit fare reductions have often been accompanied by promotional campaigns and increases in transit service frequency and coverage. Under such circumstances it is difficult to separate the impact attributable to each of the individual system changes involved.

Some of the traveler response conclusions presented in this Handbook are based wholly or in part on traveler response forecasts as contrasted to observed results. Those forecasts deemed worthy of inclusion are derived from travel demand models sometimes based on attitudinal data but more frequently based on cross-sectional survey data from a single point in time. Use of such survey data relies on the assumption that impacts over time of transportation system changes can be inferred from the response at a single point in time to differing system characteristics as observed in different locations in an urban area. This is an assumption that has neither been satisfactorily proven nor disproven (384).

Attention must be paid to the effect of inflation whenever traveler response has been the result of user cost changes, such as transit fare, highway toll, and parking fee modifications. The effect of inflation is pertinent whether traveler responses are observed or estimated.[a/] Absolute changes in user charges should be interpreted in constant dollars. By describing user cost changes in terms of relative change, the more severe of the analytical problems introduced by inflation can be largely avoided. The concept of elasticity, discussed further on, is particularly useful in this regard.

Demographic Considerations

Although the focus of this Handbook is on traveler response to transportation system changes, it is important to recognize that a number of factors external to the transportation system are also crucial determinants of travel behavior. Among these factors, the most important are land use and density, income, and auto ownership. The location and concentration of residences, employment, commercial activity, recreational areas, and other land uses are primary determinants of the number, purpose, and orientation of trips in an urban area (the trip generation and distribution). Lower worker or family income and lower auto ownership are associated with lower than average trip generation rates and higher than average transit usage (251, 567, 577).

The concept of "captivity" is sometimes used to help explain the impact of low incomes and low auto ownership on mode choice. A traveler is considered to be a "captive" of a particular mode if he or she effectively has no alternative means of transportation. Captive transit riders are those who have no automobile available for their trip, and must therefore use transit or forego the trip. System changes designed to attract more transit riders are directed toward "choice" riders; people whose auto availability allows them to choose freely between transit and auto (149).

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a/ When using travel demand models, it must be presumed unless otherwise stated that the cost expressed in the model pertains to the value of the dollar in the year of the survey upon which the model was based.

At the other end of the scale are captive auto users, those trip makers who for some reason must use an automobile. A traveler may be an auto captive because of need for the car at work, because a side trip requiring an auto is to be made, or for other reasons not necessarily well understood. The auto captive is not expected to be attracted by transit service enhancements and may be deterred from ridesharing.

The concept of captivity suffers from some theoretical and practical difficulties. One problem is that it fails to adequately address the mode choice option of traveling as an auto passenger. Another concern is that the condition of captivity, being highly related to auto ownership, is often a matter of choice. Nevertheless, captivity is sometimes referred to in this Handbook, because it is a familiar term and is used in certain Handbook references.

An advancement over the concept of captivity is the idea of distinguishing between "mobility choices" and "travel choices." If a person does not have a particular mode available for a trip, it is usually because of long-term mobility choices which were made in the past. Mobility choices include the choice of residential location (including proximity to transit service), number of automobiles owned, and employment location. The usual mode for the work trip can even be thought of as a mobility choice, as it affects auto availability for other travel.

Short-term travel choices cover the day-to-day decisions concerning trip frequency, distribution, time of day, mode, and route. In this framework, travel choices are always made in the context of longer-term mobility choices (641). The concept is particularly relevant to examining traveler responses to transportation system changes, because it recognizes not only the short-term impacts of changed travel options, but also the longer-term impacts related to residential location, workplace location, and auto ownership.

Concept of Elasticity

Elasticity measures provide a convenient tool for summarizing quantitative information about overall travel demand changes in response to certain types of system changes and are used extensively in this Handbook. For elasticity measures to be applicable, the transportation system change must be a relative one. In other words, it must involve a quantifiable percentage increase or decrease in the system parameter involved. There are a number of elasticities of interest with respect to demand for transportation, including elasticities for changes in the overall amount of transit service, transit frequencies, transit fares, vehicular tolls, parking charges, and gasoline costs (322).

Transportation elasticities are informally adopted from the economist's measure "price elasticity." Loosely speaking, price or service elasticity may be defined as the percentage change in the quantity of a commodity or service demanded by the public in response to a one percent change in price or service. For example, if transit service is measured by the number of bus miles operated, the transit service elasticity indicates the percentage change in patronage observed or expected in response to a one percent change in the number of bus miles. If the transit service elasticity is +0.6, a six-tenths-of-one percent patronage increase is indicated for each one percent increase in service.[b/]

There are several different methods for computing elasticity. An expanded discussion of these methods and their application, along with comparative examples and illustrations, is provided in Appendix A.

Two of the most frequently used forms of elasticity in transportation analyses are arc elasticity and the shrinkage factor. Arc elasticity is defined by a logarithmic formulation and, except for very large changes in price or service (P) and demand (Q), is closely approximated by a mid-point formulation which makes use of the average value of each independent variable (71, 384).

log arc elasticity:

$$\eta = \frac{\Delta \log Q}{\Delta \log P} = \frac{\log Q_2 - \log Q_1}{\log P_2 - \log P_1}$$

mid-point arc elasticity:

$$\eta = \frac{\Delta Q}{(Q_1 + Q_2)/2} \div \frac{\Delta P}{(P_1 + P_2)/2} = \frac{\Delta Q(P_1 + P_2)}{\Delta P(Q_1 + Q_2)} = \frac{(Q_2 - Q_1)(P_1 + P_2)}{(P_2 - P_1)(Q_1 + Q_2)}$$

where η is the elasticity, Q_1 and Q_2 are the demand before and after, and P_1 and P_2 are the price or service before and after.

Arc elasticity is based on both the original and final values of demand and price or service. The logarithmic formulation has been used whenever elasticities have been calculated directly from available data in this second edition Handbook. Similar values carried over from the first edition Handbook were computed using the midpoint formulation.

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b/ A negative sign used with an elasticity value simply indicates that the cause and the effect operate in opposite directions. Fare elasticities are almost always negative: when the fare goes up, patronage normally goes down, and vica versa.

The shrinkage factor or shrinkage ratio has historically been used in reporting response to transportation system change. It is defined as the change in demand relative to the original demand divided by the change in price relative to the original price, or in mathematical terms:

$$\eta = \frac{\Delta Q/Q_1}{\Delta P/P_1} = \frac{(Q_2 - Q_1)/Q_1}{(P_2 - P_1)/P_1}$$

There are certain conceptual problems with shrinkage factors (discussed in more detail in Appendix A) which have led to the predominant use of arc elasticities (or closely comparable point elasticities) in this Handbook. Shrinkage factors that are in common use are reported, but arc elasticity conversions are given where possible.[c/] Figure 1 illustrates the differences between the two arc elasticity formulations and the shrinkage factor using transit fare elasticity as an example.

[c/] Note that arc elasticities, being formulated differently, are not applied exactly the same as shrinkage factors. Formulae to apply arc elasticities are given in Appendix A.

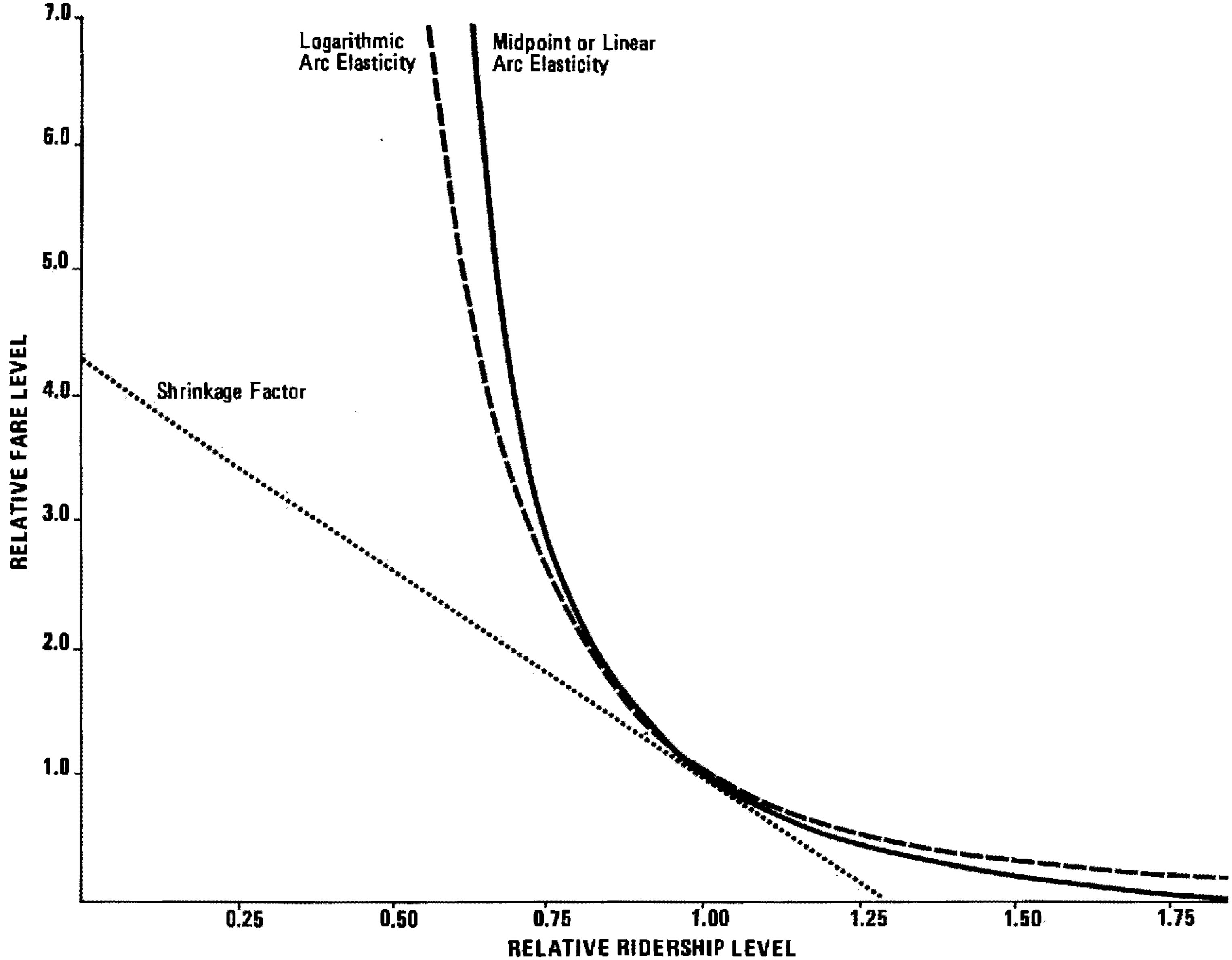

Figure 1
Elasticity of Demand Curves Based on Initial Point Elasticity of −0.30
(384)

USE OF THE BIBLIOGRAPHY AND CROSS-REFERENCE LISTS

Cross-Reference Lists

The bibliography is arranged in alphabetical order by author. Within each bibliographic reference, keywords are provided to indicate the type and nature of the subject matter. These keywords are described in detail in the next section, "Reference Format." Two of the keyword sets are used as the basis for bibliographic cross-reference lists provided in advance of the alphabetical bibliography. Together the cross-reference lists and bibliography comprise Chapter III.

The two cross-reference lists are arranged, respectively, by transportation system change topics and by traveler response categories. Each cross-reference list consists of the applicable keywords, arranged in alphabetical order, each followed by the corresponding reference sequence numbers. If a reference listing in the alphabetical bibliography contains a certain system change or traveler response keyword, the reference sequence number is listed under that keyword in the appropriate cross-reference list.

The system change topic cross-reference list is provided first. All 25 transportation system change topics are included, not just the 9 selected for preparation of the summaries (digests and reviews) in Chapter II. Among the reference numbers listed under each topic, those followed by an asterisk (*) denote papers for which reviews are provided in Chapter II under the corresponding topic heading. Number signs (#) also indicate that a review is provided, but not under the topic heading corresponding to the particular keyword in question. In such cases, the reference entry in the alphabetical bibliography should be consulted to determine the primary topic of the work; the review is under that topic heading. References followed by a plus sign (+) were reviewed in the first edition of this handbook (510), but are not included as reviews in this second edition.

The traveler response category cross-reference list is second. A number sign (#) by a reference number in this list merely indicates that a review of the corresponding paper is provided somewhere in Chapter II. Since the traveler response categories are not used as topic headings, the reference entry in the alphabetical bibliography must in all cases be consulted to determine the topic heading under which the review is found.

Reference Format

Each reference within the alphabetical bibliography includes the following elements, if available and pertinent to the referenced work:

1. Reference Sequence Number
2. Author
3. Title
4. Author's Parent or Supporting Organization
5. Sponsoring or Receiving Organization
6. Name of Publication
7. Date
8. Pages

9. NTIS Number or GPO Stock Number
10. Transportation System Change Topics
11. Type of Data Source
12. Traveler Response Investigated
13. Related Impacts Discussed

An example reference is given below:

77. Boyce, David E. Impact of a Suburban Rapid Transit Line on Fuel Consumption and Cost for the Journey-to-Work (Analysis of the Philadelphia-Lindenwold High-Speed Line). Regional Science Department, University of Pennsylvania, Philadelphia, PA. Prepared for the Federal Energy Adminstration. Contract Number 14-01-0001-1700. December 1975. 68 pages. NTIS PB 263-048. POOL/TRANSIT FRINGE PARKING, NEW TRANSIT FACILITIES/ EQUIPMENT. OBSERVED RESPONSE. MODE CHOICE, VOLUME. ENERGY.

Reference elements 1 through 8 provide identification; element 9 addresses availability, and elements 10 through 13 supply keyword description of the subject matter. A description and explanation of each bibliographic reference element follows:

1. Reference Sequence Number. References are listed in ascending alphabetical order and numbered sequentially. Literature cited in the Chapter II summaries and in the Chapter III cross-reference listings is referred to by bibliographic reference sequence number.

2. Author. The authors are listed following the reference sequence number. Last-name-first arrangement is used for the first-listed author if the author is a person. The first listed author is the basis for alphabetization. If the desired reference is not immediately encountered, it is suggested that alternate author designation and alphabetization possibilities be explored. An author's parent organization, where appropriate, is noted after the publication's title.

3. Title. The title of the paper is given except when all papers in a collection are meant to be referenced. In that case, the title of the work is given with the editor, sponsoring conference, or sponsoring agency indicated as the author. For example:

   269. Highway Research Board. Demand Responsive Transportation. Proceedings of the Fourth Annual International Conference on Demand Responsive Transportation Systems, held October 3-5, 1973 at Rochester, New York. Transportation Research Board, Washington, D.C.; Special Report No. 147. 1974. 91 pages. FLEXIBLE PARATRANSIT. OBSERVED RESPONSE, FORECAST RESPONSE, BACKGROUND INFORMATION. VOLUME.

4. Author's Parent or Supporting Organization. Organizations which have supported the preparation of the referenced paper, such as the author's employer, but are not contributing authors, are listed immediately following the paper's title. Report document and/or series numbers are separated from the parent or supporting organization by a semicolon.

5. Sponsoring or Receiving Organization. Sponsoring or receiving organizations which are not directly involved in the paper's preparation are listed next, preceded by the phrase "Prepared for", "Sponsored by", or "Presented to", as appropriate. Series, grant, or contract numbers, when available, follow the sponsoring or receiving organization. References published by the Transportation Research Board are listed as such, whether or not they were published after the organization's name change from the Highway Research Board. In instances where the Highway Research Board is the author, as in the example above, the original name is retained as author identification.

6. Name of Publication. Where applicable, the name of the publication or periodical is supplied with its volume and number.

7. Date. The official date of the report or the date of publication is given as shown on the title page.

8. Pages. The inclusive page numbers are given where the paper or article referenced is part of a larger volume. Otherwise, the total number of pages is indicated. For collections of separate papers, the number of papers is shown.

9. NTIS Number or GPO Stock Number. The National Technical Information Service (NTIS) offers for public sale technical reports prepared by Federal agencies, their contractors or grantees, or special technology groups. The initials NTIS and the NTIS retrieval number are inserted if the document is known to be currently available. NTIS offers documents in either paper copy or microfiche. Information is available from:

   U.S. Department of Commerce
   National Technical Information Service
   5285 Port Royal Road
   Springfield, Virginia 22161

   Recently, the U.S. Department of Transportation has been sending reports to the U.S. Government Printing Office (GPO) for publication and sale to the public. While NTIS remains the major source for documents, GPO is also a source to be considered. Information is available from:

   Superintendent of Documents
   U.S. Government Printing Office
   Washington, D.C. 20402

   Some reports, while listed without NTIS or GPO numbers, may now be available from one of these sources. Consulting their respective reference lists is advised.

10.-13. Keywords. The remaining four elements of the reference correspond to the four sets of keywords, listed in capital letters. One or more keywords may be used from each set. Keywords within a set are separated by commas; each set is separated by a period. The meanings of the "Type of Information Source" and "Traveler Responses Investigated" keywords are defined below.

The keywords are designed to provide information on the type and nature of the subject material covered. The first group of keywords indicates the types of transportation system change examined; the second set describes the general type of information source; the third set indicates the type of traveler responses specifically studied and the fourth set identifies any related impacts that are discussed. At least one keyword is provided for each of the first three keyword groups; the fourth group is omitted if there is no significant discussion of impacts other than traveler response.

It has not been possible, within the scope of preparing this Handbook, to review all of the referenced literature. The descriptive keywords have been selected in many instances on the basis of abstracts, and in some cases from library card descriptions. Accordingly, there can be no assurance that the keywords fully depict the content of the referenced works.

10. Transportation System Change Topics. One or more of the following keywords are used to describe the type of transportation system change or changes addressed in the referenced literature:

NEW HIGHWAY FACILITIES
NEW TRANSIT FACILITIES/EQUIPMENT
TRAFFIC OPERATIONS IMPROVEMENTS
POOL/BUS PRIORITY FACILITIES
VARIABLE WORK HOURS
POOL/TRANSIT FRINGE PARKING
CARPOOLING ENCOURAGEMENT ACTIVITIES
VANPOOLS/BUSPOOLS
AREA AUTO RESTRAINTS
AUTO FACILITY PRICING
AUTO FACILITY SUPPLY
COLLECTION/DISTRIBUTION TRANSIT
TRANSIT SCHEDULING/FREQUENCY
BUS ROUTING/COVERAGE
EXPRESS TRANSIT
FLEXIBLE PARATRANSIT
TRANSIT FARE CHANGES
TRANSIT MARKETING/BROKERAGE
PEDESTRIAN/BIKEWAY FACILITIES
RESEARCH TECHNIQUES
TRAVEL DEMAND MODELING
CONSUMER PREFERENCE ANALYSIS
TIME/COST MODELING
CONVENIENCE/COMFORT/RELIABILITY ANALYSIS
SAFETY ANALYSIS

A full discussion of the topical classification system these keywords are based on has been provided earlier in this chapter. The transportation system change elements encompassed by each topic and its corresponding keywords are described in detail in Tables 2 through 6. In the bibliographic reference, the first listed keyword specifies the principal type of transportation system change covered by the paper, and additional topical keywords indicate further coverage. An asterisk printed next to a topical keyword indicates that the paper is reviewed in the corresponding Chapter II topical summary.

11. Type of Information Source. The second of the four keyword groupings indicates the basic type of traveler response information source drawn upon by the author. One or more of the following keyword phrases are used:

    OBSERVED RESPONSE
    FORECAST RESPONSE
    OBSERVED STATIC SITUATION
    BACKGROUND INFORMATION

    Most papers are identified as being either in the OBSERVED RESPONSE or FORECAST RESPONSE categories, as response is the primary subject of this Handbook. OBSERVED RESPONSE indicates that a transportation system change has actually been demonstrated or otherwise implemented, and that the traveler response has been observed with surveys or counts and is described. FORECAST RESPONSE indicates that a transportation system change has been hypothesized, or designed for purposes of analysis, and that the traveler response has been modeled or otherwise estimated and is reported on.

    Papers analyzing data from a single point in time, unless survey questions were asked concerning prior travel actions, are not placed in the OBSERVED RESPONSE category. If cross-sectional survey data from a single point in time is used to develop a model, which is then employed for estimating or drawing of inferences concerning travel behavior, the information source is classified as FORECAST RESPONSE. If data from one point in time is examined directly in an effort to better understand one of the more poorly studied phenomena, the keywords used are OBSERVED STATIC SITUATION. A limited number of papers which do not report on traveler response are included for the purpose of better describing the nature of the less familiar system changes; these are identified as BACKGROUND INFORMATION.

12. Traveler Responses Investigated. The third keyword classification of subject matter describes the type of traveler response examined. One or more of the following identifying keyword phrases are used:

    TRIP GENERATION
    TRIP DISTRIBUTION
    TEMPORAL DISTRIBUTION
    MODE CHOICE
    AUTO OCCUPANCY
    ACCESS MODE CHOICE
    ROUTE CHOICE
    TRAVEL CHOICE
    VOLUME
    RESPONSE NOT INVESTIGATED

Papers identified with the keywords TRIP GENERATION specifically address changes or lack of change in the number of trips made per person or per dwelling unit (trip frequency) irrespective of travel mode. Similarly, TRIP DISTRIBUTION indicates discussion of impacts on traveler destination choice and average trip length. TEMPORAL DISTRIBUTION indicates analysis of changes in the departure or arrival times for travel, such as shifting of trips from peak to off-peak periods.

The keywords MODE CHOICE signify that the reference specifically quantifies impact on the percentage split of travel between the highway and transit modes, while AUTO OCCUPANCY indicates discussion of carpooling and auto occupancy rates or the percentage split of auto travel between the driver and passenger categories. The split of travel among transit access modes (walk, feeder bus, park and ride, kiss and ride) is addressed in references marked with the keywords ACCESS MODE CHOICE, while the choice among alternate routes or submodes is specifically covered when ROUTE CHOICE is indicated.

When the referenced work does not go into detail on any of the above traveler response categories, or when it is not clear from the information available what detail is provided, the keywords given are either TRAVEL CHOICE or VOLUME. VOLUME infers that impacts are described primarily in terms of traffic counts or passenger counts, whereas TRAVEL CHOICE implies additional discussion in terms of travel demand characteristics such as trip generation, distribution, mode choice, etc.

References included for the value of the background information provided, but which do not actually report on traveler response or related impacts are identified with the keywords RESPONSE NOT INVESTIGATED.

13. Related Impacts Investigated. One or more of the following keywords are included from the fourth keyword group if the referenced literature provides a significant discussion of transportation impacts in any of the subject areas listed:

    ENERGY
    AIR QUALITY
    ENVIRONMENT
    ECONOMIC IMPACT
    REVENUES/DEFICITS
    LAND USE
    EQUITY

Lacking any such discussion, this set of keywords is omitted from the individual reference listing.

CHAPTER II

TOPICAL DIGESTS AND REVIEWS

CHAPTER II

TOPICAL DIGESTS AND REVIEWS

The topical summaries of traveler response to nine types of transportation system change are presented in this chapter. Each of the nine topical summaries consists of two principal parts:

- A digest of state-of-the-art knowledge concerning traveler response to the transportation system change in question, along with other pertinent information.

- Reviews of relevant papers and documented case studies.

The chapter is divided into nine sections, corresponding to the following nine types of transportation system change:

- Pool/Bus Priority Facilities
- Variable Work Hours
- Pool/Transit Fringe Parking
- Vanpools/Buspools
- Transit Scheduling/Frequency
- Bus Routing/Coverage
- Express Transit
- Transit Fare Changes
- Transit Marketing/Brokerage

For directions and background information pertaining to the use of the topical summaries, consult "Use of the Topical Digests and Reviews" in Chapter I, page 16.

POOL/BUS PRIORITY FACILITIES

Types of Priority Facility Treatments

Provision of priority facilities reserved for buses and/or carpools and vanpools is an element of transportation system management within the category "Actions to Ensure the Efficient Use of Existing Road Space." Highway-based preferential treatments for high-occupancy vehicles (HOV's) include the following freeway HOV lane, separate roadway, priority HOV entry, and arterial street priority applications.

1. Freeway and separate roadway applications:

   a. Separate roadways for exclusive bus or shared bus, vanpool and carpool use, built either on their own right-of-way or within the right-of-way of a freeway, but physically separated from other traffic (14, 95*, 140*, 187^{+}, 357, 397#, 538, 649^{+}, 695).

   b. Priority "contra-flow" freeway lanes reserved for use by high-occupancy vehicles traveling in the peak flow direction during peak hours; usually the median lane opposing normal traffic flow. Such lanes are typically reserved for buses only, although some have potential for carpool use, and are normally separated from oncoming traffic by removable traffic posts or similar delineators (14, 67, 95*, 187^{+}, 230, 349, 357, 532, 538, 649^{+}, 695).

   c. Priority "with-flow" or "concurrent-flow" freeway lanes reserved for high-occupancy vehicles and operating in the same direction as traffic in immediately adjacent lanes (8^{+}, 14, 67, 68, 83, 95*, 309*, 310*, 349, 357, 461*, 538, 562, 563*, 649^{+}, 686, 695).

2. Priority entry applications:

   a. Priority freeway entry in the form of exclusive ramps reserved for high-occupancy vehicles, often providing direct access to high demand areas at locations where full mixed traffic flow could not be handled (14, 357, 538, 684, 695).

   b. Priority freeway entry in the form of bypass lanes at metered freeway ramps, allowing entry for high-occupancy vehicles without a wait in the meter (signal) queue (14, 95*, 227*, 357, 401#, 589, 695).

   c. Priority tollway entry in the form of exclusive lanes at toll plazas which enable high-occupancy vehicles to bypass delays caused by the toll barrier. Applications may include toll-free passage for high-occupancy vehicles (14, 67, 95*, 357, 538, 649^{+}, 695).

3. Arterial street applications:

   a. Priority surface streets with their full width reserved primarily for buses and sometimes for other high-occupancy vehicles. Such street reservations are most often implemented in connection with establishing an auto-free street or zone (covered within the topic area "Area Auto Restraints"[a/]).

   b. Priority "contra-flow" lanes for buses and sometimes carpools on surface streets, either the left lane opposing normal traffic flow on a one-way street, or the median lane opposing normal traffic flow on divided and undivided highways (14, 187+, 309*, 349, 357, 533#, 538, 695).

   c. Priority "with-flow" or "concurrent-flow" lanes for buses and sometimes carpools on surface streets. Such lanes are normally at the curb with right-turning vehices permitted to mix with priority vehicles. Curb-side with-flow lanes are often created by prohibiting parking during peak hours. Sometimes center lanes are used with passenger loading platforms (14, 95*, 137, 246, 349, 357, 406, 474, 533#, 538, 687*, 695).

Although the initial emphasis in providing priority highway facilities was on their exclusive use by buses, many programs now include carpools and vanpools. Selected examples (operating and terminated) of the different types of highway preferential treatments are given in Table 9. The impact of major new express bus operations, which frequently accompany the opening of priority facilities, is discussed primarily within the topical digest "Express Transit".

Traveler Response Summary

The primary HOV user inducements offered by priority facility treatments are reduced travel time and increased trip reliability. Separate reserved roadways and contra-flow freeway lanes can save buses and carpools 10 to 20 or more minutes of line haul travel time in congested metropolitan corridors. Time savings of 1 to 5 minutes are normal for with-flow freeway lane, priority freeway access and medium distance arterial applications. The usual benefits of short arterial applications relate less to time savings than to achievement of better bus service reliability and routings. Reliability improvement results for priority applications of various types are each favorable and average a doubling of bus on-time performance.

Both travel time and reliability are thought to be key factors in the decision to use transit or to carpool. Nevertheless, the travel time and reliability improvements afforded by most priority facilities will only induce HOV use if other determinants of mode choice, such as frequency of transit service, are favorable. With extensive express bus systems, separate roadway and contra-flow freeway applications carry

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a/ An "Area Auto Restraints" digest was provided in Edition I of this Handbook (510). For "Area Auto Restraints" references see Chapter III of this current edition.

Table 9
Examples of Pool/Bus Priority Facility Applications
(349, 357, 695)

Type of Treatment	Location
Separate Roadways	Washington - Shirley Highway* Los Angeles - San Bernadino Freeway* Pittsburgh - South PATway Runcorn, England - Busway
Contra-Flow Freeway Lanes	San Francisco - U.S. 101 New York City - Long Island Expressway Boston - Southeast Expressway (T) New Jersey - I-495 Lincoln Tunnel Approach
With-Flow Freeway Lanes	Portland - Banfield Freeway* Honolulu - Moanalua Freeway* San Francisco - U.S. 101* Los Angeles - Santa Monica Freeway* (T) Miami - I-95* Boston - Southeast Expressway* (T)
Exclusive Freeway Ramps	Seattle - I-5* Washington - Dulles Access Road*
Metered Ramp Bypass Lanes	Los Angeles - Various Freeways* Minneapolis - I-35W*
Toll Plaza Bypass Lanes	San Francisco - Oakland Bay Bridge*
Reserved Surface Streets	London - Oxford St. Chicago - 63rd and Halsted Sts. Minneapolis - Nicollet Mall Philadelphia - Chestnut Street
Contra-Flow Street Lanes	Miami - South Dixie Highway (T)1/ Honolulu - Kalanianaole Highway* Ottawa - River Parkway San Juan - Ponce de Leon/Fernandez Juncos
With-Flow Street Lanes	Miami - NW 7th Avenue (T)2/ Baltimore - York Road Dallas - Harry Hines Boulevard/Fort Worth Avenue Miami - South Dixie Highway* Honolulu - Kalanianaole Highway* Sydney, Australia - Spit Bridge Corridor*

* carpools, as well as buses, permitted.

(T) projects known to have been terminated.

1/ consolidated into with-flow carpool lane operation in 1976.

2/ superseded by with-flow operation on I-95.

5,000 to 35,000 bus passengers in the AM peak period. Corresponding volumes for other types of priority facilities with bus service range from a few hundred bus passengers to 14,000. While the mode shifts to transit attributable to priority facilities are often small, transit market share increases of more than 50 percent have been reported for entire metropolitan corridors with substantial prior transit service (see also the "Express Transit" topic area).

Opening freeway priority facilities to carpools and vanpools has led to total highway increases in high occupancy carpooling of 50 to 500 percent. Associated increases in total highway auto occupancy have typically ranged from 3 to 7 percent but have reached 19 percent. Carpool volumes range up to some 4,000 vehicles and 18,000 persons in the AM peak period. Even with facilities offering moderate time advantages, increases of 100 to 300 carpool vehicles per hour in the peak period are common. Peak period bus ridership of up to 5,000 persons and carpool volumes of 1,000 vehicles have been reported on arterial applications. Bypass lanes at metered freeway ramps have on the average increased HOV volumes by 25 percent.

Highway person volume increases of 8 to 15 percent have been typical when freeway and medium distance arterial priority facilities were introduced. Corresponding vehicle volume increases have been 5 percent or less and in some cases vehicle volumes have diminished. Person volumes declined in two applications. Both involved with-flow lane conversions ("take-a-lane" strategy) and both have been terminated. Opening of under-capacity priority facilities to all HOV vehicles has provided the maximum person flow rate because neither transit riders nor carpoolers are drawn disproportionately from competing high occupancy modes. Some 40 to 60 percent and more of bus passengers and carpoolers on newly opened freeway and medium distance arterial priority facilities formerly drove.

Priority Facility Objectives

Carpool and bus priority facility applications are generally implemented with the goal of maximizing person flow on urban highways while optimizing total person travel time. The immediate objective is to reduce travel time and increase travel reliability for high-occupancy vehicle users, with the expectation that this will result in mode shifts to transit and, where applicable, to carpools and vanpools. The ultimate objectives of such mode shifts include more efficient use of roadway space, conservation of energy, and reduction in pollutant emissions. Some regions include HOV priority facilities as first stage and long term measures in their air quality control plans (14, 20, 140*, 171, 187+, 310*, 357, 461*, 563*, 673).

Other planning objectives are also appropriate for individual priority facility treatments. Where existing high-occupancy vehicle volumes are large, use of separate HOV roadways, peak period contra-flow lanes, and peak period arterial with-flow lanes in lieu of curb parking can release capacity in the regular traffic lanes for peak-direction mixed traffic. Separate roadways and freeway or tollway priority treatments together with bus service expansion provide a flexible, easily staged and relatively low-cost form of high-capacity express transit. Along with some surface street applications, they offer transit operating economies by virtue of the higher bus operating speeds and reliability attained. Surface street contra-flow lanes may allow use of one-way streets to alleviate congestion or safety problems without the need for relocating bus routes and loading areas away from major traffic generators and other patronage sources (187+, 357, 695).

Travel Time Impacts

Experience indicates that the HOV travel time reductions achievable with individual priority facility treatments range all the way from nothing to about 30 minutes, depending on the unique physical and traffic characteristics of the applications involved (187[+], 357, 563*, 651, 695). Specific travel time impacts are given in the discussions which follow. However, there are several general points concerning travel time savings accruing from HOV priority facilities that deserve emphasis by way of introduction:

1. Without the presence of congestion, most priority facilities will not gain a significant time advantage for high-occupancy vehicles. The only exception is in the case of exclusive ramps or separate roadways that provide more direct routes. Otherwise, when congestion is lacking, as is the case in many smaller cities, the potential for benefits related to time savings is small (187[+], 357).

2. Freeway-oriented bus priority applications may not have central area distribution elements, and often have no stops along the priority facility. Without distribution elements, and without main line stops, the time savings which accrue tend to benefit mainly suburban commuters. With respect to suburban trips, buses on busways may afford overall time advantages approaching or exceeding those offered by conventional rapid transit.

3. Reported time savings typically pertain only to the leg of the trip directly affected by the priority treatment. Traveler response will ultimately be determined more by the resulting differences among overall door-to-door travel times for the available travel modes. The most successful highway priority treatments will be those which allow door-to-door HOV trip times to become competitive with low occupancy auto travel times, taking into account the time that buses, carpools and vanpools must spend in picking up and discharging passengers, and the time that bus passengers must spend in walking and waiting.

Travel Reliability Impacts

Transit and carpool reliability, in the form of travel time consistency, can be significantly improved by the implementation of HOV priority schemes. Vehicles traveling in reserved lanes often avoid unexpected congestion caused by accidents, inclement weather, breakdowns, or unusually high traffic volumes in the regular lanes. The following improvements in transit service reliability have been noted (67, 68, 95*, 187+, 357, 397#):

Freeway Priority Projects	Percent of Trips Arriving Early or On-Time	
	Before	After
Shirley Highway (Washington, DC)	33%	92%
Bay Bridge (San Francisco-Oakland)	16	55
I-95 (Miami)	69	71
Santa Monica Freeway (Los Angeles)	68 (AM) 40 (PM)	77 (AM) 65 (PM)
Arterial Priority Projects		
Geary St. (San Francisco)	24	80
NW 7th Avenue (Miami)	68	75
Fairview Bus Lane (Dublin, Ireland)	54	72

Several other freeway and arterial applications were reported to have improved travel time consistency for those using priority lanes. Impacts on the reliability of travel for non-priority vehicles were not specified.

Response to Separate Priority Vehicle Roadways

Separate roadways for priority vehicles, when they extend a significant distance outward from the urban core and are operated in conjunction with an intensive express bus system, can attract and accommodate large transit passenger volumes. The 11-mile Shirley Highway busway in the Virginia suburbs of Washington, DC carried 16,100 inbound transit passengers during the 2½ hour AM peak period as of 1974, a quadrupling of ridership in 5 years. Ridership for the most heavily patronized 3½ hours in the morning was 18,000 in the peak direction in 1977 and increased to 21,600 in March 1979. Patronage on the San Bernadino Freeway Busway, extending 11 miles from El Monte to Los Angeles, was about 6,000 (inbound and outbound) for the combined AM and PM peak hours as of 1978. The daily patronage was 18,000, a 6-fold increase over mid-1973 when the El Monte terminal opened (140*, 397#, 538, 673).

Bus routes using the South PATway in Pittsburgh, a separate bus roadway with 4 miles in operation, carry over 21,000 daily passenger trips. This represents a 17 percent increase over pre-busway patronage. An additional 22,000 daily passengers are carried by light rail vehicles which share portions of right-of-way with the buses. More detail on the passenger trends, mode shifts and associated bus service expansions for the Shirley Highway, San Bernadino and South PATway exclusive facilities is provided in the "Response to Priority Roadway Service" section of the topical digest "Express Transit"[b/].

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b/ Information on Pittsburgh's South PATway obtained from Port Authority of Allegheny County.

The Shirley Highway and San Bernadino operations are examples of where carpools have been allowed on bus lanes. The Shirley Highway busway was opened to 4-or-more occupant carpools in November 1973 without detriment to bus operations or ridership. In October 1976, 3-or-more occupant carpools began using the San Bernadino busway without hampering bus operations or causing a noticeable bus ridership decline. A comparison of carpool usage just prior to and one year after the implementation of mixed mode operations on the Shirley Highway busway (2½ hour AM peak period) and San Bernadino busway (4 hour AM peak period) is presented below (140*, 397#):

	Number of Carpools		Average Carpool	Facility Auto Occupancy		Corridor Auto Occupancy	
	Before	After	Occupancy	Before	After	Before	After
Shirley Highway (4+ person carpools)	N.A.	1,050	4.5	1.35	1.61 (+19%)	1.32	1.45 (+10%)
San Bernadino Freeway (3+ person carpools)	670	1,720 (+157%)	3.3	1.20	1.27 (+6%)	1.19	1.24 (+4%)

More recent Shirley Highway data are for the 3½ hour AM peak period. For this period the volume of 4+ passenger carpools rose to 2,900 as of 1977 and 4,000 as of March, 1979. Starting with approximately 700 high occupancy carpools in 1973, this represents almost a 6-fold increase in 6 years. Average 3½ hour AM peak period auto occupancy on the highway as a whole rose to 1.71 in 1979 (538, 673).

Use of the Shirley Highway busway saves just under 20 minutes on the line haul leg of the commuter trip over regular lane traffic; the San Bernadino busway saves up to 20 minutes during the AM peak hour and 10 minutes during the PM peak hour for those traveling the full length of the facility. Pittsburgh's South PATway, constructed on exclusive right-of-way and having use of a streetcar tunnel, saves bus riders 15 to 30 minutes as compared to the prior bus trip(140*, 205, 397#). Shorter facilities or facilities in smaller cities could logically be expected to offer correspondingly smaller time savings and corresponding benefits.

Response to Contra-Flow Freeway Priority Lanes

Although contra-flow lanes for buses on freeways can provide substantial time savings, the applications reported on have not induced bus ridership increases as large as those experienced with separate priority facilities such as the Shirley Highway and San Bernadino projects. This circumstance is at least partially explained by the fact that the most heavily used contra-flow facilities were opened in corridors which already had a high transit mode split, leaving less leeway for large shifts away from auto use. There is no reason to believe that an express bus service via contra-flow freeway lane could not induce peak period mode shifts similar to those of exclusive busways if implemented in a similar urban environment.

The largest freeway contra-flow lane bus volume and probably the largest bus volume on any priority facility worldwide is carried along a 2.5 mile section of I-495 in Northern New Jersey leading to the Lincoln Tunnel into Manhattan. It is used by about

21,000 passengers in 480 buses during the AM peak one hour, and 35,000 passengers in 800 buses during the two hour peak period (357, 695). Summaries of reported results for the I-495 facility along with those for contra-flow bus lanes on the Southeast Expressway in Boston (now terminated), U.S. 101 north of San Francisco and the Long Island Expressway are tabulated below (67, 187+, 357, 695). The 4 mile U.S. 101 contra-flow lane operates in conjunction with a 3.5 mile concurrent-flow bus and carpool lane located immediately north of the contra-flow lane terminus.

	Length	Travel Time Savings	Peak Period Bus Volume	Patronage Increase
I-495 Northern N.J.	2.5 miles	8-10 min.	800	2300 1/ (+6%)
Southeast Expressway Boston, MA	8.4 miles	14 min.	65 (peak hour)	300 (+14%) (peak hour)
U.S. 101 Marin County, CA	4 miles	6-10 min. 2/	170	1000 (+26%)
Long Island Expressway Long Island, NY	2 miles	15 min.	200	N.A.

1/ This is not an absolute increase, but represents an arrest in the declining ridership trend.

2/ Virtually all of this time savings is attributed to the adjacent with-flow section, since there are normally free-flowing conditions on the highway at the contra-flow location.

The results of the Boston project were clouded by the opening of a major new rapid transit extension in the corridor and possible ridership diversion from parallel transit routes. To date, all freeway contra-flow lanes have been limited to bus use primarily because of safety concerns.

Response to With-Flow Freeway Priority Lanes

Although most with-flow freeway priority lane strategies have resulted in increased auto occupancy and transit usage, the viability of with-flow lanes has depended on the technique used to create the lane. Where an additional lane has been constructed ("add-a-lane"), acceptance of the project has prevailed (67, 310*, 461*, 563*). Where an existing lane has been removed from normal service to create an HOV lane ("take-a-lane"), public dissatisfaction has forced project termination. Moreover, the short-term "take-a-lane" results show a decline in person-trip throughput (563*). Long term results are not available and might be more favorable if the introductory period could be hurdled.

Initially, some with-flow priority lanes were for the exclusive use of buses. Carpools and vanpools were banned due to concerns about their effects on bus operations and possible safety problems arising from nonprofessional drivers being subjected to sudden weaving of vehicles into and out of priority lanes. Subsequently, almost all freeway with-flow bus lanes have been made available for carpool use, often because of transit strikes or energy shortages. Usually this has been accomplished without detriment to transit operations or accident rates (67, 310*).

Results from several "add-a-lane" and "take-a-lane" applications of freeway with-flow priority lanes serving both transit and carpools are summarized in Table 10 (67, 310*, 461*, 563*). Comparison is provided with detailed forecasts modeled for a proposed Cleveland "take-a-'ane" application, never implemented. The forecasts were prepared in 1970 based on pre-energy crisis gasoline prices, but are of interest because the study showed the significance of the mode shifts required to achieve person-carrying capacity increases and the likelihood of congestion problems during the introductory period (8+).

In all instances except the Moanalua Freeway and the hypothetical Cleveland study assumptions, bus service was initiated or expanded in conjunction with the opening of the HOV lanes. Increased transit usage was reported to be influenced more by service level improvements than by the availability of the priority lanes (563*).

Response to Priority Freeway and Tollway Entry

Individual bypass lanes on metered freeway ramps, exclusive priority vehicle ramps, and priority vehicle lanes at toll plazas can give buses and carpools between 1 and 5 minutes of time savings advantage over low-occupancy vehicles in the majority of cases, and can thereby contribute to moderate modal shifts favoring transit and carpools. At prime locations, such as the ramps for commuter buses on Braddock Avenue-Parkway East in Pittsburgh and the Dulles Airport Access Road in suburban Washington, D.C. (now opened to carpools), priority entry schemes save users up to 10 and 20 minutes in travel time (215, 651). Express bus systems are often established in conjunction with priority freeway entry. The traveler response to such systems is discussed in full detail in the topical digest "Express Transit" under the subject heading "Response to Predominantly Mixed Traffic Freeway Service."

Express buses operating in mixed traffic, aided by exclusive ramps and bypass lanes, have been carrying peak period passenger volumes in Seattle and Minneapolis that are only moderately less than the corresponding bus passenger volumes on the San Bernadino separate roadway facility in Los Angeles. In Seattle the provision of a downtown exclusive bus ramp saves 5 minutes over the route available to mixed traffic. In Minneapolis, exclusive ramps and ramp lanes give buses up to a 2.5 minute access time advantage to I-35W, which is metered. Implementation of metering improved travel conditions on the freeway itself for both buses and autos, matching or bettering conditions two years previous when traffic was less. Metering reduced AM peak hour inbound freeway travel times by 26 percent, from 29.4 to 21.9 minutes, the most dramatic improvement. Travel time variance was reduced by 84 percent.

Over 90 California ramp meter bypasses, mostly in the Los Angeles region, have resulted in average time savings of 1½ minutes and an average increase in carpool volume of 25 percent. Experience indicates that at prime locations, a doubling of carpools may be expected, with about one-half of the new carpools having been formed as a result of the preferential ramp bypass treatment and the remainder being pre-existing carpools diverted from alternative routes. The Lakewood Boulevard and Hawthorne Avenue ramps on I-405 are examples of such locations. Afternoon peak period Lakewood Boulevard ramp usage by carpools rose from 125 to 275 in a week, with time savings of up to 9 minutes, and Hawthorne Avenue ramp carpool usage increased from 150 to 400 shortly after bypass installation (95*, 227*).

Table 10
Summary of With-flow Freeway Lane Applications
(67, 310*, 461*, 563*)

	Length (miles)	Add-or Take-a-Lane	Project Active or Terminated	Change in Travel Time (minutes) (HOV)	Change in Travel Time (minutes) (Other)	Change in Volume (Vehicles)	Change in Volume (Persons)
I-95[1/] Miami, FL	7.5	add	active	-5	-2.4	+5%	+14%
Banfield Frwy.[2/] Portland, OR	3.3	add	active	-1.4	0	+2%	+10%
Moanalua Frwy. Honolulu, HI	2.7	add	active	3.7 minute difference		-0%	0%
Southeast Expwy.[3/] Boston, MA	8	take	terminated	-8	+12	-21%	-8%
Santa Monica Frwy.[4/] Los Angeles, CA	13	take	terminated	-1	+4.8	-9%	-2%
Memorial Shoreway[5/] Cleveland, OH	12	take	study only	-5.9	+6.7	-8%	-1%

	Percent in Priority (Vehicles)	Percent in Priority (Persons)	Bus Patronage Increase	Auto Occupancy Before	Auto Occupancy After	Change in Carpool Vehicle Volume
I-95 Miami, FL	4%	10%	52%[6/]	1.23	1.28	+74%
Banfield Frwy. Portland, OR	5%	20%	43%	1.22	1.26	+389%
Moanalua, Frwy. Honolulu, HI	29%	50%	capacity restrained	1.70	1.91	+20%
Southeast Expwy. Boston, MA	9%	32%	6%[6/]	1.31	1.38	+72%
Santa Monica Frwy. Los Angeles, CA	6%	22%	22%[7/]	1.22	1.31	+65%
Memorial Shoreway Cleveland, OH	9%	25%	28%	1.37	1.45	+26%[8/]

1/ Data from 3+ person carpool phase; designation later changed to 2+ persons to improve utilization.
2/ Data adjusted relative to anticipated volumes without HOV lane.
3/ Data from period of HOV lane enforcement.
4/ Data from 7 weeks immediate prior to project termination.
5/ Data from modeled forecasts.
6/ Express bus patronage.
7/ On existing routes only; increase of 224% overall.
8/ Carpool person volume.

Reservation of lanes for high-occupancy vehicles at congested toll plazas is, in effect, a special case of providing priority entry to limited access highway facilities. An economic incentive can be added by reducing or eliminating tolls for carpools. The combination of 0.7 mile long exclusive bus and carpool lanes and toll-free passage on the San Francisco - Oakland Bay Bridge saves 3-or-more occupant carpoolers 5 to 8 minutes in the morning, 2 to 5 minutes in the evening and 60¢ in tolls. Inbound AM 3-hour peak period carpool volumes increased from 1,200 prior to the opening of the lanes to 2,200 soon after implementation. Carpool volumes have since reached 3,100 carpools. Bus ridership during the AM peak period is 14,300 (95*).

Response to Contra-Flow Arterial Priority Lanes

Contra-flow priority lanes have been reserved exclusively for buses in most cases. Operational details differ widely. Many applications are limited to a few blocks in length, being designed to avoid bottlenecks or facilitate particular bus movements. The primary benefit in such cases has been the ability they give buses to avoid traffic incidents, and thus achieve better reliability, and to use the same street routing inbound and outbound on one-way streets. In applications where time savings were of sufficient interest to be reported, the average was slightly less than 5 minutes per bus trip. Contra-flow lanes tend to be self-enforcing with respect to keeping the lane clear of autos (187+, 357, 695).

Ridership data is scarce for the majority of arterial contra-flow bus lanes in operation. In many instances, the proportion of the total transit trip spent on the contra-flow lane is small and significant modal shifts are not thought to have occurred (187+, 357). Those applications for which transit passenger statistics are available, including a preponderance of longer distance applications, are presented in Table 11 (187+, 309*, 533#, 695).[c/]

The longer contra-flow arterial lanes, as illustrated in the first four entries of Table 11, can provide more substantial travel time savings (309*, 533#, 695). Note that the time savings reported are calculated in comparison with the prior bus service and not in comparison with auto travel. Also, in most of the long priority lane applications, express bus service was added to local service. Many of the time savings reported appear to be attributable as much to the nature of newly instituted express service as to the provision of priority lanes. Similarly, ridership gains may be heavily attributable to express service institution and service frequency increases. Nevertheless, in both Miami and Honolulu express buses do save time over autos on the line haul segment of their routes.

The Honolulu Kalanianaole Highway contra-flow lane, mostly on an undivided arterial, is one of the few that permits carpool use. Since opening of the former bus-only lane to carpools, average auto occupancy has increased 8 percent, from 1.70 to 1.84 in one location and from 1.65 to 1.79 in a second location. At these two locations the number

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c/ Information on Ottawa River Parkway obtained from Ottawa City Transpo.

Table 11
Impacts on Travel Time and Patronage of Contra-flow Arterial Bus Lanes
(187[+], 309*, 533#, 695)

Location	Length (miles)	Time Savings	Effect on Patronage
South Dixie Highway Miami, FL 1/	5.5	15-20 minutes	Daily ridership of 2100 as of 1976, over 5 times pre-project levels. Number of bus trips was increased to 6 times the pre-project level.
Kalanianaole Highway Honolulu, HI	1.9	3-12 minutes	70-75% of express bus riders previously commuted by auto. Express service augmented local service when bus lane opened.
Ponce de Leon/ Fernandez Juncos San Juan, PR	10.8	Up to 30 minutes 2/	Effect unclear; lanes apparently helped to diminish a long-term systemwide patronage decline.
Ottawa River Parkway Ottawa, Ontario 3/	4.5	4-5 minutes	95% patronage increase across corridor screenline during peak hour period. Mode split increased from 36% to 57% compared to 37% to 40% in other corridors.
Third Street Louisville, KY	1.5	5-10 minutes inbound 4/	Effect unclear due to route restructuring. Preliminary data indicated that 160 of the 250 daily inbound riders formerly drove while 90 transferred from other routes.
Avenue Montaigne Paris, France	0.4	6 minutes	Increase in patronage due to bus lane estimated at 1.7% on one route and 3.5% on a second route.
Rue d'Alsace-Lorraine Toulouse, France	0.5	N.A.	8% patronage increase.
Via Saragozza Bologna, Italy	1.4	N.A.	56% patronage increase.
Delicias Madrid, Spain	0.1	N.A.	16% patronage increase.

1/ Subsequently consolidated into with-flow carpool lane.

2/ Fully attributable to the contra-flow lanes; no express service added.

3/ Information on Ottawa River Parkway obtained from Ottawa City Transpo.

4/ New express service achieved similar time savings outbound without benefit of priority lanes.

of person-trips on the highway has increased 18 percent and 9 percent, while the number of vehicle trips has decreased 1 percent and increased 3 percent, respectively. The priority lane carries 21 percent of all vehicles and 39 percent of all persons. Interestingly, of the carpools on Kalanianaole Highway, 83 percent require child riders (apparently headed to school) to qualify as carpools (309*).

Response to With-Flow Arterial Priority Lanes

When operating properly, with-flow priority lanes on urban arterials tend to afford time savings similar to contra-flow lanes, but their performance is heavily affected by the level of moving and parking violation enforcement. The vast majority of with-flow arterial lanes are reserved exclusively for buses and turning vehicles, although carpools and taxis are permitted use of the lanes in some applications, principally outside the United States.

As with contra-flow lanes, the short length of most with-flow arterial lanes and the changes in transit service which accompany introduction of most priority schemes makes it difficult to separate out patronage effects attributable to the lanes from effects attributable to other causes. Information for those locations where patronage data are available is summarized below (137, 246, 687*, 695):

Location	Length (miles)	Travel time savings (minutes)	Patronage change
NW 7th Avenue Miami, FL 1/	10	6-8 (AM) 7-9 (PM)	+18 to 23% (AM) + 8 to 14% (PM)
Spit Bridge Corridor Sydney, Australia	4.3	11	-4% 2/
Harry Hines Boulevard/ Fort Worth Avenue Dallas, TX	2 2	2 3	+11% (AM), 0% (PM) +11% (AM), 0% (PM)
Six locations Canada	variable	variable	+7% (average)
Fairview Dublin, Ireland 3/	2.1	2.5	+13%

1/ Superseded by with-flow operation on I-95.

2/ Overall person trip decline of 2%.

3/ One week experiment; long term effects unknown.

The Sydney project, which showed a slight bus ridership reduction, is one of the few where carpools as well as taxis share the exclusive lane with buses. In the year following implementation of the priority lane, carpooling increased 52 percent and overall auto occupancy rose 4 percent from 1.43 to 1.49. Carpools save one minute over non-carpools on the average, and six minutes over pre-project conditions, but carpool time savings over regular traffic during critical congestion periods is on the order of 10 to 20 minutes. Variance in carpool travel time is less than one quarter that of regular vehicles (246). On Miami's South Dixie Highway (US 1) a with-flow carpool priority lane operating adjacent to a contra-flow bus lane resulted in an auto occupancy increase from 1.30 to 1.45. The bus lane was ultimately consolidated into the carpool lane.

Underlying Traveler Response Mechanisms

A large number of bus priority facilities are actually or effectively peak-period-only in their application, and thus emphasize service to work purpose travel. Exceptions include the San Bernadino Freeway and Pittsburgh busways, and a number of arterial priority lanes and bus-only streets (187+, 357, 563*, 695). Most carpool priority treatments are inherently work-trip oriented, given the usual nature of carpooling. Traveler response to the typical priority facility will thus be manifested primarily in the form of work trip modal choice and route choice shifts, with little impact on trip generation or distribution, except insofar as choice of residence or workplace location may ultimately be affected by new travel opportunities.

The primary commodities that priority facilities themselves can potentially offer the high occupancy vehicle user are reduced travel time and increased travel time consistency. Time factors have been thought to be the more important in the time vs. cost tradeoff that is inherent in the decision to carpool (326+), and without doubt remain very potent. More recent attitudinal surveys tend to show cost as an increasingly important factor in mode choice, and continuing increases in the cost of gasoline are thought to be a major cause of the current growth of carpooling and also transit usage throughout the United States (461*, 563*). In any case, improved carpool and transit travel times will only induce commuters to use high occupancy vehicles if the other determinants of mode choice, such as availability and frequency of transit service or known existence of potential carpool partners, are favorable.

Priority facilities per se do not offer cost savings to the transit user, or carpool cost savings of a perceivable magnitude. Neither do they in and of themselves offer improvements of convenience to the traveler. In the choice of mode, convenience as expressed in minimization of walk and wait time is thought to be more important on a minute for minute basis than in-vehicle travel time. These are key reasons that some of the most successful preferential treatments are those which have been implemented in combination with other measures such as fringe parking lots, increased transit service, and priority parking for carpools in central cities (67, 397#, 563*, 649+). In fact, the transit patronage increases in a number of applications are thought to be more the result of bus service enhancements such as expanded express service coverage and increased frequencies than of the time savings afforded by the exclusive lanes themselves (461*, 563*). Other factors conducive to success include the presence of intensively developed downtown areas with high all day parking costs (357).

Exclusive lanes may offer some intangible psychological inducement to carpooling and transit use to the extent that they are clearly identifiable transit system elements (357, 695) and offer the high-occupancy vehicle user visible evidence of moving faster than other traffic. It is interesting to note that when surveyed, both users and nonusers of priority lanes in Honolulu perceived the time savings of priority lanes to be two or three times the actual average savings (309*, 310*). (The transit mode choice decision and related factors are discussed more extensively within the topical digest "Bus Routing/Coverage," under the headings "Underlying Travel Response Mechanisms" and "Implications of Travel Patterns." For further discussion of carpooling as a mode choice decision see the references listed under "Carpooling Encouragement Activities"[d/].)

Sources of Priority Lane Users

Figure 2 illustrates the primary mode changes that can occur upon introduction of new priority facilities, and also identifies the background trip making changes that can affect surveys of traveler response (140*). User surveys show that while buses on priority facilities attract some carpool passengers, they attract proportionately more former auto drivers. When carpools are allowed in high occupancy lanes, some transit riders are drawn to carpooling, but proportionately more low-occupant auto commuters are attracted (140*, 309*, 310*, 397#, 461*, 563*, 649+, 687*). These observations indicate that opening priority facilities to both buses and carpools will induce the maximum shift from low occupancy vehicles. As discussed in the next section, "Impacts on Traffic Volumes," this does indeed seem to be the case.

Table 12 details the prior travel modes for the principal categories of users on the Shirley Highway project in Washington, D.C., five years after initial opening of the busway and approximately one year after carpools were allowed on. Table 13 provides a consolidation of this data plus the prior mode of travel for transit riders and carpoolers surveyed in seven additional priority lane applications (140*, 309*, 310*, 397#, 461*, 533#, 686, 687*). In the case of the Shirley Highway priority roadway, it can be demonstrated that the proportions of prior auto passengers among bus passengers and of prior bus riders among carpoolers, while significant, were each less than the previous proportional usage of these modes in the travel corridor. It is probable that this relationship holds true for most of the other examples in Table 13.

Other experiences tend to confirm that new transit riders or carpoolers attracted by priority lane advantages are normally not drawn disproportionately from competing high-occupancy modes. On the San Francisco-Oakland Bay Bridge, a survey indicated that approximately 8 percent of new carpoolers using the exclusive carpool lanes were former transit riders. By comparison approximately 40 percent of all morning peak period bridge commuters were transit riders (95*, 649+). On Route I-35W in Minneapolis, no statistically significant changes in auto occupancies were observed during the large increase in express bus transit ridership (401#).

Some users of high-occupancy lanes are transit riders or carpoolers who previously used alternative routes before making a route choice shift to obtain the high-occupancy lane time savings. Among bus passengers, this shifting accounts for a major part of the bus prior mode percentages reported in Table 13. It is also seen in the 12

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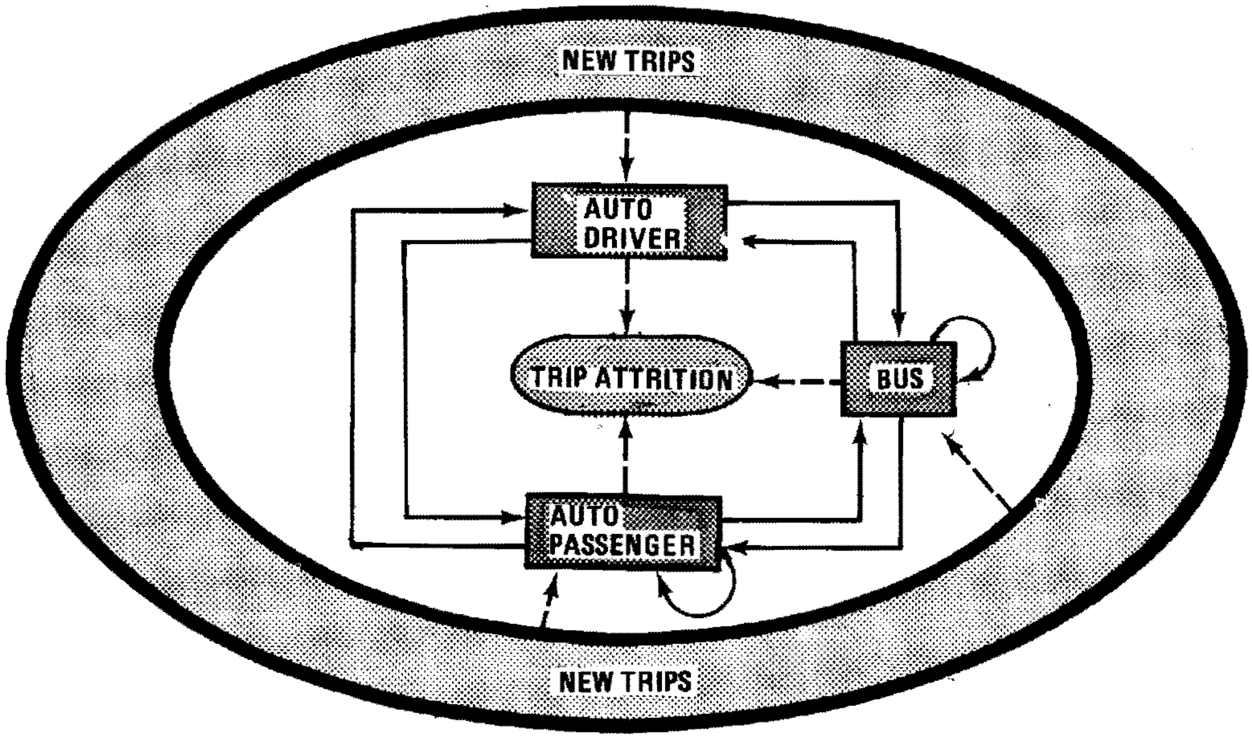
d/ A "Carpooling Encouragement Activities" digest was provided in Edition I of this Handbook (510). For "Carpooling Encouragement Activities" references see Chapter III of this current edition.



- A NEW COMMUTER MAY CHOOSE FROM AMONG ANY MODE
- AUTO DRIVERS MAY CHANGE TO BUS OR TO AUTO PASSENGER IN A QUALIFYING OR NON-QUALIFYING CARPOOL
- BUS PASSENGERS MAY CHANGE TO ANOTHER BUS SERVICE, TO AUTO PASSENGER IN A QUALIFYING OR NON-QUALIFYING CARPOOL, OR TO AUTO DRIVER
- AUTO PASSENGERS MAY CHANGE TO ANOTHER CARPOOL, QUALIFYING OR NON-QUALIFYING, TO BUS, OR TO AUTO DRIVING
- A USER OF ANY MODE MAY CEASE COMMUTING

NOTE:
COMBINATIONS SUCH AS PARK-AND-RIDE AND PARK-AND-POOL ARE NOT SHOWN FOR SIMPLICITY

Figure 2
Priority Facility Modes and Possible Mode Shifts
(140*)

Table 12
Prior Travel Mode of Shirley Busway Users
(397#)

	"Choice" Busway Transit Riders[1/]	Busway Carpool Drivers	Busway Carpool Passengers
Did not make present trip[2/]			
Used Auto	30%	22%	18%
Used Bus	23	9	9
Other	4	1	2
Drive alone	19	23	16
Alternating driver in carpool	3	23	20
Drove in carpool	5	3	2
Passenger in carpool	3	4	4
Bus	8	12	24
Other	5	3	5
TOTAL	100%	100%	100%

1/ Riders who had an automobile available for their work trip (includes 81 percent of all busway transit riders).

2/ Users who did not have a prior mode for their present trip, their prior condition having involved a different residence or workplace. The modes shown are those for the comparable prior trip.

Table 13

Prior Travel Mode of Priority Facility Users[1/]

(140*, 309*, 310*, 397#, 461*, 533#, 686, 687*)

	Shirley Highway[2/] Washington, DC		NW 7th Avenue Miami, FL	Banfield Freeway Portland, OR		San Bernadino Busway[3/] Los Angeles, CA	
	Bus Passengers	Carpoolers	Bus Passengers	Bus Passengers	Carpoolers	Bus Passengers	Carpoolers
Prior Mode							
Auto Driver	41%	39%	49%	44%	47%	58%	43%
Auto Passenger	12	30	15		35	16	9
Bus	38	25	22	47	18	10	32
Other/Did not make trip	9	6	14	9	—	16	16
Priority Treatment	Separate Roadway		With-flow Arterial	With-flow Freeway		Separate Roadway	

	US 1[4/] Miami, FL	I-95 Miami, FL		Kalanianaole Highway[5/] Honolulu, HI	Moanaluo Freeway[5/] Honolulu, HI
	Bus Passengers	Bus Passengers	Carpoolers	Carpoolers	Carpoolers
Prior Mode					
Auto Driver	69%	50%	60%	43%	37%
Auto Passenger	8	9	23	45	43
Bus	17	16	12	3	3
Other/Did not make trip	6	25	5	9	17
Priority Treatment	Contra-flow Arterial	With-flow Freeway		Contra-flow Arterial	With-flow Freeway

1/ Table derived making certain assumptions about the occupancy of prior mode carpools.

2/ Derived making certain assumptions about prior mode of non-choice bus riders, auto occupancy, and the number of members in alternating driver carpools. Those who did not previously make their present trip are assigned to the mode used for their corresponding prior trip.

3/ Bus passengers 1974; Carpoolers 1977. A separate analysis of only those who shifted mode during carpool introduction onto the busway gives differing results, e.g., a bus prior mode for carpoolers of 24%.

4/ No data for accompanying with-flow carpool priority lane.

5/ No data on prior mode of express bus riders.

percent of all bus riders on the New Jersey I-495 contra-flow bus lane approaching the Lincoln Tunnel who were diverted from other transit routes (187[+]), and in the 1,900 loss in daily local bus ridership which accompanied the 5,000 express bus ridership gain in the I-35W corridor of Minneapolis (401#). Of the carpool increases achieved in Los Angeles at the Lakewood Boulevard and Hawthorne Avenue I-405 preferential entry ramp meter bypass lanes, as previously noted, approximately one-half were newly formed carpools and the other half were existing carpools diverted from alternative routes (227*). On the other hand, it was concluded that the growth of carpools on the San Bernadino Freeway upon opening of the busway to carpools was not caused by diversion of carpools from parallel roadways (140*).

Impacts on Traffic Volumes

Table 14 gives changes in vehicle volumes and auto and bus person volumes along the highway in question after implementation of various major priority lane projects. In all cases, person volumes rose at a greater rate than did vehicle volumes or decreased less than vehicle volumes. The ratio of person to vehicle volumes thus increased without exception (67, 140*, 310*, 397#, 461*, 533#, 563*, 687*). Figure 3 depicts one aspect of this phenomenon; the increases in highway auto occupancy accompanying the introduction of carpool priority.

In only two applications, South Dixie Highway and NW 7th Avenue in Miami, did vehicle volumes decrease while person volumes increased. The two instances in the United States where both vehicle volumes and person volumes declined (Boston and Los Angeles) were the two "take-a-lane" projects now terminated. Increased congestion on the regular lanes is reported to have caused some low-occupancy vehicle drivers to divert to parallel arterials. In addition, construction and seasonal fluctuations accounted for some of the decrease in Boston (563*).

Figure 4 illustrates changes in auto and person volumes in the Shirley Highway corridor during the 1970 through 1974 priority roadway development period. These data are of particular interest because they cover a 4-mile wide band which includes parallel highways. The impact on an entire urban sector is thus shown. Carpools were permitted access to the priority roadway in December 1973, the beginning of the peak of the 1973-74 fuel shortage.

Impacts on VMT, Energy and Environment

The diversion of commuters to high occupancy vehicles is the primary agent of VMT reduction in pool/bus priority facility projects. Energy use and pollutant emissions are affected by this VMT reduction and also by traffic flow condition changes. Separate facility, "add-a-lane," and most contra-flow lane projects inherently result in automotive fuel savings because of simultaneous reduction in vehicle use and improvement in overall traffic flow. "Take-a-lane" projects, because non-priority traffic and average overall traffic may be slowed, may not save energy even though VMT is reduced. The following illustrative estimate, constructed using the Miami-I-95, Portland-Banfield Freeway, Honolulu-Kalanianaole Highway and Los Angeles-Santa Monica Freeway projects as a guide to travel time effects, illustrates the marginal energy impact potential of "take-a-lane" strategies (673):

Table 14
Impacts on Traffic Volumes of Selected HOV Priority Treatments
(67, 140*, 309*, 397#, 461*, 533#, 563*, 687*)

Type of Treatment	Location	Change in Vehicle Volume	Change in Person Volume	Time Frame
Separate Roadway	Washington-Shirley Highway	+ 0.4%	+15%	1970 - 1974
	Los Angeles-San Bernadino Freeway 1/	+ 7 (AM) + 3 (PM)	+12 (AM) + 5 (PM)	1976 - 1977
With-Flow Freeway Lanes	Boston-Southeast Expressway	-21	- 8	1977 - 1977
	Los Angeles-Santa Monica Freeway	- 9	- 2	1976 - 1976
	Miami-I-95 2/	+ 5	+14	1976 - 1977
	Portland-Banfield Freeway	+ 3	+ 9	1975 - 1977
	San Francisco-U.S. 101 3/	+ 4	+ 6	1974 - 1976
Contra-Flow Street Lanes	Miami-South Dixie Highway	- 3	+13	1974 - 1975
	Honolulu-Kalanianaole Highway 4/	+ 3	+12	1974 - 1977
With-Flow Street Lanes	Miami-NW 7th Avenue	-13 (AM) - 8 (PM)	+18 (AM) +14 (PM)	1974 - 1976

1/ effect of shift from bus-only to mixed mode operations.

2/ carpool defined as 3+ persons; later changed to 2+ persons.

3/ includes contra-flow section.

4/ includes with-flow freeway section.

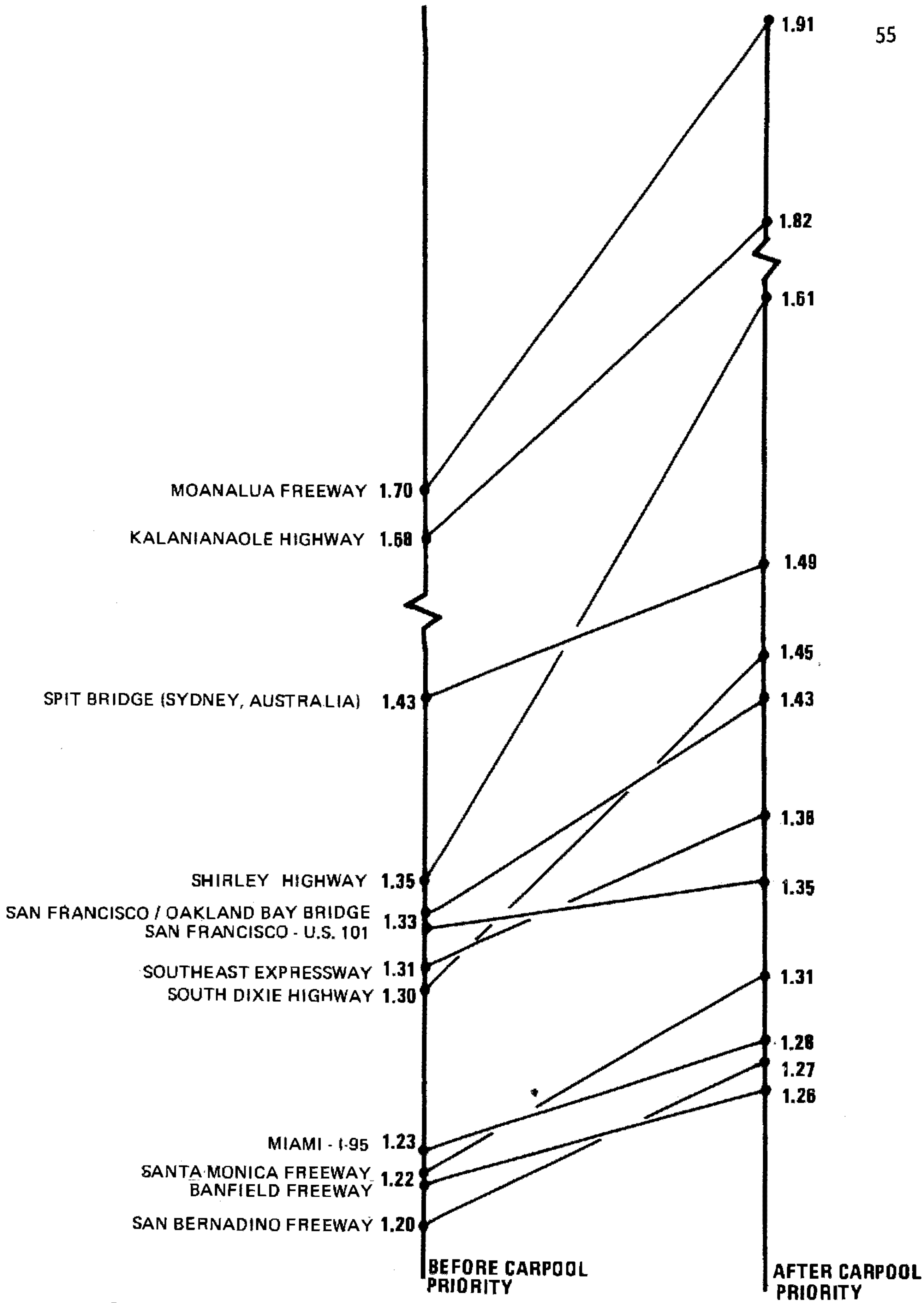
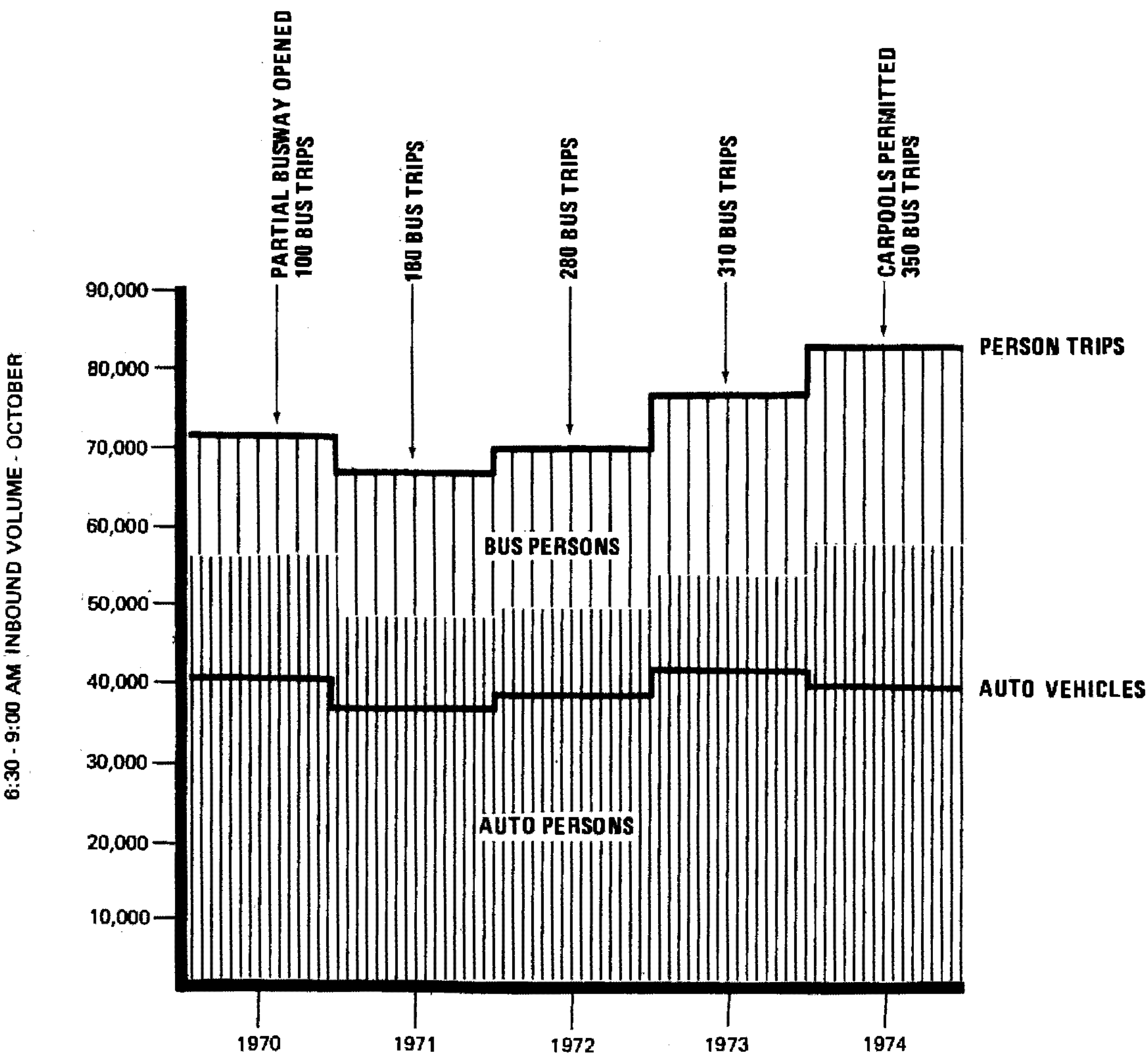


Figure 3
Changes in Auto Occupancy for Highways with Carpool Priority



Note: More recent facility data, not compatible, are given in the text under " Response to Separate Priority Facility Roadways".

Figure 4
Shirley Highway Corridor Usage Trends
(397#)

	Percent Change (within the travel market)		
	VMT (Assumed)	Fuel Per VMT	Total Fuel
"Add-a-lane" example	-5%	-2.4%	-7.3%
"Take-a-lane" example	-5	+4.8	-0.4

Reliable assessment of the VMT, energy and environmental impact of pool/bus priority facilities requires taking into account several factors which have been considered to varying degrees in currently available studies. In addition to the traffic flow impacts already mentioned, these factors include the auto travel required for access to pool/transit fringe parking lots, carpool trip circuity to pick up passengers and gain facility access, increased bus miles of travel, and induced auto trips made with those autos newly left at home. A rule of thumb that takes account of auto access and carpool circuity is that 35 to 45 percent of the gross VMT reduction offered by pool/bus priority facility strategies is counterbalanced by VMT incurred in these activities (673). Analysis of San Bernadino busway VMT savings (bus riders only) showed that 41 percent of the gross VMT reduction was counterbalanced by access requirements plus another 16 percent by use of autos left at home (148#). This dilution of VMT savings applies only to total VMT; it does not affect volume, congestion or localized emissions reduction benefits along the main line facility.

No urban area has yet made areawide application of a fully comprehensive program of high occupancy vehicle priorities. Corridor level experience has been extrapolated to provide estimates of the short term VMT, fuel use and emissions reductions that could be achieved from areawide program implementation in a large, prototypical urban area. The estimated average weekday reductions for alternative program combinations are given in Table 15. The automotive fuel savings estimates for the implementation of an areawide arterial bus-lane program range from 0.12 to 0.22 percent of annual consumption. For the same prototypical city, a program of freeway bus and carpool lanes, ramp metering and bus bypass lanes was estimated to be equally effective in saving fuel and better from an air quality standpoint. When this program was combined with a carpool/vanpool promotion effect, estimated energy savings (0.6 to 1.1 percent) were significantly higher. The contribution of the ramp-metering and bus by-pass component of the program was minimal, less than 0.1 percent of annual auto fuel consumption (171).

Impacts on Bus Service Costs

Bus priority treatments tend to be economically beneficial to transit operations but conditions can vary markedly from case to case. The labor intensiveness of bus operation is reduced at higher operating speeds, safety is usually improved and per-mile maintenance costs are reduced. Time savings and increased reliability make it possible to shorten the scheduled running and layover time for buses, and as a result the number of buses required can often be lowered, even in the case of relatively short surface street bus lanes. If priority treatment leads to more ridership without need

Table 15
Estimated Protypical Urban Area Impact of Priority Facility Programs
(171)

Strategy	Range	Change in Regional Weekday VMT: As % of Total VMT	Change in Regional Weekday VMT: As % of Work VMT	Change in Regional Weekday Emissions in Tons: HC	Change in Regional Weekday Emissions in Tons: NOx	Change in Regional Weekday Emissions in Tons: CO	Change in Regional Annual Highway Fuel Consumption in Gallons
Reserved median lane for express buses on appropriate arterials	Modest Impacts	-0.23%	-0.8%	+2.1	-0.4	+37.2	-1,600,000
	Favorable Impacts	-0.38	-1.3	-0.7	-0.6	+5.8	-2,900,000
Reserved pool/bus lanes, ramp metering and bus by-pass lanes on all appropriate freeways	Modest Impacts	-0.25	-0.8	-0.3	-0.5	+2.6	-1,500,000
	Favorable Impacts	-0.44	-1.5	-2.5	-0.4	-17.9	-2,700,000
Same as above plus carpool/vanpool program	Modest Impacts	-1.0	-3.3	-4.5	-1.6	-29.0	-7,300,000
	Favorable Impacts	-1.9	-6.5	-10.9	-3.3	-83.9	-14,200,000
Carpool/vanpool program only	Favorable Impacts	-1.5	-5.0	-8.3	-2.8	-63.4	-11,600,000

for additional buses, farebox revenues increase without concommitant increase in cost. However, when additional equipment is required to handle or induce increases in peak period ridership, net costs may rise, particularly if there are not also increases in off-peak patronage. The cost effectiveness of additional service will often be determined by the degree to which express service can command a higher fare than standard peak period service (187+, 357, 695).

Several projects have reported benefits to transit operators in terms of increased reliability and operating speeds along with increased passenger revenue, though few have cited quantified cost savings. It is estimated that priority lanes on US 101 north of San Francisco reduced operating costs by 2 percent annually or $240,000/year (1975 dollars), primarily though reduced labor requirements. The Ottawa River Parkway priority lanes obviated the need for four buses and reduced platform hours by 5,150, representing capital cost savings of $428,000 and annual operating cost savings of $128,000 (1980 Canadian dollars). Shorter priority lanes have shown correspondingly smaller savings with Chicago's Washington Street saving an estimated $25,000/year in operating costs and 30 applications in London saving an average of $8,000/year (passenger travel time value included) (67, 695). Operating costs associated with major express bus systems operating on priority facilities are discussed in the "Impacts on Cost/Revenues" section of the "Express Transit" topic area.

Impacts on Safety

Despite the unusual and seemingly hazardous traffic patterns inherent in some priority lane applications, particularly those of the contra-flow variety, safety has not been compromised in the majority of projects examined. In fact, safety appears to be more of a problem for with-flow lanes than for contra-flow lanes. In some applications the accident rate rose initially, then declined to a level at or below the rate prior to project inception (187+, 695).

Contra-flow lanes on New Jersey I-495 near New York City, the Long Island Expressway and Boston's Southeast Expressway are all reported to have had a favorable accident experience. Numerous accidents occurred along the San Juan arterial contra-flow lane when it first opened, but the accident rate apparently then declined to a level lower than the pre-bus lane experience. Conversion of two-way street operation to one-way street operation with a contra-flow bus lane reduced total accidents by 51 percent along College Avenue in Indianapolis. No significant long term safety problems were reported for the contra-flow lanes on U.S. 101 north of San Francisco, Marquette/Second Avenues in Minneapolis, Kalanianaole Highway in Honolulu and applications in Paris and London. Accidents along Miami's South Dixie Highway increased 66 percent during the first nine months of contra-flow lane operation. Long term effects were not available (67, 187+, 310*, 357, 533#, 695).

Accidents associated with priority with-flow lanes arise from the differential speeds of priority lane and non-priority lane vehicles, and from weaving of non-priority vehicles into and out of the priority lanes to avoid congestion (67, 140*, 563*). Auto accident rates declined after buses began operating in an exclusive lane on NW 7th Avenue in Miami, however bus accident rates more than doubled. Overall accident rates also doubled on the sections of highway where with-flow lanes were added on US

101 near San Francisco and on the Santa Monica Freeway. The number of bus accidents on the San Francisco-Oakland Bay Bridge declined from 20 to 13 in the year after the bus lane was implemented. The Banfield Freeway in Portland, Honolulu's Moanalua Freeway, I-95 in Miami and Boston's Southeast Expressway reported no rise in accidents associated with the advent of with-flow lanes (67, 68, 309*, 357, 461*, 563*, 687*).

Allowing carpools onto the Shirley Highway Busway led to only four bus-carpool accidents in 1974, all non-injury sideswipes. The addition of carpools to the San Bernadino Busway gave rise to accident rates similar to the regular freeway lanes along those sections not physically separated from the freeway (140*, 397#).

Public Acceptance and Enforcement

Public acceptance hinges to a large extent on the method used to create priority facilities. Where capacity heavily used by regular traffic is not affected by the provision of the priority facility, public reaction has generally been favorable. Such situations include utilization of the "add-a-lane" strategy, a new separate roadway or a peak period contra-flow lane. Where priority lanes have been formed by removing freeway lanes from regular peak direction service, as with the "take-a-lane" strategy, public and media opposition has often been vehement. With-flow lane projects on Boston's Southeast Expressway and Los Angeles' Santa Monica Freeway were both cancelled after less than six months of operation due to public outcry, despite favorable transit patronage and ridesharing results (140*, 309*, 310*, 461*, 563*). Designation of a previously mixed-mode lane on an arterial street (Miami's South Dixie Highway) as a priority with-flow lane apparently did not evoke as negative a response (533#).

The efficacy of priority facilities for carpools is to a large degree dependent on voluntary or enforced compliance with the minimum passenger restrictions adopted for the HOV lanes. Boston and Miami provide two prime examples. Initial lax enforcement on Boston's Southeast Expressway resulted in violators accounting for 80 percent of the priority lane vehicles. Stepped up enforcement reduced this amount to 35 percent while increasing the number of carpools by 30 percent. Redesignation of the minimum passenger requirement for carpools on Miami's I-95 from 3 persons to 2 persons lowered the violation rate in the lane from 75 percent to 37 percent. The number of 3-or-more person carpools decreased by 15 percent.

Bus-only facilities report few violators due to the ease of violator identification. Similarly, exclusive right-of-way and contra-flow facilities are easy to control because entry and exit is typically restricted to a limited number of locations. Table 16 lists the percentages of priority lane vehicles using the HOV lane illegally for several projects (67, 95*, 246, 309*, 310*, 461*, 538, 563*, 593+, 687*).

Additional References

National Cooperative Highway Research Program Report 143, "Bus Use of Highways" by Herbert S. Levinson, William F. Hoey, David B. Sanders, and F. Houston Wynn (357) and NATO Committee on the Challenges of Modern Society Report 45 "Bus Priority

Table 16
Violator Percentages in HOV Lanes
(67, 95*, 246, 309*, 310*, 461*, 538, 563*, 593+, 687*)

Location	Facility Type	Percent Violators in HOV Lane
Boston - Southeast Expressway	With-flow freeway	80% (pre-enforcement) 35 (during enforcement)
Miami - I-95	With-flow freeway	75 (3-person phase) 37 (2-person phase)
Los Angeles - Santa Monica Freeway	With-flow freeway	10-20
Sydney - Spit Bridge Corridor	With-flow arterial	20-25
San Francisco - I-280	With-flow freeway	80 16 (during enforcement)
Los Angeles - 90 ramp bypasses	Ramp bypass	30 (10%-56% range)
Miami - NW 7th Avenue	With-flow arterial	3-6[1/] (bus-only lane)
San Francisco - U.S. 101	With-flow freeway	15-25 (PM peak hour)
San Francisco - Route 580	With-flow freeway	30
Los Angeles - San Bernadino Busway	Separate roadway	10
Honolulu - Kalanianaole Highway	Contra-flow arterial	10
Honolulu - Moanalua Freeway	With-flow freeway	5-15
Portland - Banfield Freeway	With-flow freeway	12
Washington - Shirley Highway	Separate roadway	3

[1/] Percent of total automobile traffic.

Systems" edited by F.V. Webster, P.H. Bly and M.A. Budillon (695) provide two major sources of additional literature, case study reviews and references concerning Pool/ Bus Priority Facilities. Both emphasize bus applications and the latter presents both European and North American experience. For additional material on Pool/Bus Priority Facilities consult references:

6, 8+, 10, 11, 14, 18, 20, 59, 60, 65, 67, 68, 72, 83, 87, 93, 95*, 99, 102, 111, 134, 137, 139, 140*, 141, 144, 146, 147, 148#, 159, 171, 186, 187+, 195, 198, 199, 205, 216, 223, 227*, 230, 235, 243, 246, 258, 271, 273, 301, 309*, 310*, 311, 330, 336, 349, 357, 358, 361, 383, 387, 394, 397#, 401#, 406, 420, 422, 448, 452, 461*, 464, 474, 484, 499, 502, 504, 505+, 512, 532, 533#, 538, 562, 563*, 580, 582, 589, 593+, 603, 604, 625, 647, 649+, 651, 654, 662, 664, 669, 670, 671, 673, 684, 686, 687*, 689, 695.

95. California Department of Transportation. Ridesharing Facilities and Services. Prepared for the Senate of the State of California, March, 1979. 56 pages. POOL/BUS PRIORITY FACILITIES*. OBSERVED RESPONSE. TRAVEL CHOICE, VOLUME. ENERGY, AIR QUALITY.

This document, prepared for the California legislature, summarizes the operational experience of bus and carpool lanes, ramp meter bypass lanes, HOV parking facilities and ridesharing services in California through 1978. Programmed and proposed future ridesharing activities are also listed.

An exclusive bus lane opened in 1970 plus two exclusive carpool lanes opened in 1971, mile in length, permit peak period HOV's to bypass congestion at the San Francisco-Oakland Bay Bridge toll plaza and a metering gate downtstream form the toll plaza. In addition, carpools are permitted free passage in contrast to the 75¢ charge (60¢ if purchased in quantity) levied on other vehicles. During the period September 1974 to November 1978, traffic on the bridge increase 7% and the number of carpools increased 58%. The exclusive lane is used by 100 PM hour buses and 250 AM peak hour buses. Average carpool time savings are 5-8 minutes in the morning and 2-5 minutes in the evening over regular traffic. Of the vehicles using the lanes, 2-6% are violators. Carpool 6:00-9:00 AM volumes as they relate to changes in the operation of the facility are listed below. "BART opened" refers to initiation of service in the parallel San Francisco-Oakland rail transit tube.

Before carpool lanes opened (1971)	1,200 carpools
Toll-free carpool lanes opened (1971-72)	2,200
$1/month/carpool toll levied (1972-74)	1,700-2,000
Transit Strike (1974)	4,600
BART opened, carpool toll remaining (1974-75)	1,900-2,100
Toll removed for HOV's (1975-77)	2,300-2,900
Toll increased for other vehicles (1977)	3,000
Bus Transit Strike (1977-78)	3,800
Volume at time of report (1978)	3,100

A 7.7 mile long combined contraflow bus lane (opened in 1972) and concurrent flow bus/carpool lane (opened to buses in 1974 and to carpools in 1976) stretches north from the Golden Gate Bridge into Marin County on Route 101. The contraflow section, the southern 4 miles, is open from 4-6:30 PM and is used by 130 northbound buses, 100 during the peak hour. The primary benefit is bypassing congestion when incidents in the regular travel lanes occur. The northern 3.7 miles, running in both directions, carries 100 buses, 400 carpools and 30 violators southbound during the AM peak hour and 70 buses, 180 carpools and 20 violators northbound during the PM peka hour. Interestingly, 375 AM peak hour carpools and 745 PM peka hour carpools travel in the regular lanes. Time savings for the 1977-78 total traffic increased 1.5%/year while carpool volumes increased 12%/year. Carpools are permitted to travel toll-free across the Golden Gate Bridge. The peak hour carpool volume on the bridge was 700-800 carpols before the carpool strategies were implemented, increased to 1000-1200 when the Route 101 lane opened and was 1,300 at the time of the report. Public reaction has been favorable and only 10% of all accidents involve vehicles in the ridesharing lanes.

In 1977, 2.4 miles of Route 580 freeway in Alameda County were opened including 6 AM - 6 PM weekday HOV with-flow priority lane in both directions. Seven buses, 130 carpols and 60 violators use the westbound lane in the AM peak hour and eastbound PM volumes are similar. Weekday ADT is 1,300 per exclusive lane and 14,300 per regular lane. Maximum time savings for carpools is 1-2 minutes. The lanes are to be extended in the future despite initial public criticism.

Over 90 ramp meter bypasses, mostly in the Los Angeles region, afford average time savings of 1½ minutes for the buses and/or 2+ person carpools permitted to use them. There has been a 25% increase overall in HOV's on ramps with bypass lanes. The violation rate has been 10%-56% averaging 30%.

140. Crain and Associates. San Bernadino Freeway Express Busway: Evaluation of Mixed-Mode Operations. Prepared for Southern California Association of Governments. Sponsored by Urban Mass Transportation Administration, U.S. Department of Transportation. Final Report; UMTA-CA-09-0059-78-1. July, 1978. 204 Pages. NTIS PB 285-913. POOL/BUS PRIORITY FACILITIES*, POOL/TRANSIT FRINGE PARKING, COLLECTION/DISTRIBUTION TRANSIT, EXPRESS TRANSIT. OBSERVED RESPONSE. MODE CHOICE, AUTO OCCUPANCY. REVENUES/DEFICITS.

In October 1976, seven miles of an eleven mile exclusive bus facility, linking Los Angeles with its eastern suburbs along the San Bernadino Freeway, were opened to three-or-more person carpools during peak periods. In October 1977, the remaining four miles were opened to carpools also. The $57 million facility was originally opened for buses in stages beginning in 1973. It has two on-line stations, park-and-ride lots, feeder bus services, outlying park-and-pool lots, HOV-only access ramps and access to a contra-flow bus lane in the CBD. During the bus only phase, bus ridership grew from 3,200 to 14,500 trips/day in the 2 years from when the 1,400 space park-and-ride lot at the busway's eastern terminus was opened until it reached capacity. Subsequent rerouting of bus routes onto the busway has raised busway patronage to 18,000 trips/day. A survey during this time indicated that 75% of the busway users formerly used a car for the trip, half driving alone. Only 10% were former bus riders. Buses have captured 24% of service area to CBD travel.

The current study specifically addresses impacts related to the conversion to mixed-mode operation. Two carpool surveys were conducted, one during the initial mixed-mode phase and one in November 1977 when the entire facility was open to carpools. In the second survey, responses were received from 43% of the 2,300 questionnaires distributed at two ramps. Single occupant auto drivers were also surveyed as were bus riders. Bus timings, auto travel time runs, vehicle counts and vehicle occupancy observations were made along with some data collection on parallel facilities. Comparisons between before and after travel on the San Bernadino Freeway and the Pamona Freeway which parallels it but has no priority facilities are provided below for the 6-10 AM period. Note that some 30% of San Bernodino Freeway carpools use the regular lanes.

	San Bernadino Fwy.			Pamona Freeway		
	Before	After		Before	After	
autos & buses	27,700	29,700	(+7%)	30,400	31,900	(+5%)
persons	38,100	42,600	(+12%)	36,100	37,900	(+5%)
auto occupancy	1.20	1.27	(+6%)	1.19	1.19	(—)
carpools	670	1,720	(+157%)	580	800	(+38%)

Results for the PM period showed less dramatic changes and smaller differences between facilities. Buses and carpools travelling the full length of the facility realize a travel time savings between 13 and 20 minutes during the AM peak hour and between 6 and 10 minutes during the PM peak hour over regular traffic and obtain greater reliability. During the peak one hour, the busway carries twice as many people as the average freeway lane at approximately 2/3 the capacity of the busway. The violation rate on the median portion is 6% of the vehicles on the busway, and is negligible on the portion constructed on exclusive right of way. The accident rate is similar to that of other freeways in the vicinity in that all have been experiencing increased accident rates of about the same magnitude. An accident problem area is access lanes to the busway, where violations can occur easily. The busway eliminates an estimated 150,000 VMT/day in mixed-mode operation as compared to 100,000 VMT/day as a bus-only facility. Introduction of carpools to the busway did not noticeably affect bus travel times or transit ridership, however, a 25% fare increase a short time afterwards did result in a ridership loss of 1,000 persons during the four hour peak of which an estimated 200 formed carpools. Of all busway carpools, 72% have been formed since carpools were permitted on, 49% of the pools would not exist without the busway, 47% of the poolers use another vehicle to access the carpool, 39% of the carpool vehicles pay for parking (average-$15/month) and 29% of the carpoolers have employer-sponsored carpool incentives (14% monetary). Although 42% of the single-occupant vehicle drivers pay for parking, the average is only $3/month while 24% of their employers offer carpool incentives (6% monetary). Prior to using the busway 39% of the carpoolers drove alone, 12% were in 2-or-more person autos, 32% traveled by bus and 16% did not make the trip. More poolers cited cost than time or convenience as their reason for pooling. The average round trip carpool distance was 50 miles, 0.5% of this for pick-up and drop-off. The busway and the use of the busway by carpools received overwhelming support from all surveyed groups.

227. Goodell, Robert G.B. Preferential Access for Multi-Occupant Vehicles at Metered On-Ramps. Freeway Operation Branch, California Department of Transportation. Undated. 12 pages. POOL/BUS PRIORITY FACILITIES.* OBSERVED RESPONSE. AUTO OCCUPANCY, ROUTE CHOICE.

A preferential freeway entrance lane was opened in June 1973 on the southbound entrance ramp to the San Diego Freeway, in Long Beach, California, from southbound Lakewood Boulevard. Use of the lane was restricted, on weekdays between 3 and 6 PM, to vehicles carrying 2 or more occupants. The lane bypassed the freeway ramp meter (signal) queue. This was the first preferential entry lane in the Los Angeles area and the site was deliberately picked for its high chance of success. An origin-destination survey showed that during the PM peak hour, over 90% of the vehicles using this ramp originated around the McDonnell Douglas Corporation complex just to the north and drove to Orange County, thereby providing excellent potential for carpool formation. The freeway ramp was already metered prior to implementation of the carpool lane, but with only 1 of 2 available ramp lanes open. Behind the ramp meter, backup queues of 30 to 35 vehicles and delays of 7 to 9 minutes were being experienced during certain periods. The average occupancy rate between 3:30 and 6:00 PM was 1.23, and 17% of the vehicles were multi-occupant automobiles.

Prior to implementation, an extensive but localized information and publicity campaign was carried out using handouts to ramp users, notification of McDonnell Douglas employees, and a news release to the local newspaper. On the first day of operations the number of carpools using the ramp from 3:30 to 6:00 PM jumped from 125 to 208. By the end of the first week there were 294 carpools, and from the second week of operation throughout the summer vacation season the average daily use of the lane was 275 carpools, a 120% increase over "before" conditions. Of the 275 carpools (including 12 to 25 a day which still used the metered lane), 66% were 2-person carpools, 22% 3-person, and 12% 4-person or more. The average occupancy of all vehicles using the ramp increased by 23% to 1.51.

Counts of 5 nearby ramps and adjacent streets showed no significant difference in the number of carpools, before and after, on alternate routes. However, returns from a handout questionnaire given to carpoolers using the exclusive lane 10 weeks after the start of the project did identify some route diversion. Preliminary analysis indicated the formation of 80 to 100 new carpools, the shifting of 50 to 70 carpools from other ramps or city streets, and the expansion of 20 to 25 carpools to include more occupants. The analysis also indicated that between 160 and 180 of the passengers in these carpools formerly drove alone. Some of the carpools diverted from other routes probably drove previously to a ramp 2 miles downstream which, since it was beyond a bottleneck on the San Diego freeway, had a high metering rate.

Public reaction to the carpool lane was generally favorable, with no formal complaints having been received during the first 3 months. The violation rate was 3% of all single occupant vehicles on the ramp for the first 3 weeks, when enforcement was relatively strict. The rate of violation went up to 5% in the next 2 weeks, when enforcement was lax, dropped to 3% in the sixth week when persistent violators were citied, and rose to 7% in the next 6 weeks when no enforcement methods were employed.

309 and
310. Kaku, D., F. Yamamoto, F. Wagner, M. Rothenberg. Evaluation of the Moanalua Freeway Carpool/Bus Bypass Lane and Evaluation of the Kalanianaole Highway Carpool/Bus Lane. JHK and Associates. Sponsored by Office of Research, Traffic Systems Division, Federal Highway Administration, U.S. Department of Transportation. Final Reports; FHWA-RD-77-99 and 100. August 1977. 125 pages and 142 pages. NTIS PB 275-205 and 275-232. POOL/BUS PRIORITY FACILITIES*. OBSERVED RESPONSE. MODE CHOICE, VOLUME. REVENUES/DEFICITS.

In late 1974, the Moanalua Freeway, linking Honolulu with its western suburbs, was widened from four to six lanes and upgraded to interstate standards. The median lane for 2.66 miles inbound and 1.33 miles outbound was reserved for buses and 3+ person carpools 24 hours a day. In September, 1975 one lane of a 2.5 mile long portion of Kalanianaole Highway, the only major highway serving the area east of Honolulu, was designated an inbound 3+ person carpool/bus priority lane for the morning peak period, after having been an exclusive bus lane since 1973. The priority lane is contra-flow for 1.9 miles where the highway is four lanes undivided before becoming with-flow for the remaining 0.6 miles where Kalanianaole Highway is six lanes divided.

Data for these studies were obtained through point-to-point travel time observations, mail-back surveys of highway users, interviews with officials, and traffic observations yielding volume counts, mode splits, and violation rates. Information is for the 6-8 AM inbound peak in non-summer months unless otherwise noted. Because of the upgrading of the Moanalua Freeway, using "before" data for comparison purposes was judged to be unsound at this location. For this reason, the primary comparison period is between December, 1974, soon after the inbound priority lane was opened, and October, 1976, before the opening of another freeway serving the same corridor. True "before and after" counts were made for the Kalanianaole Highway but changes in bus usage could not be determined since buses had access to the facility before the study began.

The Moanalua Freeway carried approximately 12,000 AM peak period persons in both December, 1974, and October, 1976, but the number of vehicles decreased 9% with an average auto occupancy increase from 1.70 to 1.91. Carpools in the carpool/bus lane accounted for 29% of the vehicles and 49% of the people on the three lanes in October, 1976 and exhibited an average occupancy of 3.28 as compared to 1.38 in the regular lanes. Bus service was minimal and operated at near capacity loads carrying 3% of the people. Results from Kalanianaole Highway are similar, on a smaller scale. Average auto occupancy at two locations increased from 1.65 to 1.79 and from 1.70 to 1.84. Approximately 10% of person-trips on the highway are made by bus. Forty percent (40%) of the person-trips and 20% of the vehicle-trips are carried in the priority lane. Results from the Moanalua Freeway and Kalanianole Highway surveys indicate that 13% and 8.6% respectively of Freeway/ Highway auto users switched from one and two person autos to carpools while 2.6% and 2.8% did the reverse. Of those who switched to carpools, time savings were cited by most as "very important" while inadequate bus service and cost savings were thought "very important" by about one-third. Measured travel time savings (in minutes) for HOV lane vehicles over regular lane vehicles are given below for two non-summer months in comparison with the perceived time savings reported by survey respondents:

	Actual Savings		Perceived Savings	
	Average	Maximum	Poolers	Non-poolers
Moanalua Freeway	3.6-3.7	10	11.3	7.9
Kalanianaole Highway	2.0-2.9	8.5-12	11.0	9.0

The violation rate was 3% to 12% of vehicles in the priority lane on the two highways once enforcement was stabilized. The accident rate on the Moanalua Freeway is comparable to that on the new H-1 Freeway; 6% of both vehicles and accidents are in the reserved lane. The accident rate on the inbound Kalanianaole Highway increased 10% in the after condition, however, the total number of accidents remained constant and one-third of them occurred in the priority lane. Of Moanalua and Kalanianaole passengers 47% and 64% respectively were children, and 71% and 83% of the carpools required child riders to qualify as a carpool. This statistic helps to explain a significant drop in pooling and person volumes during the summer. Sixty percent (60%) of the Moanalua respondents and 73% of the Kalanianaole respondents felt that the priority lane improved traffic flow, a perception confirmed by analysis. The projects resulted in estimated annual VMT reductions of 8.7 and 1.5 million miles respectively.

461. Oregon Department of Transportation, Metropolitan Branch. Banfield High Occupancy Vehicle Lanes. Sponsored by Office of Research, Traffic Systems Division, Federal Highway Administration, U.S. Department of Transportotion. Contract No. DOT-FH-11-9127. March, 1978. 124 pages. POOL/BUS PRIORITY FACILITIES*, EXPRESS TRANSIT. OBSERVED RESPONSE. MODE CHOICE, TRAVEL CHOICE. OBSERVED RESPONSE. ENERGY, AIR QUALITY.

On December 15, 1975, a concurrent-flow HOV lane was opened to buses and 3-or-more person carpools on Banfield Freeway, the primary route between Portland and its eastern suburbs. The 3.3 mile inbound and 1.8 mile outbound priority lanes were part of a reconstruction project which increased the cross section from 4 to 6 lanes, enabling non-HOV traffic to use 2 lanes in each direction both before and after project implementation. The Freeway has been characterized by above-capacity peak hour volumes and an increasing spread of the peak period during the past ten years. Initially, the project called for 24 hour enforcement and 45 mph speed limits. After 3 months only peak periods were designated as priority times and the facility was returned to a 55 mph limit. An intensive marketing effort, initiation of express bus service (the Banfield Flyer) and a carpool matching program accompanied the opening of the facility.

Data from speed and delay runs and from automatic traffic counters were supplemented by peak hour lane volume and auto occupancy counts made by inspection. Auto occupancies of greater than 3 were assigned a value of 3 leading to an estimated 11 percent undercount of carpool person trips based on spot checks. The data in this report were not corrected for this discrepancy. Questionnaires were distributed to determine travel patterns and attitudes; 310 forms to express bus passengers, 750 to HOV auto owners and passengers, and 2,250 to non-HOV auto owners. The response rate was 80% for bus passengers and 35-37% for auto owners/passengers.

Average weekday traffic volumes increased 4% after one year, 2% more than would have occurred due to normal growth. Weekday traffic on parallel arterials decreased 3% indicating diversion to the Banfield Freeway. Morning peak hour auto occupancy on the Freeway rose from 1.22 to 1.26, while the auto occupancy on other major highways into the downtown decreased slightly. The inbound HOV lane carries 20% of the people and 5% of the vehicles during the morning peak hour. Express bus ridership increased from 300 passengers per day in January, 1976, one month after initiation, to 633 passengers/day in June, 1977. The express service and exclusive lane are estimated to have increased bus patronage on the Freeway 43%. The number of carpools using the Banfield Freeway during peak hours increased from a range of 100 to 250 before the project to a fairly steady carpool count of about 500 in mid-1977. Forty-four percent of the express bus riders formerly rode in or drove cars (63% of these on Banfield) and 47% previously rode buses. Surveyed carpoolers indicated that 62% of the drivers and 41% of the passengers had previously been in one- and two-passenger autos (70% of the respondents previously commuted on the Banfield Expressway), while 41% of carpool drivers and 27% of carpool passengers switched from bus (18% of total carpoolers).

Average travel speed became 37.9 mph in the regular lanes and 51.5 mph in the priority lane in the inbound direction, equating to a travel time difference of 1.4 minutes over the length of the HOV lane. The violation rate in April-June, 1977, despite enforcement problems, was 12 percent of the vehicles in the priority lane. The accident rate per million VMT appeared unchanged. Analysis of accident statistics indicates that narrower lanes, absence of shoulders and differential speeds resulting from the lane are not causal variables in many accidents. It is estimated that the HOV lanes and express buses resulted in annual savings of 1.3 million VMT, 23,000 gallons of fuel and 62,500 person hours. Estimated pollutant emissions increased in absolute terms due to diversion of vehicles from other routes, but were reduced on a per person basis. The express bus rider survey revealed the following access mode split: drive alone - 55%, carpool - 15%, dropped off - 14%, walk - 12%. Sixty-nine percent indicated that the availability of non-stop service was a "factor affecting their decision" to use transit, 67% cited cost savings and 56% cited time savings. Carpool drivers indicated that cost savings were the most important incentive for pooling while carpool passengers cited both cost savings and convenience.

563. Simkowitz, Howard J. A Comparative Analysis of Results From Three Recent Non-Separated Concurrent-Flow High Occupancy Freeway Lane Projects: Boston, Santa Monica and Miami. Transportation Systems Center, Urban Mass Transportation Administration, U.S. Department of Transportation. Final Report. June 1978. 52 pages. NTIS PB 289-278. POOL/BUS PRIORITY FACILITIES*, POOL/TRANSIT FRINGE PARKING, EXPRESS TRANSIT. OBSERVED RESPONSE. MODE CHOICE, VOLUME.

Boston, Los Angeles, and Miami experimented in 1976 and 1977 with shared-roadway, concurrent-flow, high occupancy vehicle (HOV) lanes on freeways radial to the CBD. Boston created their HOV lane by redesignating an existing inbound lane, along 8 miles of the 3-4 lane Southeast Expressway. Los Angeles did the same, inbound and outbound, along 13 miles of the metered, 4-5 lane Santa Monica Freeway. Miami constructed a new lane in each direction on I-95 for 7.5 miles. Access to HOV lanes from the adjoining lane was essentially unrestricted in all cases and the 3+ person carpool rule was utilized. Both Boston and Los Angeles initiated a carpool matching project, a marketing campaign, and a telephone information service in conjunction with the HOV facility. Miami instituted a marketing strategy only. All three cities provided park-n-ride facilities and improved transit headways and feeder services. Los Angeles and Miami also substantially expanded their bus coverage in the target corridors.

The data in this report was garnered from separate studies and are presented in the aggregate without adjustment for exogenous factors. The short duration of the projects raises doubts as to whether the data reflects equilibrium conditions. Traveler response information for Boston is for inbound travel during the 3 hour AM peak period, for Miami it is for the inbound 2 hour AM peak period, and for Los Angeles, it is for 2-way travel during the 7 hour combined AM and PM peak periods. The following changes were recorded for the different stages of the three projects in comparison to conditions before the projects began:

	Travel Time: HOV Lane	Travel Time: Other Lanes	3+ Carpool Vehicle Volume	Corridor Bus Ridership	Total Vehicle Volumes	Total Person Volumes
Boston: before enforcement	-36%	-18%	+32%	+5%	-10%	-5%
after enforcement	-36	+43	+72	--	-21	-8
Los Angeles: first seven weeks	-6	+36	+25	--	-32	-27
last seven weeks	-6	+31	+65	+224	-9	-2
after termination			+5	+149	-1	+1
Miami: 3+ person stage	-41	-17	+74	+10	+5	+14 1/
2+ person stage	-41	-17	+51	+18	+20	+38 1/

1/ includes bus passengers previously travelling another route.

Table 10 of this Handbook provides additional data. The initial decrease in Boston travel time is attributed to a metering effect at the start of the HOV lane while the decreased Miami time is due to the additional capacity. Peak hour travel times in the regular lanes were often greater and highly variable. In Los Angeles an estimated 10% to 15% increase in volume occurred on adjacent arterial streets during the initial operation. Freeway travel times had been 45% higher prior to the implementation of ramp metering than immediately before HOV lane operation. The Santa Monica freeway accident rate increased by 193%, a result attributed in large part to the speed differential of HOV and adjacent lane vehicles. Park-and-ride lots in Boston and Los Angeles were judged failures, while in Miami a 1320-space lot was successful. In Los Angeles and Miami, where the prior market area of CBD transit mode split was 16% and 2% respectively, increased bus route coverage and express service had more impact on ridership levels than HOV time savings. In Miami, 50% of the auto users, 86% of the poolers, and 94% of the transit riders favored retention of the added HOV lane. In Los Angeles, 86% of auto drivers, including a majority of carpoolers, felt the lane redesignation was harmful or useless. The Boston project was terminated under political pressure two and a half weeks after enforcement began. The Los Angeles project was suspended by court action after five months. Miami achieved reasonable HOV lane utilization and decreased violations from 75% to 37% by dropping the carpool occupancy requirement to 2+ persons.

687\. Wattleworth, J.A., et. al. Evaluation of the NW 7th Avenue Express Bus and Bus Priority Systems. Transportation Research Center, Department of Civil Engineering, University of Florida. Sponsored by Florida Department of Transportation. Final Report UMTA-FL-06-0006. September, 1978. 128 pages. NTIS PB 291-137. POOL/BUS PRIORITY FACILITIES*, EXPRESS TRANSIT, POOL/TRANSIT FRINGE PARKING, TRAFFIC OPERATIONS IMPROVEMENTS. OBSERVED RESPONSE. MODE CHOICE, VOLUME. REVENUES/DEFICITS.

From April 1974 through March 1976 an uncongested 10 mile segment of NW 7th Avenue in Miami served as a demonstration corridor for 3 bus priority systems: a reversible exclusive lane, bus signal preemption and bus timed signal progression. Twenty-six (26) AM and 27 PM peak period express bus runs (the Orange Streaker) linked a 967 space park/ride lot at the confluence of 3 major highways with 4 employment areas, including Miami's CBD. The project segment had 35 signalized intersections and two auto travel lanes in each direction with a median bus lane. No travel lanes were taken from auto traffic to form the bus lane. The project ended when parallel HOV lanes opened on I-95. Data gathered included passenger and traffic counts, bus rider and carpooler surveys, telephone surveys of other travellers in the corridor, speed and delay runs and accident and violation statistics. The project had five stages, each with a different combination of priority treatments as follows:

Stage	No. of Days	Exclusive Lane	Signal Preemption	Signal Progression
0	162			
1	105	2.7 mi. southbound	X	
2	226	X	X	
3	38	X		X
4	29	X	X	X

The following vehicle and person volumes were recorded for the AM peak period (6:30-9:00):

Stage	0	1	2	3&4
Auto volume	1,634	1,797	1,445	1,392
Auto occupancy	1.30	1.29	1.28	1.28
Auto persons	2,121	2,313	1,852	1,775
Bus volume	0*	26	26	26
Bus passengers	0*	673	751	735
Total persons	2,121	2,986	2,603	2,510
Number of violators	—	—	74	45

* 500 passengers on 21 express buses operating in mixed traffic on I-95.

Express buses carried 3% of service market trips before the project and 8.6% during the project. Average bus and auto travel times over the 10 mile section for the five stages are listed below:

	AM travel time (minutes)				
Stage	0	1	2	3	4
Auto	27.3	25.0	24.0	20.6	21.7
Bus	26.3	21.2	18.5	20.1	19.4

Reliability improved for reserved lane and signal progression strategies, but deteriorated for signal preemption. The bus accident rate increased 180% between stages 0 and 4 while the auto accident rate declined. Forty-five carpools used the park-and-ride lot as a staging area. Of 640 vehicles using the lot, 34% did not park (7% carpools, 27% kiss-and-ride) and 66% did park (59% bus riders, 7% carpoolers). The authors estimate ridership would be 30% lower without the park-and-ride lot. Prior mode of bus riders was: auto driver 49%, auto passenger. 15%, bus 22%, didn't make trip 14%. Carpoolers and bus riders using the lot had the following access modes and destinations:

Access mode:	auto driver	auto passenger	dropped off	bus rider	other
carpoolers	85%	7%	4%	—	4%
bus riders	52%	3%	21%	18%	6%

Destination:	Miami CBD	Civic Center	36th Street	MIA/Coral Gables	Other
carpoolers	7%	20%	9%	7%	57%
bus riders	64%	19%	14%	1%	2%

VARIABLE WORK HOURS

Types of Programs

Variable work hours fall within the overall transportation system management category of "Actions to Ensure Efficient Use of Existing Road Space." Variable work hours programs include:

1. Staggered work hours, a fixed scheduling of work that normally spreads the employee starting and quitting times over a one to three hour period, with individual groups of employees designated to report and leave at 15 to 30 minute intervals (63, 187+, 222, 305, 446, 459*, 541*, 612).

2. Flexible work hours, a program allowing employees a degree of freedom in choosing their starting and quitting times. Employees must be at work during core periods (typically 9:30 to 11:30 AM and 1:30 to 3:30 PM) and must observe earliest allowed starting time and latest allowed quitting time limitations. Three typical program variations are (187+, 247*, 303, 304, 443*, 541*, 609, 612):

   a. Self-staggered start or "flexitour." Employees choose their individual start times on a periodic basis, but then must arrive at that time every day and work the standard number of daily hours.

   b. Modified flexitime or "floating day". Employees can choose their work start time each morning, but must then work the standard number of daily hours.

   c. Full flexitime or "gliding schedule." Employees can vary their starting time, time worked and quitting time each day, but must work a prescribed number of hours each week or other period.

3. The compressed work week, whereby the working hours are allocated into fewer than 5 days per week or fewer than 10 days per 2-week period. Because this type of program involves a longer working day than the standard, a staggered or flexible hours effect is achieved in addition to eliminating one day of commuting weekly or biweekly. Compressed work week schedules may be fixed, or flexible within limits. The two most common variations are (98, 569, 612):

   a. The four-day week. Employees work 9 to 10 hours per day, depending on the total hours per work week, 4 days a week.

   b. The 5-4/9 plan. Employees work approximately 9 hours per day, 5 days one week and 4 days the next, on a 2-week cycle.

Traveler Response Summary

A quarter to a half of all employees in a localized employment area can be expected to become involved in a variable work hours program if a dominant employer or an important employer or employee organization takes the initiative. The trip timing decisions employees make when given the option of flexible work hours are as effective as mandatory staggered work hours in spreading out work arrival and departure times. A large-scale program can smooth traffic peaks enough to reduce maximum 15 minute passenger and vehicular loads by 15 to 35 percent at terminal facilities such as rapid transit stations and major parking lots.

Variable work hour program effects dissipate, to become diluted by 50 percent or more, on radial transportation facilities serving the involved employment core. Even so, the impact may remain quite significant, particularly on transportation system elements such as radial bus routes. Maximum 15 minute bus passenger load reductions as great as 21 to 29 percent have been reported. The transportation system elements offering the least potential for peak period volume modification are those used heavily by traffic from diverse locations.

The majority of findings from actual program applications contradict any supposition of potential shifts to single occupant auto use in response to variable work hours, or of possible increases in total household travel in response to compressed work weeks. In the case of flexible work hours programs, there is evidence that carpooling may be facilitated and increased, as would logically be inferred. First year results for the Denver Federal employee compressed work week experiment show household vehicle miles of travel decreases for both work and non-work travel, with a 14 percent reduction overall for participating agency households relative to those of other agencies.

Employee attitudes toward staggered and flexible work hours are generally positive, with 80 to 95 percent of workers involved expressing a favorable overall reaction. The employee reaction to compressed work week programs is mixed, but appears to be favorable in current Federal worker programs. Most employers report increased or unchanged efficiency, on balance, under staggered and flexible work hours programs.

Program Objectives

The primary urban transportation objective of variable work hours programs is to effect work scheduling changes that will reduce the degree of vehicular traffic and transit passenger peaking that occurs during the normal workday. The idea is to spread out travel demand by achieving work hours changes for a segment of all employees in the employment areas involved. Of interest is not only a reduction of AM and PM peak hour traffic and passenger loads, but also a smoothing out of the sharply peaked loads often prevalent during short intervals within peak hours. The resultant reduction in peak transportation demand is intended to reduce rush hour highway congestion and transit overcrowding, and to alleviate pressures for new transportation facilities or transit vehicle scheduling designed solely to serve heavy peak period demands (187+, 303, 304, 446, 541*).

The compressed work week has the additional and overriding objective of eliminating some commuter travel outright. To the extent total travel is correspondingly reduced, energy conservation and pollutant emissions reduction goals are served (98, 612).

Variable work hours programs may legitimately have non-transportation objectives, particularly for employers. These may include improvement of employee morale, better punctuality and attendance, increased productivity and creation of an additional worker benefit (303, 446).

Employer Participation

The implementation of variable work hours, while transportation agencies may assist, inherently must be sanctioned and accomplished by the individual employers involved. The active support of a very large employer or an important employee or employer organization is a major factor in success (187^{+}). In Ottawa, where the Canadian Government is the dominant employer, it proved possible to include almost all government workers and thus almost 50 percent of central area workers in a variable work hours program (541*, 612). Staggered and flexible hours and compressed work week programs deemed effective in the Washington, DC and Denver areas have had U.S. Federal Government support (98, 187^{+}, 305, 569). About 100,000 out of some 480,000 Lower Manhattan employees eventually became involved in a program jointly sponsored by the Downtown-Lower Manhattan Association and The Port Authority of New York and New Jersey (446, 458, 459*).

In contrast, the Midtown extension of the Manhattan staggered work hours program yielded few concrete results. Baseline data was collected on only 300,000 out of 1.5 million area workers, and their ultimate participation rate is not known (446, 458). Similarly, the British Ministry of Transport was able to involve only 143 firms with 21,400 employees out of one million daily London commuters (187^{+}). Variable work hours programs in Vancouver, British Columbia, and Atlanta were cut short because of low participation among the firms contacted (117, 187^{+}). Reasons given for program failures include lack of contact with company officials able to make such decisions, employer fears of inefficiency and employee dissatisfaction, union disinterest and reticence, difficulties in achieving city bus rescheduling, and resistance to post 9:00 AM start times (117, 187^{+}, 303, 446, 458).

At least two studies have found that uninitiated employers prefer the concept of staggered hours to flexible hours. Investigators noted that in Manhattan virtually all firms found using flexible hours had previously used a staggered hours program of some sort, and recommended that initial program implementation be on the basis of staggered hours (117, 446). However, this may not be necessary or appropriate once flexitime and other alternative work schedules are more common in North America. The degree of comprehensive variable work hours program participation as of 1976 is indicated by the following statistics for seven North American urban areas with major program accomplishments (675):

Urban Region	Employees in Formal Variable Hours Programs	Percent of Total Employment: Overall Region	Percent of Total Employment: CBD Only
New York	220,000	3%	11%
Philadelphia	43,000	2	14
Toronto	68,000	7	26
Washington	200,000	16	40
Madison, WI	5,000	4	30
Riverside, CA	3,200	6	N.A.
Ottawa	33,000	N.A.	47

U.S.A. participation in compressed work week schedules grew to cover over 1,300,000 employees nationwide in 1975, but apparently steadied or declined in the latter part of the decade. Presently there is renewed interest, on the part of the Federal

Government, as shown by passage of the Federal Employees Flexible and Compressed Work Schedules Act of 1978 (P.L. 95-390)-(98).

Employee Participation

Once an employer adopts variable work hours for some or all departments, the individual employee may be given the choice of participating or not, or even of what type of program in which to participate. This degree of employee freedom of choice is not common, but is a feature of certain U.S. Federal Government experimental programs implemented under P.L. 95-390. Given three options, 15 percent of Federal Highway Administration (FHWA) employees in the Offices of Planning and Policy Development in Washington elected the standard 7:45 AM to 4:15 PM fixed schedule, 35 percent chose 5-day week flexitour, and 50 percent opted for the 5-4/9 compressed work week plan (569). In Denver, 65 percent of the employees in participating Federal agencies were on some form of compressed work schedule after one year (98). The FHWA-Washington and Denver comparative profiles of employees choosing a compressed work week schedule versus their 5-day week counterparts are in large measure contradictory, suggesting that it is premature to predict which employees might voluntarily select compressed work week schedules[a/].

Employees on flexitime programs in effect have free choice to not participate. They almost always have the built-in option of selecting a fixed "standard" work schedule.

Employee Trip Timing Response

The temporal distribution of employee journey to work trips is largely dictated in the case of staggered work hours programs. The only latitude the employee has is circumscribed by his willingness to arrive early, leave late, or be tardy. The same applies to those particular four day work week programs using fixed reporting and quitting times.

The timing of employee work trips under a flexitime program is, in contrast, more at the discretion of the employee. Current evidence indicates that employees on flexible hours do tend to stagger their own work hours. Between 73 and 75 percent of employees involved in flexitime studies in San Francisco and at the Port Authority of New York and New Jersey reported selecting work arrival and departure times designed to avoid traffic and transit congestion (247*, 304, 443*). The trip timing results are comparable to those achieved with typical staggered hours schedules.

The impacts of the Port Authority of New York and New Jersey flexitime experiment on employee work trip peaking are summarized in Table 17. Fifteen-minute workfloor arrival and departure peaks were decreased by 42 and 29 percent respectively on the floor where the majority of employees changed from a conventional fixed schedule to flexitime. Peaking changes were insignificant on floors involved in change from staggered hours to flexitime (443*). Thirty-minute workplace arrival distributions for

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a/ The comparative profiles may differ for several reasons, including differences in survey sampling techniques, response rates, participating office/agency makeup and location, and transportation/land use infrastructure.

Table 17
15-Minute Peaking Before and After Flexible Work Hours
(443*)

	Peak Arrivals[1/]		Peak Departures[1/]	
	% of Total[2/]	AM Time Period	% of Total[3/]	PM Time Period
Floor "A"				
Before (Conventional Hours)	31	8:45-9:00	35	4:30-4:45
After (Flexible Hours)	18	8:45-9:00	25	4:30-4:45
Floor "B"				
Before (Staggered Hours)	20	8:15-8:30	26	4:00-4:15
After (Flexible Hours)	20	8:15-8:30	27	4:00-4:15
Floor "C"				
Before (Staggered Hours)	28	8:15-8:30	25	4:00-4:15[4/]
After (Flexible Hours)	24	8:30-8:45	26	4:15-4:30
Floor "D" (Control)				
Before (Floating Day)	24	8:15-8:30	30	4:00-4:15
After (Floating Day)	29	8:15-8:30	25	4:00-4:15
Floor "E" (Control)				
Before (Conventional Hours)	27	8:30-8:45	30	4:15-4:30
After (Conventional Hours)	27	8:15-8:30	28	4:15-4:30

1/ Arrivals and departures surveyed on the individual work floors. Surveys included some employees not participating in the Port Authority of New York and New Jersey flexible work hours experiment.

2/ 7:30 to 10:00 AM arrivals.

3/ 3:30 to 6:00 PM departures.

4/ Peak departures also 25% of total 4:15-4:30 PM.

three San Francisco employers on flexitime are tabulated below in comparison with all downtown employees, and are illustrated in Figure 5 (247*):

Arrival Time	Fireman's Fund (Self-Staggered Start)	CSAA (Flexitime[1/])	Metropolitan Life (Flexitime)	All Downtown Employees
7-7:30	31%	16%	53%	8%
7:30-8	34	31	24	13
8-8:30	20	40	14	61
8:30-9	10	7	6	1
after 9	5	6	3	17
	100%	100%	100%	100%

[1/] Earliest sanctioned time 7:30 AM.

The start time peaks of the firms on flexitime are significantly smaller than the peak for downtown employees as a whole and/or occur before the downtown peak (247*). The distribution for Metropolitan Life's southeast home office is very similar to the San Francisco office except that self-staggered start arrivals as early as 6:30 are sanctioned. As a result 37 percent arrive in the 6:30 to 7:00 AM period (22 percent 7:30 to 8:00). The typical flexitime employee in the U.S.A., and in Germany's extensive programs as well, selects earlier schedules than the pre-existing standard (446).

Terminal Facility Impacts

The transit stations, parking garages, freeway ramps, and intersections which primarily serve the involved employment areas receive the most pronounced impact of variable hours programs. A limiting factor in the capacity of urban street systems and rapid transit is often the operation of such ramp, intersection, and station facilities (63).

In the Lower Manhattan staggered work hours project area, subway station passenger volumes declined by 26 percent in the AM peak 15 minutes. World Trade Center Terminal passenger counts fell by 18 percent in the PM peak 15 minutes. Loadings increased during other peak period time intervals, resulting overall in a much improved distribution of volumes (446, 459*). Implementation of flexible hours at the Department of Health and Social Security Central Office in Newcastle upon Tyne, England, resulted in a 35 percent decline in 15 minute peak period vehicle movement to and from parking facilities. Peak hour arrivals were reduced by about 15 percent and peak hour departures by 25 percent. Employee parking outside the provided facilities, a source of local complaint, ceased after implementation of the program (609).

Partial compressed work week participation in the Denver Federal Center has slightly reduced midweek peak hour traffic volumes at the Federal Center cordon. The reduction is from 45 percent of total 5 to 9 AM traffic to 42 percent (98). Peak 15 minute loadings were reduced significantly upon introduction of variable work hours in Ottawa, Ontario, as were peak hour volumes relative to the 2½ hour AM peak period and the 3 hour PM peak period. Before and after peak hour to peak period ratios for employees using transit and for vehicles entering and leaving parking lots were as follows (541*):

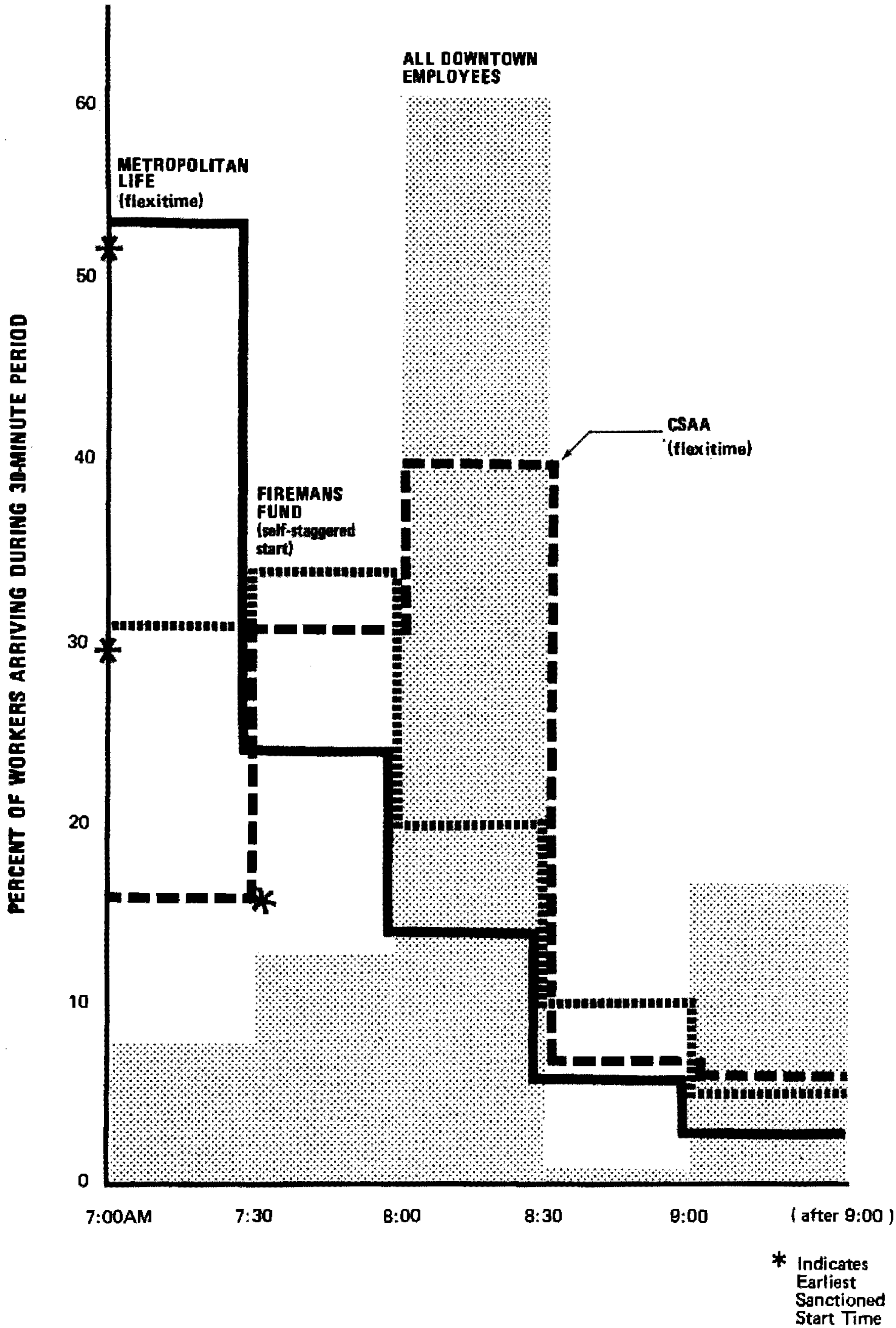

Figure 5
Workplace Arrival Time Distributions
San Francisco
(247*)

	AM		PM	
	Before	After	Before	After
Theoretical Ideal (no peaking at all)	--	40.0%	--	33.3%
Workplace arrivals/ departures of government employees using transit	86.2%	71.6%	85.3%	65.1%
Average parking lot auto arrivals/departures	62.1%	53.7%	57.3%	44.9%

Through Facility Impacts

Passenger and vehicular volumes on line-haul and through facilities such as transit lines, bridges, tunnels, and major highway links characteristically serve traffic from diverse locations. For this reason, the volumes on such facilities are normally more evenly distributed than terminal facility volumes, and offer somewhat less potential for modification with variable work hours programs. For example, traffic counts at the Lincoln tunnel and other major Manhattan access and egress points indicate that these facilities operate at capacity for almost three hours in both the morning and evening peak periods. Not surprisingly, the Manhattan Staggered Work Hours program failed to have any demonstrable impact on traffic congestion at these facilities (446, 459*).

Dissipation of program effects as one moves away from the involved employment area was specially measured in Ottawa. The relative impacts are of interest even though the specific reductions obtained are probably unique because of the dominance of a single employer, the Canadian Federal Government. Percentage reductions in the peak hour to peak period traffic ratios[b/] for O - C Transpo transit riders are given in the table below (541*):

	AM Reduction	PM Reduction
Workplace arrivals/departures of government employees using transit	16.9%	23.7%
Peak direction transit passenger volumes at central Ottawa Cordon	8.4	19.2

The workplace arrival and departure volumes serve as a surrogate for terminal facility volumes, and show a greater reduction in peaking than observed for line-haul volumes

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b/ Percentage reduction equals $\frac{\text{before peak hour}}{\text{before peak period}}$ minus $\frac{\text{after peak hour}}{\text{after peak period}}$

taken as a percent of $\frac{\text{before peak hour}}{\text{before peak period}}$

In those instances where there is no change in peak period traffic, this percentage is equal to the absolute reduction in peak hour traffic.

at the Ottawa cordon. Nevertheless, the beneficial effect on peak transit loadings was notable. The AM and PM peak transit loads decreased by 21 and 29 percent, respectively, in spite of overall patronage increases.

Program effects on auto volumes showed even more dissipation and are illustrated in the peak hour to peak volume ratio reductions given below (not seasonally adjusted):

	PM Reduction
Average parking lot arrivals/departures	21.6%
Volumes at the central Ottawa Cordon	10.2
Volumes at the Ottawa River screenline	5.7

The impact of the program was clearly diluted at the central area cordon, and further diluted at the Ottawa River. Figure 6 provides a graphic illustration. Still, traffic peaking was reduced. Absolute peak hour auto traffic volumes at the central cordon were lowered slightly despite 6 to 10 percent increases in overall peak period volumes largely attributable to seasonal variations.

Underlying Traveler Response Mechanisms

The trip timing decision process of the individual employee comes into full play when employees are given the discretion to choose their own work times, as with flexitime. This decision process involves tradeoffs among partially conflicting factors. A survey of California State Automobile Association (CSAA) employees indicated the following four casual factors to be important (247*, 304):

Casual Factor	Percent Responding Important
Occupational Factors	81%
Congestion Effects	75
Social/Family Responsibilities	71
Modal Usage	36-92 1/

1/ Depending on mode, excluding drive-alone.

Occupational factors equate to employee matching of work hours to the needs of the office, which include work unit coverage requirements such as telephone answering. Congestion effects equate to employee avoidance of the rush hour to achieve greater travel speed or comfort. Social/family responsibilities include the desire to spend more productive time at home with friends and family, and such responsibilities as getting children off to school. Modal usage factors encompass the trip coordination required to match public transit schedules (50 percent responding important in the CSAA interviews) and to participate in carpools (increasingly important with increasing carpool size)-(247*, 304).

The interplay and relative importance of factors influencing changes of travel mode in conjunction with work time shifts are not well understood. Up to 20 percent of affected employees have been reported to shift from one mode to another upon

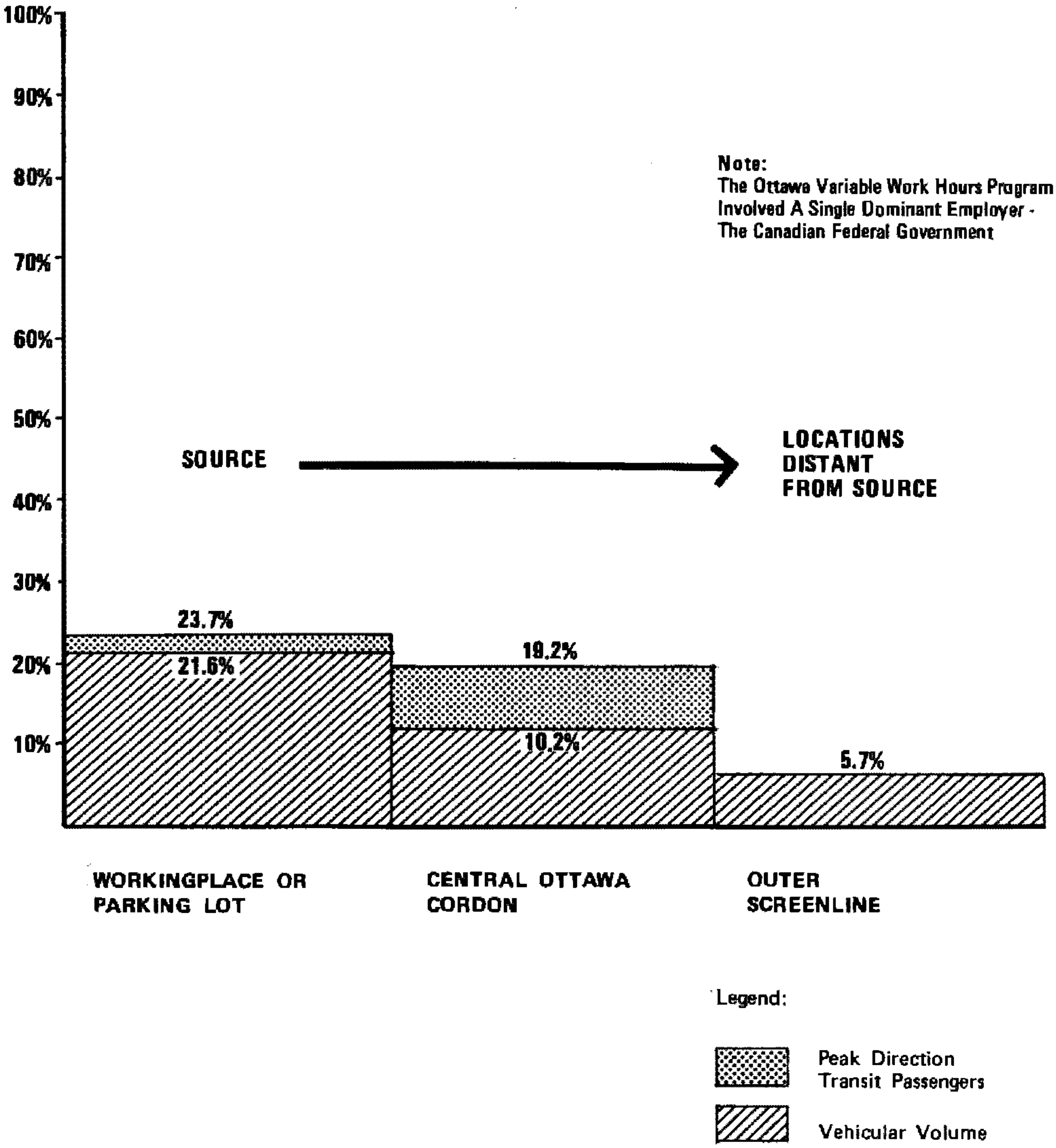

Figure 6
PM Reductions in Peaking – Ottawa Variable Work Hours Program
(541*)

institution of flexitime (247*), but direct comparisons are not available with the number of mode shifts which normally occur in a similar time frame without work hours changes. Evidence is beginning to accumulate that the typical net effect of variable work hours on mode choice is not detrimental to high occupancy vehicle usage overall. Hypothesized detrimental and positive mode choice factors are listed below (187^{+}, 303, 612):

Detrimental Factors	Positive Factors
Fixed work schedules concentrate employee arrivals and departures and thereby aid ridesharing arrangements.	Flexible work hours (staggered hours excluded) allow employees to mesh their schedule with others for purposes of ridesharing.
Staggered hours in particular may disrupt carpools and conflict with catching infrequently scheduled transit services.	Flexible work hours allow work scheduling to match infrequent transit services.
Variable work hours may shift travel into periods when transit service is less available and therefore less attractive.	The workplace consequences of transit service irregularities or carpool delays are eased by flexible hours.
The opportunity to avoid peak traffic congestion may encourage single occupant auto use.	Transit usage may be enhanced by variable work hours, in that transit vehicles are less crowded before and after the peak.

Compressed work week options introduce another dimension of travel pattern effects, in that they introduce the opportunity and/or necessity for major non-work travel adjustments. Evidence from the Federal employee experimental programs indicates that travel on the week day off typically consists of urban trip tours (multiple destination trips) like normal Saturday travel, with trip purposes similar to the usual weekday non-work trips. Extension of weekday work trips to include intermediate destinations becomes less common, either because non-work travel needs are met on the weekday off, or because the workday simply becomes too long for much detouring. Previous weekend travel may also be shifted to the weekday off (98, 569).

Impacts on Mode Choice

Queried in advance, employees faced with proposed work hours changes have anticipated making shifts to the single occupant auto mode. Crystal City (Arlington), VA employees were found to be thinking of switching from bus to auto commutation in response to imposition of staggered work hours (187^{+}, 305). Similarly, 30 to 35 percent of carpooling or transit using Milwaukee employees, asked to consider a hypothetical flexible hours program, thought they would decide to shift from bus or carpool to private auto concurrently with choosing earlier work start times (303).

These potentially disturbing attitudinal survey results are contradicted by most available information on actual mode shift experience. Overall shifts away from high occupancy modes have not been observed. The majority of actual before and after survey data, albeit limited, indicates at worst an insignificant or neutral effect on single occupant auto usage and gives some evidence of a predominance of mode shifting to carpools. The tabulation below gives percent changes in mode shares reported by San Francisco Bay Area employees changing to flexitime (247*, 304):

Organization	Drive Alone	Shared Ride	Transit	Other
CSAA	-3%	+4%	-2%	N/A
Lawrence Berkeley Lab.	-10	+18	+8	0% 1/
Caltrans	-26	+28	-22	0 1/
Chubb-Pacific Indemnity	-67 1/	+1	+5	0 1/
Standard Oil	-50 1/	+13	-3	+33 1/
Metropolitan Life	-50 1/	+6	+3	0 1/

1/ Prior mode share 6% or less of total.

In depth survey results for the CSAA organization showed that flexitime had especially aided work trip ridesharing among friends and family, a particularly resilient form of carpooling (247*). A 7 percent drop in vehicle occupancy (with unknown impact on transit usage) was reported after flexible work hours were introduced at the Social Security office in Newcastle upon Tyne, but the count of employee autos did not change (609).

Five percent more employees took transit and six percent more were ridesharing after flexitime introduction at the Transportation Systems Center in Cambridge, MA. After flexible hours implementation at the California Department of Water Resources, 14 percent of employees stated they took the bus more often and 12 percent more carpooled. With institution of the Ottawa variable work hours program, localized auto occupancy changes showed no consistent pattern, and the mode share of peak period travel to the central area via transit increased by about 5 percent. In the latter two cases, the shifts to high occupancy modes are not necessarily attributable to the work hours changes because of confounding events including energy shortages (303, 541*).

The Denver Federal employee compressed work week program, while having little effect on aggregate mode shares, provides additional insight on carpooling effects in particular. Table 18 gives before and after mode choice percentages from a matched data set of survey respondents. Within participating agencies, non-participating employees show decreased ridesharing and increased solo driving and transit usage, tending to indicate disruption of ridesharing arrangements. Participating employees, on the other hand, show increased ridesharing. The increases do not quite compensate for those carpools dissolved as a result of the schedule change, but do demonstrate that those electing the compressed work week schedule have been able to form carpools and to do so to a greater degree than before (98).

Impacts on Travel Time

Variable work hours serve to shorten highway travel times by means of reducing congestion. Estimates based on Denver and San Francisco traffic conditions indicate that one percent peak hour volume reductions will decrease travel time by 0.6 to 1.2 percent. In the less congested "shoulders" of the peak period, travel times are already shorter, and are less sensitive to volume changes. This situation allows overall peak period travel time savings to be achieved with work time shifts. The tabulation below

Table 18
Impact on Mode Choice of Compressed Work Schedules in Denver
(98)

	Participating Agencies					
	Non-Participating Employees (N=181)[1/]		Participating Employees (N=405)		All Employees (N=586)	
Mode	Before	After	Before	After	Before	After
Drive Alone	54.1%	61.3%	57.3%	55.1%	56.3%	57.0%
Shared Ride	35.5	24.4	29.4	32.0	31.3	29.7
Transit	8.3	9.4	7.9	7.2	8.0	7.9
Other	2.3	5.1	5.4	5.9	4.4	5.7

[1/] N=number of samples in the matched data set.

gives average peak period travel time reductions, estimated primarily from questionnaire surveys, for actual staggered and flexible work hours programs (612, 673, 675):

Variable Work Hours Program	Travel Category	Travel Time Reduction One Way	Travel Time Reduction Round Trip
Toronto-Queens Park	Participants only	3 min.	
Riverside, CA	All employees	2.5	
Washington, DC - EPA	Participants only		8 min.

Results from the Denver Federal employees compressed work week experiment indicate reported one-way travel time savings of the same order of magnitude, but with lesser savings for agencies outside the central business district (98):

Location within Denver	Participating Agencies: Participating Employees	Participating Agencies: Non-Participating Employees	Non-Participating Agencies--All Employees
CBD	5.3 min	0.6 min	2.2 min
Non-CBD	0.8	1.5	(0.5)[1/]

1/ Longer travel time.

Surface transit vehicles may be expected to save about half as much travel time as autos, except in express operation, where the savings should be equivalent. However, transit rider benefits are more in the realm of avoiding uncomfortable crowding and vehicles too full to board. Lower Manhattan participants saved an average of 3.5 minutes each morning merely by avoiding the period of maximum train annulments and delays.

Impacts on VMT, Energy and Environment

Staggered and flexible work hours programs, with no change in the work week, depend on lessened traffic congestion for energy savings and emissions reduction impacts. Travel time reduction estimates modeled for a hypothetical city of 1,000,000 have been used as the basis for a variable work hours energy savings estimate. The modeled time savings for a typical CBD employee are as follows:

	Peak Hour	Peak Period
50% CBD participation	3.75 min.	2 min.
20% CBD participation	1.5	0.8

The Ottawa variable work hours program, which involved roughly half of all CBD employees, was used as a travel impacts data source. The calculated vehicle time savings for the extensive, 50 percent CBD worker participation scenario is 600,000 vehicle hours annually. Assuming no change in regional VMT, this congestion reduction equates to a modest 360,000 gallon annual energy savings, about 0.11 percent of regional auto fuel consumption (673). Variable work hours can also assist in carrying more passengers with a given transit fleet and workforce, thus complementing strategies to increase transit usage or deal with energy emergencies.

Unlike other variable work hours programs, the compressed work week reduces the actual number of individual worker commute trips. It has the potential to reduce commutation VMT by 20 percent for 4-day work week participants and 10 percent for 5-4/9 plan participants if there are no significant mode shifts. The potential for net overall VMT reduction will be reduced to the extent that increased non-work travel is induced on days off (612, 673). In theory, the possibility exists for total household VMT to actually increase. At least one 4-day worker survey, not recent, has suggested the occurrence of increased recreational travel in most family categories (311+).

Concerns about possible total VMT increases are not supported by first year Denver and first quarter FHWA-Washington results of Federal employee compressed work week experiments. In Denver, where roughly half of the individual participants are on a 4-day work week and half are on the 5-4/9 plan, total family VMT, for participating agencies relative to control groups has been reduced by 14 percent[c/]. This reduction is apparently spread across all 7 days of the week. The strong implication in Denver is that the compressed work week has allowed more efficient accomplishment of non-work travel objectives, may have discouraged non-work travel on the inherently longer workdays, and has not induced expanded weekend travel. Likewise, no expansion of out-of-area travel and no offsetting of work trip VMT savings have been observed in Washington. Denver household average 7-day VMT is summarized below for before conditions and one year after implementation (98, 569):

	Average Household Total Weekly VMT			
	Employees in Participating Agencies[1/]		Employees in Non-Participating Agencies	
Agency Location within Denver	Before	After	Before	After
CBD	256	233	2/	219
Non-CBD	286	266	285	315

1/ Includes individual non-participating employees.

2/ Insufficient sample size.

c/ These results are for non-CBD employees, and include non-participating employees within participating agencies. The literature notes that sample size among those keeping 7-day vehicle use logs prevented control group comparisons for CBD employees. Less than 10 percent of the compressed work week program participants worked in the CBD (98). The VMT percentage reduction, fuel consumption reduction and emissions reduction estimates reported here for the Denver experiment have been adjusted on the basis of and extrapolating from the Executive Summary errata sheet.

This 14 percent relative VMT reduction for participating agencies equates to a 5 percent reduction for all Denver Federal employees and a 0.3 percent reduction relative to total regionwide travel. The corresponding reductions calculated for energy use and air pollutant emissions are virtually the same, with the energy savings equating to 1,200,000 gallons per year. Actual air quality improvements obviously vary by time and location, and 38 percent of the total emissions reduction pertains to weekend travel (98).

Impact on Employers and Employees

Concerns expressed by firms asked to consider variable work hours programs include maintenance of supervisory and timekeeping control, handling of customer contacts and other external/internal communications, overall internal efficiency and productivity, and renegotiation of certain labor contracts. Labor opposition can indeed be a problem (117,187+, 311+, 612). However, overall, the experimental findings tend to indicate that these concerns need not be serious and that operations may actually benefit. A summary of relevant survey responses is given in Table 19 (237, 446).

Management cites employee welfare and morale as among the most important motivations for implementing flexible work schedules. Reduction of absenteeism, personal time off and sick time is another key consideration (612). There are side benefits as well. Variable work hours were observed to significantly reduce elevator queues in both the Lower Manhattan staggered hours and the Port Authority flexible hours studies. Surveys in the Lower Manhattan experiment showed that 18 percent of the program's participants reported less crowding in restaurants and stores during the lunch hour (443*, 446, 459*).

Where reported, employee reaction to staggered and flexible work hours programs has been uniformly positive. Percentages of workers favoring variable work hours programs implemented by their employers range between 80 and 99 percent. Specific benefits reported include higher job satisfaction, reduced commute times and more travel comfort and convenience (237, 303, 443*, 446, 459*).

In contrast, Port Authority experimentation with the four-day work week gained only 50 percent approval among employees (446). However, as noted earlier, 50 to 65 percent of U.S. Federal employees have elected some form of compressed work week when given the choice (98, 569). FHWA-Washington employees perceived 5-4/9 plan effects on accomplishing personal business, leisure time activities and vacations as being highly favorable. Moderately favorable effects were reported on meeting family needs, job satisfaction, commuting traffic and work trip gas consumption. Activities affected moderately unfavorably included making stops enroute while commuting, communication with the public, and using the prior travel mode, while very unfavorable impacts were perceived with respect to ease of carpooling and fatigue. Most carpoolers and vanpoolers elected flexitime in preference to the compressed work week (569).

Additional References

The ongoing research project Temporal Demand in Freeway Corridors, directed by Adolf D. May, provides additional literature review material and research results on Variable Work Hours (247*, 303, 304). National Cooperative Highway Research

Table 19

Employer Assessment of Internal Variable Work Hours Effects[1]
(237, 446)

	Internal/External Communications		Punctuality		Efficiency		Productivity	
	Better	Worse	Better	Worse	Better	Worse	Better	Worse
Lower Manhattan Staggered Hours	N.A	15%	25%	12%	N.A.	N.A.	86%	14%
Port Authority Flexible Hours	55%	30%	N.A.	N.A.	16%	N.A.	98%[2]	2%
Queens Park Demonstration	4%[3] 8%[4]	21%[3] 7%[4]	36%	5%	32%	N.A.	22%	5%

1/ Interpretation and comparison of these study results should be made with caution. The Lower Manhattan data are the results of a supervisor survey. The Port Authority (New York) and Queen's Park (Toronto) data are the results of employee surveys, with the exception of the Queen's Park punctuality reports, which were made by supervisors. In addition, "productivity" and "efficiency" were sometimes measured under other terms, such as "High ability to turn out work," or "completion of daily work."

2/ Better or same.

3/ Internal communications.

4/ External communications.

Program Synthesis of Highway Practice 73, Alternative Work Schedules: Impact on Transportation, provides background and implementation information covering all variable work hours options and additional staggered hours and flexitime case study details (612). For further information on Variable Work Hours consult references:

4, 10, 63, 98, 117, 127, 168, 187+, 222, 237, 238, 243, 247*, 254, 256, 301, 302, 303, 304, 305, 307, 311+, 330, 381, 402, 443*, 445, 446, 458, 459*, 466, 500, 523, 541*, 569, 596, 597, 609, 612, 638, 673, 681, 696, 706, 719, 720.

247. Harrison, Frances, David Jones and Paul Jovanis. Flex-Time and Commuting Behavior in San Francisco: Some Preliminary Findings. Summary Report. Institute of Transportation Studies, University of California; Research Report UCB-ITS-RR-79-12. Sponsored by Division of Transportation Planning, California Department of Transportation. August, 1979. 19 pages. VARIABLE WORK HOURS. OBSERVED RESPONSE. TEMPORAL DISTRIBUTION, MODE CHOICE, AUTO OCCUPANCY.

Researchers under the auspices of the Downtown San Francisco Flex-Time Demonstration Project and the Temporal Demand in Freeway Corridors project conducted a pilot survey of the 1100 employee California State Automobile Association (CSAA) in February 1978 to record employee experiences with flex-time. At this point CSAA employees had been on flex-time for about 3½ years, so their response reflected long-term impacts. Surveys were then taken at additional firms with flex-time, with survey sample sizes ranging from 88 to 392 employees. The findings and conclusions reported are preliminary and require further statistical analysis for full substantiation.

Flex-time work arrival times were reported for CSAA, Metropolitan Life and Fireman's Fund (see Figure 5 and also table within the "Employee Trip Timing Response" section of the preceding digest). The arrival time profiles gave evidence that flex-time adoption would spread peak demand. The peak 30-minute arrival periods and the percentage of arrivals during these periods were found to be 8-8:30 AM and 61% respectively for downtown employees as a whole, compared to 8-8:30 and 40% for CSAA, 7-7:30 and 53% for Metropolitan Life, and 7:30-8 and 34% for Fireman's Fund. The three firms on flex-time exhibited an employee preference for arriving early. While 21% of downtown employees overall arrive before 8:00 AM, 47% do so at CSAA despite a 7:30 earliest sanctioned time, 77% arrive before 8:00 at Metropolitan Life, and 65% at Fireman's fund. Fireman's fund employees must choose a time at which they will arrive every day consistently (self-staggered start) and it was hypothesized that the commitment required in this choice mitigates somewhat against early arrivals.

The CSAA survey indicated that the employees value the opportunity to vary their start time and many do so occasionally. However 75% usually arrive at the same time each day. Managerial and supervisory employees reported more extreme shifts in start time and later arrivals than clerical, professional and technical employees. Clerical employees tend toward stable work hours, quite possibly due to defacto limitations on the flexibility available to clerical staff. Carpooling employees were found to tend toward extremely early arrivals and showed the least daily variation. Employees driving alone showed the greatest tendency for extreme time shifts, early and late, and exhibited the greatest daily variation. Transit users exhibited less extreme time shifts and fell between carpoolers and drive alone employees in their daily variation of work schedules.

Among CSAA employees, there was not a significant shift in mode of travel to work. Only 7% changed modes, resulting in a 4% increase in carpool use and slight reductions in the drive alone and transit modes. Among other firms a consistent pattern of decline in driving alone to work and an increase in ride sharing was reported. No consistent pattern appeared with regard to use of transit. (See table within the "Impacts on Mode Choice" section of the preceding digest.) CSAA employees were questioned about travel time savings achieved through avoiding congestion, and almost half reported a saving of five minutes or more. However, more important to many employees surveyed is the ability to avoid stop and go traffic, to get seats on transit, and to coordinate rides with family and friends. The researchers suggest that time savings are far less important to commuters on flex-time than the increased flexibility afforded in scheduling the often conflicting needs and desires of home, office, and personal business. The three reasons most often cited by CSAA employees in their choice of start time were: occupational demands, avoidance of congestion and more time for home and personal activities.

443. New York and New Jersey, Port Authority of, Planning and Development Department. Flexible Work Hours Experiment at the Port Authority of New York and New Jersey. 1974-1975. Sponsored by Urban Mass Transportation Administration, U.S. Department of Transportation. December, 1975. 48 pages. VARIABLE WORK HOURS.* OBSERVED RESPONSE. TEMPORAL DISTRIBUTION.

In September 1974, The Port Authority of New York and New Jersey began a flexible hours experiment that lasted 8 months and involved approximately 850 headquarters staff. Those involved in the experiment included employees previously on staggered hours and employees previously on a normal work schedule. The basic five-day work week at The Port Authority remained unchanged for flexible hours program participants. The total expanded day covered the period between 8:00 AM and 5:30 PM, during which time employees were required to be at work for a core period from 9:30 AM to 4:00 PM. Workers were given 45 minutes for lunch. The 1-1/2 hour periods preceding and following the core period were flexible periods within which an employee could vary his or her time to any extent, as long as a 36-1/4 hour per week requirement was fulfilled.

To determine program results, four basic evaluation techniques were used: arrival and departure counts before and during the experiment; analysis of special timesheets for job attendance; attitudinal questionnaires filled out before and during the experiment; and personal interviews with program participants. Arrival and departure counts were also made of two control groups of employees whose work schedule ("floating day" and normal) did not change during the experiment. Because the different participating and control groups worked on separate floors, arrival and departure times by floor could be compared meaningfully (see Table 17 of this Handbook for a summary tabulation). The participating employees were in departments that volunteered their involvement.

The flexible hours program appeared to be comparable to staggered hours programs in its potential to reduce transportation peaking. As might be expected, the floor which exhibited the most marked shift in arrival and departure patterns was the floor with the group which changed from a normal schedule to a flexible hours schedule. Here the size of the 15-minute AM arrival peak was reduced about 42%, accompanied by a 27% reduction in the 15-minute PM departure peak. The flexible hours effect on the two floors with employee groups previously on staggered hours was considerably more muted, and the size of the peak was largely unaffected. There was, however, some improvement in the distribution pattern. In all cases shifts in the time of peak arrivals and departures were minor but there was a distinct shift toward later arrivals and departures overall. While one control group (that on a normal schedule) showed only minor variations, the other control group (on a "floating day" schedule) showed increased peaking in the AM 15-minute peak balanced by decreased peaking in the PM (about 18% in both cases). There was no other significant change in either control group distribution pattern.

About 45% of the participants maintained a constant schedule of arrivals and departures of their own choosing and worked a standard 7 1/4 hour day. Another 25% chose to vary their arrival/departure times but worked a 7 1/4 day each day. Some 30% chose to work a non-standard day but only a quarter of such days varied beyond the range of 6 3/4 to 7 3/4 hours. Choice of arrival/departure times to avoid the most congested periods was reported by 73%. A survey of those who did not avoid congested periods indicated conflicting car-pool commitments or lack of trains outside peak periods as major factors. Over 94% of those surveyed indicated no change in mode of travel to/from work, and no significant pattern of mode shifts developed. It was frequently remarked that flexible hours relieved the pressure of being late, making the commute less stressful regardless of delays. Some 45% reported they worked more effectively during the program and, 53% reported improvement in internal/external communications, but 30% felt that communications became more difficult. Overall, 98% were more or as satisfied with their jobs.

459. O'Malley, B. W. and C. S. Selinger. "Staggered Work Hours in Manhattan." Traffic Engineering and Control. Printerhall Limited, London. Volume 14, No. 9. January 1973. Pages 418-423. VARIABLE WORK HOURS. OBSERVED RESPONSE. TEMPORAL DISTRIBUTION.

On April 1, 1970, the Port Authority of New York and New Jersey (PATH: Trans-Hudson Transit), in cooperation with the Downtown-Lower Manhattan Association, initiated a staggered work hour program. The Lower Manhattan area had a worker population of 480,000, about 85% of whom used rail transportation for their work trip. A survey of 113 firms with 136,000 employees total indicated that 66% began their work day at 9:00 AM and that 64% ended it at 5:00 PM. The program at first involved about 50,000 employees of 45 concerns; 46,000 had their beginning time shifted from 9:00 to 8:30 AM, and 4,000 to 9:30 AM. Within 2 years 250 offices with over 100,000 employees total were participating, and a similar program was being developed for Midtown Manhattan. Schedule shifts of at least 30 minutes were recommended to compel a definite change in commuting habits.

Before and after passenger counts were taken in February 1970 and 1972 at 3 of the area's most heavily used subway stations. The counts showed a 26% decline in station usage (17,658 to 13,074) during the peak 9:00-9:15 AM period, and a 24% passenger volume increase (12,024 to 14,864) between 8:30 and 8:45 AM. At the PATH World Trade Center Terminal, passenger counts fell 18% (7,500 to 6,224) between 5:00 and 5:15 PM, and rose more than 50% (3,100 to 4,750) between 4:30 and 4:45 PM. In contrast, monitoring of vehicular volumes at the Brooklyn Battery Tunnel and the Battery Parking Garage showed little or no significant change attributable to staggered hours.

The employees of 27 firms were surveyed to assess reaction. About 85% of the participating employees sampled favored staggered hours. Some 45% reported they were experiencing less congestion (50% reported no change), and 50% were more satisfied with their work trips at the staggered hours (9.8% were less satisfied). Of the supervisors sampled, 24.6% reported improved employee punctuality; only 11.6% reported increased tardiness. About 15% cited some operational communications problems, but none indicated any actual drop in efficiency.

Reasons for the improved employee punctuality were examined with a study of the distribution and length of all rail rapid transit and commuter rail system AM peak period delays recorded on 18 randomly selected days in 1970. The study indicated that a rapid rail commuter with a 9:00 AM reporting time at work, compared to a commuter with an 8:30 AM reporting time, had a 25% greater likelihood of encountering a delay, and that each delay averaged 40% longer in duration. Similarly, a commuter rail user starting work at 9:00 AM had a delay likelihood 67% greater and an average delay duration 50% longer. This equates to a 1-hour morning trip time reduction each month for rapid rail users on an 8:30 AM schedule, and a larger savings for commuter rail users. Interestingly, rapid rail service between 8:10 AM and 8:30 AM (2,369 trains scheduled) was found to be nearly equal to the service offered between 8:40 AM and 9:00 AM (2,427 trains scheduled), and train annulments (i.e., cancelled or out-of-service trains which figure more heavily in passenger overcrowding than delay) were 17% more frequent for the 9:00 AM commuter than the 8:30 AM commuter.

541. Safavian, Reza and Keith G. McLean. "Variable Work Hours: Who Benefits?" Traffic Engineering. Institute of Transportation Engineers, Arlington, Virginia. Volume 45, No. 3. March 1975. Pages 17-25. VARIABLE WORK HOURS.* OBSERVED RESPONSE. TEMPORAL DISTRIBUTION, MODE CHOICE, AUTO OCCUPANCY.

A variable work hours program, involving both staggered and flexible hour program elements, was implemented in the central area of Ottawa-Carleton, Ontario, on March 4, 1974. Approximately 70,000 persons work in the central area of Ottawa. Almost 33,000 of the 35,000 central area federal government workers were involved. The program was designed to even out the peak demands placed on the transportation system; particularly the bus transit system, which was overtaxed by increased ridership.

Traffic data was obtained for two principal screenlines; Screenline A, coincident with the Ottawa River separating Ottawa from Hull, and Screenline B, enclosing the central area of Ottawa. Screenline data obtained for 1974 included counts for buses and private passenger vehicles in February, counts for buses in March, and counts for all modes in May. Other data gathering included sampling peak period automobile arrival and departure volumes and vehicle occupancies during February and April at six Ottawa parking areas, encompassing 6,000 short-term and long-term parking spaces.

The ratio of peak hour to peak period traffic was used as a measure of traffic peaking intensity, with the peak periods being 7:00 to 9:30 AM and 3:00 to 6:00 PM. At Screenline B (central Ottawa cordon) this peaking ratio for bus ridership fell between February and March, from 67.9% to 62.2% in the AM and from 62.0% to 50.1% in the PM. The peak period modal split, in the peak direction radial to central Ottawa, rose in the AM from 50% of all person trips on transit to 53% on transit, and in the PM from 43% to 45% on transit. In view of confounding events, including the "energy crisis" and new O.C. Transpo express services, the apparent increase in transit ridership was not ascribed to the variable work hours program. However, the absence of a shift away from transit, despite reduced road congestion, was deemed encouraging. Even with the patronage increases, the absolute number of peak direction riders in the morning and evening peak fifteen minute loading periods decreased 21% and 29% respectively, enhancing the comfort of transit riding.

In respect to vehicular traffic, the ratio of peak hour to peak period auto traffic volumes crossing Screenline A (Ottawa River) fell between February and May from 53.0% to 51.6% in the AM and from 45.7% to 43.1% in the PM. The ratio of auto traffic crossing Screenline B (central Ottawa cordon) dropped from 55.0% to 49.2% in the AM and from 46.3% to 41.6% in the PM. About half of these reductions in auto traffic peaking were attributed to seasonal variations and the remainder to the variable work hours program. Lower Screenline B auto volumes were recorded in both peak hours (down 1% in the AM and 4% in the PM) despite higher volumes overall during the peak periods (up 10% in the AM and 6% in the PM). The strongest program impact on traffic peaking was registered at the six downtown parking lots surveyed. Between February and April 1974, the ratio of peak period arrivals fell from 62.1% to 53.7%, and the departure ratio fell from 57.3% to 44.9%. No consistent changes in auto occupancy were detected in either the parking lot or screenline counts.

POOL/TRANSIT FRINGE PARKING

Types of Fringe Parking

Fringe parking for modal transfers to carpools, vanpools or transit is an element in the overall transportation system management category of "Actions to Reduce Vehicle Use in Congested Areas." Fringe parking facilities include:

1. Fringe parking for commuter rail, rapid rail and light rail service, usually in established lots at outlying residential stations (114, 158, 192*, 286, 483, 509, 576).

2. Fringe parking for express bus service involving non-stop transit service from the mode change facility to the traveler's destination along expressways or major arterials (16*, 45*, 88*, 140#, 158, 162, 192*, 286, 292#, 357, 401#, 406, 408, 416, 563#, 576, 595, 605*, 684#, 687#).

3. Fringe parking for local bus service either at designated lots along the route or on an unstructured basis at a bus stop convenient for the auto driver (16*, 158, 286, 595).

4. Fringe parking for carpooling/vanpooling at locations where either transit service is not offered to the traveler's destination or where the traveler eschews available transit service for the attributes of ridesharing (17, 45*, 207, 605*).

5. Peripheral parking lots located adjacent to congested areas, usually the CBD of a major city, and served by shuttle transit to take travelers to their ultimate destination (16*, 158, 192*, 286, 316, 595, 685).

Fringe parking lots can range in size from less than twenty to several thousand spaces. Although many lots have been specifically constructed as park/ride facilities, a large number involve joint use with activities having peak parking demands outside of normal working hours: shopping centers, movie theaters, stadiums and churches. In areas where no designated park/ride facility exists, unstructured parking for mode changes to bus or carpool has occurred at convenient lots or on the street, usually in the vicinity of expressway interchanges.

Traveler Response Summary

The typical park/ride lot served by rail rapid transit offers 400 parking spaces, is filled if parking is free, and is three quarters utilized if a fee is charged. Commuter and light rail parking lots tend to be smaller but also obtain high utilization. Fringe parking lots served by express bus offer spaces for 150 to nearly 1000 vehicles and obtain widely varying utilization rates, averaging 50 percent. The more successful bus service park/ride facilities are in cities with downtown parking charges of over $2.00 per day, are served with buses running at least every 15 minutes, and are less than a 30 minute bus ride from the CBD.

Approximately 80 to 90 percent of fringe lot users travel less than 5 miles to park/ride service. Some 40 to 60 percent of park/ride transit users previously commuted as auto drivers. In many instances, it is doubtful that high levels of transit service could be supported without fringe parking. The park/ride mode substitutes for expensive transit feeder services in low density areas, especially those with high auto ownership and above average income.

Nationally, 60 percent of the carpoolers at fringe lots drove alone prior to fringe parking availability. It appears that fringe lots for carpooling do induce carpool formation to some extent, and may serve as an identifying factor for the carpool mode. Park-and-pool lots usually serve less than 60 vehicles, with an average of 20 to 30. Carpool fringe parking lots are normally free and are most successful where they are close to convenient routes of access, offer users advantages in safety or security, and alleviate parking shortages at stategic locations. Among fringe lot users, carpoolers differ from transit riders in that most have destinations in suburban and outlying areas, where transit service is poor. Carpoolers cite trip cost as the primary inducement for using fringe parking.

Peripheral parking lots close to the CBD and served by shuttle transit service provide parking for between 1,400 and 4,200 autos in four instances and for over 200 autos in several others. High downtown parking cost is the primary reason for using peripheral lots. Peripheral lots that failed generally did so because they did not offer a sufficient total cost savings to the user. Charging a fee for peripheral lot use has been successful as long as the fee is significantly lower than commercial rates in the downtown. In instances where lots are within one mile of the CBD, a substantial portion of users eschew the available shuttle service and walk to their destination.

Program Objectives

When properly planned and executed, fringe parking and associated multi-occupant vehicle travel can provide the benefits of transit and carpooling to low density areas in particular while minimizing the disincentives of these modes. The primary purposes of fringe parking are to induce a concentrated level of demand sufficient to warrant transit service or support ridesharing in locations where sufficient demand might not otherwise occur. From the user's perspective, the primary purpose is to provide a convenient means, in terms of time, cost, convenience and safety, to avail themselves of the transit and ridesharing opportunities offered.

Successful fringe parking operations can help to alleviate congestion on CBD streets and approach routes, and reduce the need for additional downtown parking facilities. Other specific objectives of fringe parking programs, in addition to increasing overall transit and carpool usage, include reduction in central area pollutant emissions and energy conservation. In locations where substantial fringe parking occurs on residential streets or highway shoulders, fringe lots can enhance traffic safety and the residential environment, in addition to providing users with more convenient and secure parking areas. In less populated areas, auto access to fringe lots for transit usage can obviate the need for expensive or prohibitive route extensions or feeder services to support line haul service (45*, 207, 329, 357).

Response to Rail Service Fringe Parking

Fringe parking for modal transfers to rail lines has been well utilized in almost every application where a study of fringe parking has been conducted. The following table summarizes overall lot usage at rapid rail stations in five cities and also at stations along five specific rail services: the Lindenwold High Speed Line in the New Jersey suburbs of Philadelphia, a light rail line in Pittsburgh, the 5-mile long non-stop Skokie Swift rapid transit shuttle near Chicago (suburban terminus), the Milwaukee Road commuter rail service in the Chicago north suburbs, and the C&NW commuter rail service in the same corridor (114, 158, 192*, 509, 576):

Location	Parking Charge	Parking Capacity	Spaces Used	Utilization	Number of Lots
New York	pay	4,518	2,775	61%[1]	6
Chicago	pay	1,083	918	85	7
	free	715	695	97	3
Philadelphia	pay	1,835	1,880	102	5
Boston	pay	4,490	2,763	61[2]	15
Cleveland	free	7,256	7,443	103	20
Lindenwold Line	pay	3,660	2,070	57	6 [3]
	free	4,440	4,340	98	6 [3]
Pittsburgh	pay	600	270	45	2
	free	390	390	100	4
Skokie Swift	pay	550 [4]	550	100	1
Milwaukee Road	pay	282	186	66	1
	free	1,311	1,156	88	9 [5]
C&NW Railway	pay	1,046	847	81	5
	free	1,467	1,431	98	12 [5]
Total free lots		15,579	15,455	99%	54
Total pay lots		18,064	12,259	68%	48

1/ Utilization of 85% discounting one 2,550 space lot with 1,000 parked autos.

2/ Utilization of 78% discounting one 1,600 space lot with 514 parked autos.

3/ All lots have both close-in pay parking and more remote free parking.

4/ The 550 space lot provided parking for only 53% of commuter parked cars and has since been expanded.

5/ Includes one location also having a pay parking lot.

Station distances from the CBD ranged from 3 to 30 miles and had no discernible effect on the level of usage. Service was good to excellent, with peak headways under 8 minutes except for the commuter railroads, which offered 16 to 28 minute headways at most stations.[a] Mid-day and evening service was provided in all instances.

a/ Headway is the time interval between trains or buses, while service frequency is the number of buses or trains per hour or day.

The BART rapid rail system in San Francisco has recently expanded fringe parking capacity to 20,300 spaces, offered free to BART riders. Severe shortages of parking still exist, primarily at terminal stations. The original design estimates recommended provision of 36,000 spaces. Fewer were constructed due to financial limitations (483).

Response to Bus Service Fringe Parking

Fringe parking facilities for bus service differ widely in their size and characteristics, the level of transit service provided and their degree of usage. Table 20 summarizes the characteristics of a cross section of bus fringe lots and accompanying transit service. Table 21 lists characteristics of users of fringe parking facilities (88*, 158, 192*, 292#, 408, 416, 563#, 605*, 687#).

Several lots accommodated over 150 parked autos daily with the most heavily used lot, in Vancouver, British Columbia, attracting 600 vehicles and 900 transit patrons. Lots constructed specifically for commuter parking were not more heavily patronized than lots serving multiple uses (88*, 192*, 292#, 416, 687#). It is difficult to qualify particular park/ride services or their characteristics as categorically successful or unsuccessful. However, examination of user responses along with locational and service characteristics indicates aspects of park/ride service which tend to impede or promote usage of park/ride lots and should be addressed in planning future facilities.[b/]

Locational and Service Impacts on Fringe Parking

Figures 7 through 10, summarizing data from 37 bus and 139 rail fringe parking facilities, relate parking utilization to several characteristics of fringe lots and accompanying transit service (286). In general, usage of rail fringe lots is more impervious to differences in parking costs, absolute travel time and transit service frequency characteristics than is usage of bus-oriented lots. Reasons cited for high utilization of rail lots across a wide spectrum of operating conditions include competitive travel times vis-a-vis auto travel, intensive development around stations resulting in a premium on parking availability, and the high visibility of rail travel (158, 286).

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b/ Throughout this digest, the occupancy rate of park/ride lots (autos parked/spaces provided) is used as a prime measure of the utilization of a particular service. Several potential flaws surround the use of this measure if it is used exclusively. First, it does not reflect actual volume of usage. Thirty autos in a 35 space lot cannot be considered more successful than 1,000 autos in a 2,000 space lot. Similarly, if one shopping center allocates 200 spaces to park/riders and another allocates 400 spaces, but both serve 50 autos, the former is not necessarily more successful than the latter. Therefore volume, along with utilization, is cited when possible. In general, the two are very closely correlated in the literature. Secondly, neither volume nor utilization necessarily reflects the proportion of the market population that the facility serves. This estimate was rarely made, making impossible any comparison of market penetration among different applications. Given these data limitations, rather than labeling particular characteristics of fringe facilities and associated transit service as either successful or unsuccessful, emphasis is placed on the tendency of particular characteristics to assist or detract from the park/ride concept.

Table 20
Characteristics of Bus Fringe Parking Facilities and Service
(88*, 158, 192*, 292#, 408, 416, 563#, 605*, 687#)

	Milwaukee	Seattle	Vancouver	Miami	Shirley Highway
Lot type	shopping center	park/ride only	exhibition park	park/ride only	park/ride only
Bus service	freeway express	freeway express	express	arterial express	freeway express
Bus headway (minutes)	12	15	5-10	10	15
Mid-day/evening service	local bus	local bus	n/a	n/a	n/a
Distance to CBD (miles)	10	9	5	10	16
Priority facilities	none	exclusive ramp	none	exclusive lane	exclusive lane
Highway congestion	moderate	moderate	moderate	light	severe
Access to/from highway 1/	good	good	good	good	poor
Amenities	lighting/shelter	lighting/shelter	lighting/shelter	lighting/shelter	n/a
Tolls, CBD parking cost	$1.25	$1.00	$.82	n/a	$1.45
Park/ride daily cost	$1.00	$.70	$.50	$1.20	$1.45
Usage/capacity	150/300	475/475	600/-	400/950	250/400

	Hartford	Washington, DC	Atlanta	Santa Monica	San Francisco
Lot type	shopping center	shopping center	shopping center	park/ride only	park/ride only
Bus service	freeway express	arterial express	n/a	freeway express	freeway express
Bus headway (minutes)	10	18	15	15	10
Mid-day/evening service	n/a	n/a	mid-day only	none	n/a
Distance to CBD (miles)	7	10	5	13	9
Priority facilities	none	none	none	exclusive lane	exclusive bridge lane
Highway congestion	moderate	n/a	n/a	severe	severe
Access to/from highway 1/	good	good	n/a	poor	good
Amenities	lighting/shelter	lighting	n/a	attendant/shelter	lighting/shelter
Tolls, CBD parking cost	n/a	n/a	$.50 - $.60	$1.50	n/a 2/
Park/ride daily cost	$.90	$1.60	$.50	$1.00	n/a 2/
Usage/capacity	200/250	80/150	40/200	30/300	60/165

1/ "Good" access is within approximately ½ mile of the major highway.

2/ The cost difference is believed to be significant due to high San Francisco parking costs and toll on the Bay Bridge.

n/a Information not available.

Table 21
Characteristics of Usage of Fringe Parking Facilities for Bus Service
(88*, 192*, 292*, 408, 416, 563#, 687#)

<table>
<tr><th></th><th></th><th>Milwaukee</th><th>Seattle</th><th>Vancouver</th><th>Miami</th></tr>
<tr><td>Prior mode:</td><td>auto driver</td><td>42%</td><td>59%</td><td>38%</td><td>54% 1/</td></tr>
<tr><td></td><td>auto passenger</td><td>12</td><td>11</td><td>8</td><td>10</td></tr>
<tr><td></td><td>walk to transit</td><td rowspan="2">44</td><td>18</td><td>21</td><td rowspan="2">22</td></tr>
<tr><td></td><td>park/ride</td><td>11</td><td rowspan="2">33</td></tr>
<tr><td></td><td>other/trip not made</td><td>2</td><td>1</td><td>14</td></tr>
<tr><td>Access mode:</td><td>auto driver</td><td>46%</td><td>62%</td><td>77%</td><td rowspan="2">54%</td></tr>
<tr><td></td><td>auto passenger</td><td rowspan="2">33</td><td>20</td><td rowspan="2">11</td></tr>
<tr><td></td><td>kiss/ride</td><td>11</td><td>20</td></tr>
<tr><td></td><td>walk</td><td>12</td><td>7</td><td>10</td><td>0</td></tr>
<tr><td></td><td>transit/other</td><td>9</td><td>---</td><td>2</td><td>26</td></tr>
<tr><td>Access distance:</td><td>average</td><td>n/a</td><td>n/a</td><td>(15 minutes)</td><td>n/a</td></tr>
<tr><td>(time)</td><td>within 2 miles</td><td>53%</td><td>47%</td><td rowspan="2">n/a</td><td rowspan="2">n/a</td></tr>
<tr><td></td><td>within 5 miles</td><td>88</td><td>80</td></tr>
<tr><td>Parked auto occupancy:</td><td></td><td>1.2</td><td>1.06</td><td>n/a</td><td>n/a</td></tr>
</table>

1/ Assumes 3 persons/carpool.

Table 21 (Continued)
Characteristics of Usage of Fringe Parking Facilities for Bus Service

		Washington, DC	Hartford	Shirley Highway	San Francisco
Prior mode:	auto driver	38%	57%	38% 1/	45%
	auto passenger		15	12	
	walk to transit	30	16	14	n/a
	park/ride		7	27	
	other/trip not made	32	5	9	
Access mode:	auto driver	52%	69%	87%	48%
	auto passenger	4	26		
	kiss/ride	32		4	5
	walk	13	5	9	21
	transit/other	0	0		26
Access distance:	average	n/a	n/a	(13 minutes)	3.5 miles
(time)	within 2 miles	n/a	n/a	50	n/a
	within 5 miles			80	
Parked auto occupancy:		n/a	n/a	n/a	1.07

1/ Assumes 3 persons/carpool.

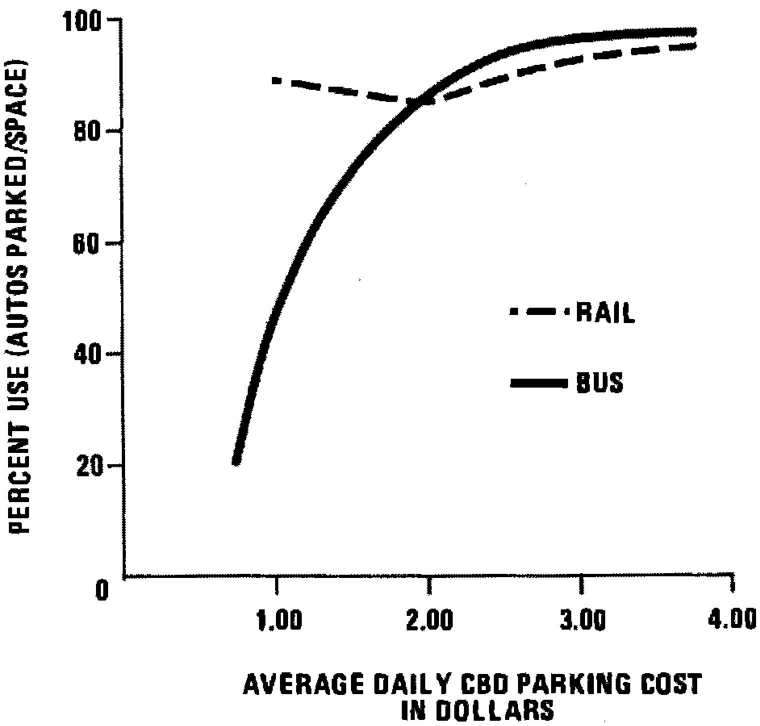

Figure 7
Effect of CBD Parking Cost on Fringe Parking
(286)

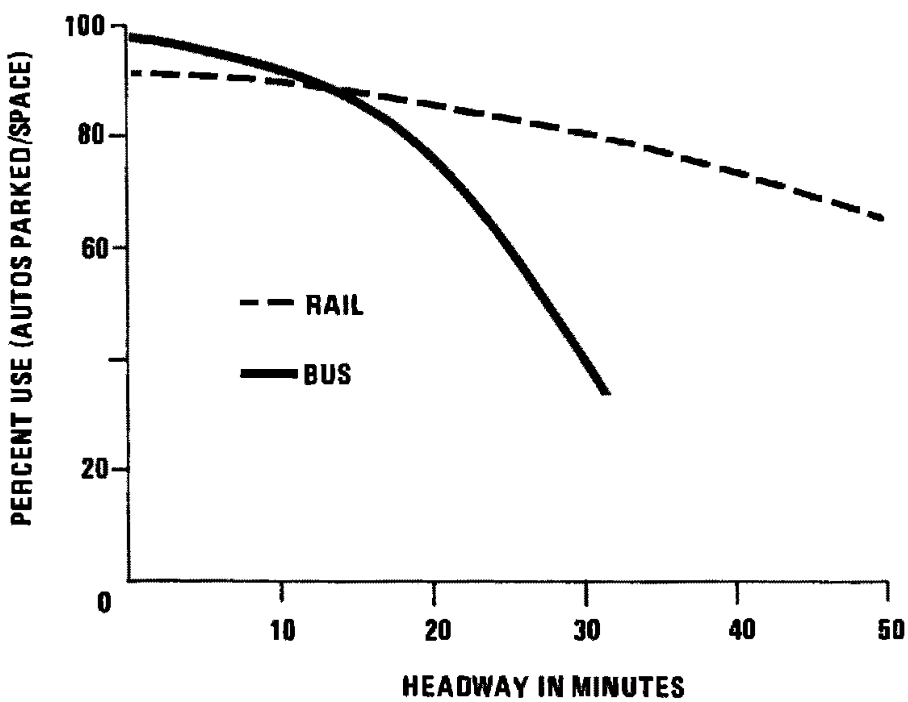

Figure 8
Effect of Transit Frequency on Fringe Parking
(286)

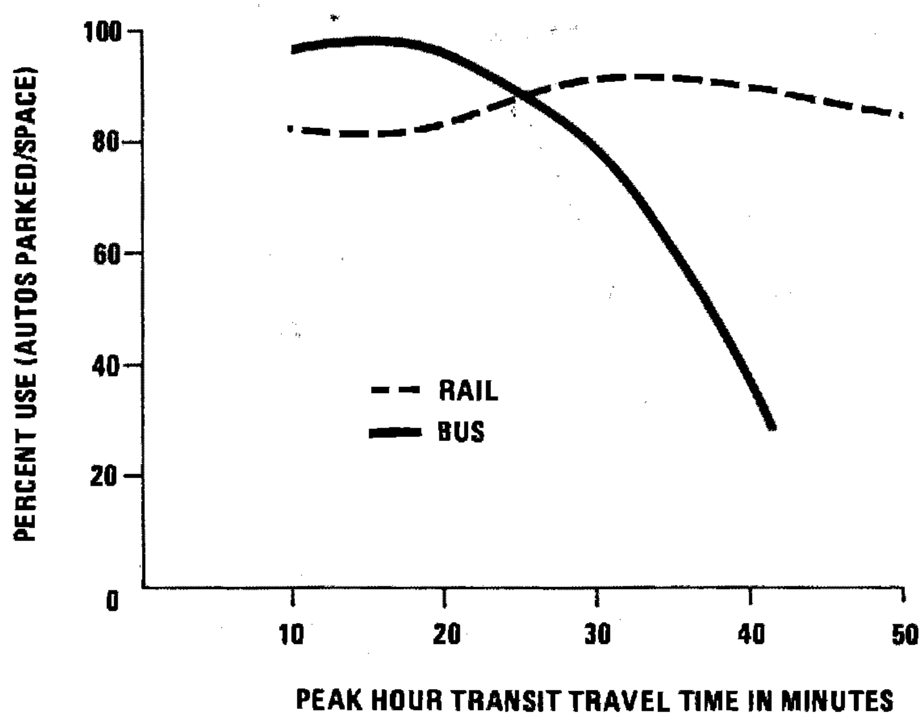

Figure 9
Effect of Transit Travel Time on Fringe Parking
(286)

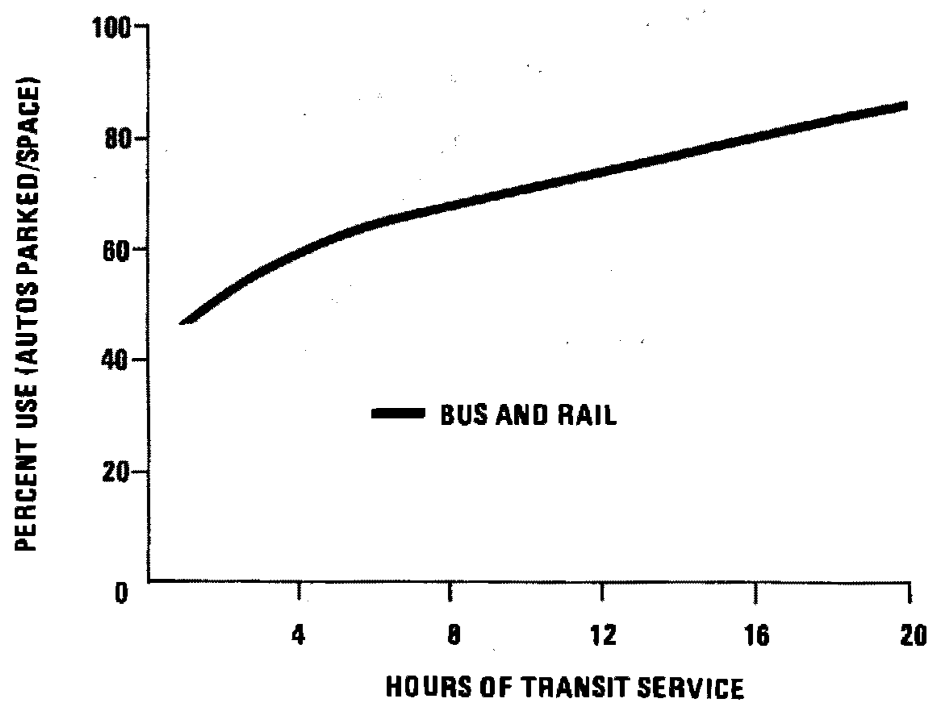

Figure 10
Effect of Transit Service Hours on Fringe Parking
(286)

These conditions may also be responsible for the relatively high usage of rail fringe lots where a lot parking fee is charged (as distinct from CBD parking cost). The effect of parking charges at fringe bus lots is less clear due to there being relatively few applications. Parking fees were blamed for lot failures in Los Angeles and Baltimore, while 2,150 autos park in three pay lots outside Dallas. A 475 space pay lot in Northern New Jersey served by New York City bound buses is filled to overflowing (70, 158). The difference between auto and bus commute cost may be more important than the additional out-of-pocket payment required by fringe parking fees, although Table 20, which includes parking and transit costs, provides no clear insight in this regard.

The relationship between CBD parking cost and park/ride usage is more clearly defined, as depicted by Figure 7. In surveys of park/ride service users, downtown parking cost was usually cited as the primary or secondary reason for the use of fringe lots (45*, 88*, 114, 192*, 286, 292#, 605*). An analysis of 5 discontinued fringe bus lots concluded that low downtown parking costs were a contributing factor to underutilization in 4 cases (158).

Figure 8 depicts the effect of transit frequency on fringe lot utilization. Experience indicates that as headways become longer, park/ride lot utilization declines, and sharply so in the case of bus service headways in excess of 15 minutes. In an analysis of 11 park/ride bus lots in Pittsburgh, the three lots with the highest rate of usage (and highest volume) had the shortest headways, while the three with the lowest rate of usage had the longest headways (576). The failure of several lots in Washington, DC was in part attributed to headways of 20 to 30 minutes (158).

The effects of transit travel time, illustrated in Figure 9, and the closely related measure of lot distance to the CBD, are also significant for bus service fringe parking. Peak hour bus travel times exceeding 30 minutes exhibited significantly lower usage of park/ride facilities (286). A second study noted that the most successful park/ride operations were located within 5 miles or 25 minutes of the downtown (158). Little variation in usage was reported for park/ride lots up to 15 miles from the CBD in Pittsburgh, but beyond this point ridership deteriorated significantly (576). Park/ride patronage in Rochester appeared to be insensitive to auto/bus travel time differences of up to 10 minutes, but minimal lot usage was noted as the difference exceeded 25 minutes (595). Several authors have noted that the actual distance or travel time is less likely to matter than the point at which radial highways become so congested as to result in increased stress and frustration for the auto driver without appreciable time savings over the bus mode (158, 192*, 286, 329).

The availability of mid-day and evening service, by providing flexibility for regular commuters and an alternative for non-peak riders, apparently enhances the performance of park/ride operations as depicted in Figure 10. While the "Hours of Transit Service" measure shown may act as a surrogate for other factors, the relationship is inherently logical and supported by other data. Several successful park/ride lots are served by express buses during peak hours and local buses at other times as shown in Table 20. Failure to provide adequate off-peak service was cited as a contributing factor in the discontinuance of park/ride operations in San Diego and Louisville and may have been a factor in poor performance in Atlanta and Santa Monica (158, 563#).

Several other factors have been cited as impedances to park/ride patronage in particular instances. In Santa Monica, one bus route required substantial backtracking to access a freeway for the line-haul portion of the trip (563#). Several lots in Washington, DC failed due to a combination of long headways, inconvenient lot location and more frequent, less expensive transit service a short drive away (158). Usage of two lots in the San Francisco region was believed to suffer due to overcrowding on buses serving the lots, resulting in some standees among park/ride patrons for the bus trip into the CBD (605*). Although difficult to correlate with lot usage, several authors cited lighting, shelter and lot identification through signing as inducements to ridership (158, 329, 576, 595).

Response to Carpool Fringe Parking

Although evidence is limited, the provision of formal fringe parking for carpoolers has apparently induced the formation of carpools in some applications. In a survey of users of three lots along a freeway between Dallas and Fort Worth, 21 percent of respondents indicated they would not be carpooling if the lot were not available while 62 percent cited the lot as one of several factors in their decision to carpool (17). Prior to the opening of a large, fenced and lighted carpool and transit fringe parking lot near Miami, over 60 percent of the carpoolers surveyed had driven alone (687#). A survey of 150 lots nationally also found 60 percent of carpoolers to have driven alone before fringe parking was available (207). Normal carpool breakup and reformation rates may account for some fraction of these survey results. The effect on carpool formation of providing lots for carpools appeared less significant at three locations in California. Two lots experienced negligible increases in carpooling while the number of carpools using the third lot fluctuated from survey to survey (605*).

Usually, less than 60 vehicles park at carpool fringe lots; the average being 20-30 vehicles (17, 45*, 207). Extensive unplanned carpool fringe parking near interchanges in several northeastern states indicates that unless an authorized lot can offer advantages in safety or security, or alleviate a parking shortage at a desirable location, carpool formation and parking location will depend primarily on other factors such as convenience and cost (45*). It may be speculated that increases in carpooling, such as encountered in Miami, may have partly resulted from the lots being an identifying factor for the carpooling mode. The lots may serve as a focal point for marketing strategies or as a visible incentive to commuters who would not otherwise consider forming a carpool. The nationwide survey revealed that the majority of users learned of their lot by driving past it (207).

The characteristics of carpool fringe parkers differ markedly from transit fringe parkers, normally resulting in minimal competition between the two modes. An analysis of fringe parkers in Pennsylvania, Connecticut, New Jersey and Massachusetts revealed that while virtually all transit fringe parkers were destined for a CBD, only 10 percent of carpoolers had CBD destinations. Among carpoolers, 11 percent were destined for non-downtown areas of cities and 79 percent ended their trip in suburban or outlying areas (45*). Similarly, 57 precent of Miami carpoolers were destined for locations not served by transit from the lot and only 7 percent were oriented to the CBD. The remainder could potentially be served by buses, but headways on the applicable routes often exceeded 30 minutes (687#). In the Dallas study, two of the three lots were not served by transit while the third was served by 1 bus trip daily in each direction (17). Interestingly, when an exclusive lane for buses and carpools was added in Miami, linking the lot with the CBD, the percentage of CBD bound carpools jumped to 44 percent, with 13 percent of the carpoolers being prior bus riders. The availability of free parking for 64 percent of the carpools at their destination and the absence of congestion due to the exclusive lane probably account for the many carpoolers eschewing the excellent express bus service to downtown in this instance (687#).

Carpoolers also differed from transit riders in their reasons for choosing their travel mode. Transit riders in the Northeast cited congestion and parking costs as the primary reasons for using the bus, while carpoolers ranked congestion low and parking cost last; trip cost being their primary inducement (45*). Parking cost was also unimportant to Miami carpool drivers as 76 percent paid less than 25¢ per day to park (687#).

Average auto occupancy to fringe lots was 1.08 in Miami and 1.38 in Dallas while average carpool occupancy leaving the lots was 2.75 in Miami and 3.76 in Dallas. This limited evidence suggests that one carpool is formed for every 2.5 to 2.7 autos entering the lot, or for every 1.5 to 1.7 autos parking in the lot (17, 687#).

Response to Peripheral Parking

Peripheral fringe lots, generally less than 3 miles from the CBD and served by shuttle transit service, have in the most successful applications served significantly larger volumes of autos than individual remote fringe lots. Several of the peripheral lots accommodated over 1,000 autos daily. The most heavily used lot, serving 4,200 vehicles daily, was linked to a downtown Fort Worth department store by a store-operated shuttle subway. Both parking and the subway trip were free. The ability to draw from a large market area of commuters as they converge on the CBD, and to provide frequent shuttle service (with a comparatively small number of vehicles and drivers), has resulted in significant diversion of downtown destined parkers. Characteristics and usage of both successful and unsuccessful peripheral lots are given in Table 22.

Peripheral lots that failed generally did so for reasons of user cost. Low usage in Atlanta was attributed to minimal user cost savings associated with parking at the fringe lot versus downtown, as were failures in Baltimore and San Diego (158, 192*). An extensive peripheral parking scheme operated in conjunction with a highly successful central area auto restraint program in Singapore failed due to higher fares on the express shuttle buses than on normal suburban-to-downtown routes (685). Low usage in Pittsburgh was unexplained, but the presence of free parking for light rail service with competitive travel times to auto in the corridor may have siphoned off much of the potential peripheral parking market (576).

A substantial number of peripheral parkers eschew available transit service and walk to their final destination, often over 1/2 mile away. Although detrimental from a transit operating standpoint, the result is still decreased parking demand and congestion in core areas; the principal objective of most peripheral lots. In Cleveland, 63 percent of parkers walk from the lot as do 11 percent of parkers in Atlanta. Despite the lot being filled to capacity, connecting transit service was discontinued in Cincinnati because of lack of patronage (158, 192*).

Travel Time and Cost Impacts on Peripheral Parking

Because users of peripheral lots do not have the opportunity to avoid congestion on routes leading to the CBD or to significantly decrease vehicle operating costs, downtown parking saturation and cost are the primary inducements to park in peripheral lots (158, 192*). Although unlike some remote lots, peripheral lots have been successful in charging a nominal parking fee, the level of the parking charge has affected usage. Increasing the fee from 25¢ to 50¢ in Cleveland after peripheral

Table 22
Characteristics and Usage of Peripheral Fringe Lots
(158, 192*, 316, 576)

	Cincinnati	Cleveland	Cleveland	Washington, DC	Washington, DC
Volume/capacity	1400/1400	2200/2500	1450/1450	615/625	220/290
Distance to CBD (miles)	0.6	1	1	3.2	3.1
Transit headway (minutes)	6	5-10	5-10	4	4
Parking fee	$.25	$ .25	$ .25	0	0
Roundtrip transit fare	$.20	$ .50	$ .50	$.50	$.50
CBD parking cost	n/a	$2.00	$2.00	n/a	n/a

	Fort Worth	Albany 1/	Atlanta 1/	San Diego	Pittsburgh
Volume/capacity	4200/5000	850/1900	375/1250	10/900	20/2000
Distance to CBD (miles)	0.3	1-3	1	2	1
Transit headway (minutes)	2/	5-7	10	15	5-10
Parking fee	0	$5.00/month 3/	$.50 3/	0	n/a
Roundtrip transit fare	0			$.35	n/a
CBD parking cost	n/a	$15-$40/month	$1.00 4/	n/a	n/a

1/ Two lots.

2/ Frequent, free, light rail shuttle transit service.

3/ Covers parking and round trip fare for all occupants of parking auto.

4/ Estimated.

parking had been in use for several months reduced the volume of autos parked at one lot from 2,200 to 1,500, an implied arc elasticity[c/] of -0.55. Usage declined from 365 to 310 in Atlanta when after a similar time period the parking/transit charge was increased from 50¢ to 75¢, representing an elasticity of -0.40 (192*).

The peripheral lot and shuttle service in Albany were operated as a benefit to state employees, in response to a long waiting list for parking spaces at state facilities. The $5.00 monthly parking/shuttle cost compared to an average $14.00 monthly transit cost from the suburbs to downtown. An analysis by residential zone was performed comparing park/ride users as a percent of total employees with the difference in travel characteristics between the park/ride and auto driver modes. Results from zones with a 20 percent or greater park/ride mode share are compared with zones with less than 2 percent park/ride mode share below (316):

	Zones with 20% or more park/ ride mode share	Zones with 2% or less park/ ride mode share
Average time savings (loss) per trip 1/	7 minutes	(4 minutes)
Average cost savings per day 2/	$.75 - .80	$.25 - .30
Average increase in travel distance	.4 miles	2.7 miles
Average park/ride mode share	30%	1%

1/ includes all walking and waiting time (unfactored)

2/ includes all out of pocket operating costs

Peripheral lot users in Cleveland were surveyed as to the cost and travel time differences between park/ride and their next best alternative, with the results shown in Table 23. Only 41 percent of those who would otherwise travel by auto and 28 percent of those who would otherwise use transit perceived that they spent either more time or money by using the peripheral lot. Within this group perceiving expenditure of more time or money, most of those who would otherwise have driven all the way were sacrificing time to save money, whereas most of those who would otherwise have taken transit for the entire journey were accepting extra cost to save time (192*).

Underlying Traveler Response Mechanisms

Commuters driving to transit fringe parking lots are obviously transit riders by choice, because their combined mode involves auto use. For the same reason, their chosen

c/ Elasticity as used here refers to the percentage change in volume for each 1 percent change in price. A parking price elasticity of -0.40, for example, indicates that a 1 percent parking price increase has caused or is expected to cause a 0.40 percent reduction in the number of vehicles parking. The negative sign indicates that the effect operates in the opposite direction from the cause. When the price goes up, the volume goes down, and vice versa. See Appendix A for a discussion of elasticity measures.

Table 23
Perceived Travel Time and Cost Comparison Between Peripheral Parking and Alternative Mode - Cleveland (192*)

Alternative Mode Auto Driver:	Park/Ride Travel Time Lower	Park/Ride Travel Time the Same	Park/Ride Travel Time Greater
Park/Ride Cost Lower	25%	29%	37%
Park/Ride Cost the Same	1%	4%	2%
Park/Ride Cost Greater	1%	1%	0%

Alternative Mode Transit:[1/]	Park/Ride Travel Time Lower	Park/Ride Travel Time the Same	Park/Ride Travel Time Greater
Park/Ride Cost Lower	46%	6%	2%
Park/Ride Cost the Same	14%	6%	2%
Park/Ride Cost Greater	19%	4%	1%

1/ Includes park/ride at other locations.

mode affords no opportunity to avoid fixed costs of auto ownership or to make the auto available to other family members.

In mode choice travel demand models, it has been found that a penalty must be assessed for auto use in order to treat park/ride transit trips in the same time and cost framework as other trips. Expressed in minutes of equivalent in-vehicle travel time, these penalties have ranged from 16 equivalent minutes in Washington, DC, to 28 equivalent minutes in Minneapolis-St. Paul for the average work purpose trip. Examiniation of different income levels in Houston produced penalty values of 38 to 44 minutes for lower and low income trips and 6 to 4 minutes for higher and high income trips. Similar penalties for non-work trips are very high. These modeling results show transit park/ride trips to clearly be the province of middle and high income journey-to-work travel (409, 604).

The attributes of fringe lots and associated transit service, highway congestion, and downtown parking characteristics must combine in certain ways to induce the auto commuter to leave his or her auto and change modes. In considering use of a mode change facility, any lot parking fee, the walk from parked car to transit service, and the transit service frequency all come into play (509). With respect to the trip as a whole, experience indicates that if substantial benefits can be derived among time, cost or convenience/comfort, without significant deterioration in any of these categories, park/ride lots are generally well utilized. Applications where routing was circuitous or lot location inconvenient (158, 207, 316, 563#) or where crowded buses required park/riders to stand for long distances (605*) had very low utilization despite significant cost savings and comparable travel times.

Table 20 indicates that where the extra time to park/ride is not excessive, daily out-of-pocket cost savings of $0.30[d/] or more combined with auto operating cost savings and relief from driving in commuter traffic are sufficient to attract park/ride users to fringe lots (88*, 192*). At peripheral lots, where relief from congested radial routes and significant auto operating cost savings are not available, daily out-of-pocket cost savings on the order of $0.75 or more appear necessary (192*, 316). The point at which the difference between total park/ride transit travel time and drive alone auto time becomes quite detrimental to park/ride usage when transit is slower has been estimated at approximately 10 minutes, with travel time differences greater than 25 minutes resulting in minimal use (595). The decline in park/ride usage as bus transit headways exceed 15 minutes (286), resulting in average access plus waiting times of 10 minutes or more, is a correlative finding.

<u>Facility Access and Market Shed</u>

Fringe lot location and access is an important element in the success or failure of park/ride service. Several studies have noted that for both transit and carpool lots, distances greater than 1/2 to 3/4 mile from the auto travel line haul route adversely affect usage (45*, 158, 207, 329, 563#, 576). The importance of easy radial highway

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d/ Dollar amounts are from 1970-1974.

access to fringe parking for carpools is demonstrated by the 30 to 40 percent of carpoolers who approached fringe facilities along the ultimate carpool route as opposed to cross routes in the Northeast (45*).

In most applications, 80 to 90 percent of transit users travel 5 miles or less in accessing fringe lots. Average access travel is on the order of 3 to 3.5 miles or 9 to 15 minutes (16*, 88*, 192*, 416, 605*). Based on data from Dallas/Fort Worth and Skokie, IL, there does not appear to be much resistance to back tracking up to 2 miles in order to reach the lot, although backtracking was cited as one of several possibilities for a lot failure in Washington, DC (16*, 114, 158).

The market shed for two highly successful park/ride operations, Lindenwold (rail) and Seattle (bus), can be inferred from Table 24, which gives access distance stratified by mode of access. Transit patrons carpooling to fringe lots tend to travel greater distances, and kiss/ride transit patrons shorter distances, than do park/ride auto drivers. The table below gives for each auto access mode the percentage of transit riders who travel less than three miles to reach the lot (192*):

	Lindenwold	Seattle
Kiss/ride	80%	77%
Auto driver	62	55
Carpooler	52	47

In the C&NW and Milwaukee Road commuter railroad park/ride lots of the Chicago north suburbs, 67 percent of identifiable autos were at stations within their own municipality. This was true for only 54 percent of the autos in rail rapid transit lots. Interestingly, use of parking along the C&NW and the Skokie Swift rapid transit by residents of the Milwaukee Road service area was fairly common, while the reverse was not observed. These phenomena were presumably induced by the more frequent service offered by the C&NW and rapid transit lines, and demonstrate the inherent ability of the park/ride patron to drive to the best of competing services (509). This flexibility of lot choice can be taken advantage of to increase park/ride lot utilization while relieving crowding. In Boston, selective reduction of fees at rapid transit parking lots caused parking load shifts from overutilized to previously underutilized lots, and increased parking along the affected transit lines by 48 percent. A $165,000 (1963) annual net gain in farebox plus parking revenue was achieved (377#).

Despite the seeming ability among members of a carpool to minimize access distance, carpoolers tend to have longer access distances than transit riders. Only 2 percent of transit riders vs 22 percent of carpoolers had origins outside the estimated service area of a lot in Miami (687#). Comparison between carpoolers and transit riders in the Northeast, where access distances were longer than the norm, reveals the following allocation (45*):

Access Distance	Carpoolers	Transit Riders
2 miles or less	12%	19%
5	48	59
10	72	80
15	88	90
20	93	94

Table 24
Access Mode versus Distance to Facility
(192*)

Distance 1/	Kiss-and-Ride		Auto Driver		Car Pool		Total 4/	
(miles)	Lindenwold 2/	Seattle	Lindenwold 2/	Seattle	Lindenwold 2/	Seattle 3/	Lindenwold 2/	Seattle
Under 1	31%	26%	20%	10%	13%	11%	33%	15%
1-2	32	37	26	32	29	25	23	32
2-3	17	14	16	13	10	11	15	12
3-4	7	8	9	10	6	18	8	10
4-6	5	9	8	15	22	14	7	13
6-8	3	6	7	20	8	21	5	18
8-10	1	0	5	0	9	0	3	0
10-15	3	0	7	0	3	0	5	0
Over 15	1	0	2	0	0	0	1	0
	100%	100%	100%	100%	100%	100%	100%	100%

1/ Straight line distance.

2/ Excludes Lindenwold terminal station.

3/ Auto passenger mode.

4/ Includes walk and transit access modes.

It is estimated that access distance accounts for approximately 20 percent of total trip distance for both transit riders and carpoolers (45*).

As would be expected, access distances and market areas for peripheral lots differ markedly from fringe lots. Average access distance for users of a Fort Worth peripheral lot was over 6 miles while more than 75 percent of users of two lots in Atlanta traveled greater than 7 miles. In both cases, origins of park/riders were widely dispersed rather than being confined to a specific corridor as is the case with most fringe lots (16*, 192*).

Prior Mode of Fringe Parkers

All types of fringe lots -- rail, bus, carpool and peripheral — are able to capture a very substantial but not overwhelming proportion of their patrons from the auto driver mode. Prior mode for Lindenwold High Speed Line riders not making a new trip, the majority of whom are park and ride patrons, is listed below (192*):

Prior mode	
Auto driver	43.8%
Carpool	6.2
Bus	50.0

Table 21, describing characteristics of users of bus fringe parking facilities, shows that 40 to 60 percent of the trips made both before and after fringe facilities were available were previously made as an auto driver. Approximately 25 to 45 percent were former transit trips. Where the distinction was reported, one to two thirds of these former transit trips were already utilizing the park/ride mode at another location. Whereas 5 to 10 percent of transit riders boarding vehicles at fringe parking lots walk to the lot, 15 to 20 percent report that they walked directly to transit service before fringe parking was available. This shift indicates increased localized auto use associated with switching from local transit service to park/ride usage. (88*, 192*, 292#, 408, 416, 563#).

Respondents to a survey of 150 carpool fringe lots nationwide and carpoolers using a fringe lot in Miami reported having used the following travel modes before fringe parking was made available (207, 687#):

Prior mode	150 lots	Miami
Drive alone	60%	61.3%
Carpool	34	36.3
Transit	6	--
Other/Trip not made	--	2.3

Prior modes of Washington, DC peripheral lot users and alternative modes for those driving to peripheral lots in Cleveland and Atlanta are given below (158, 192*):

Prior/Alternative Mode	Washington	Cleveland	Atlanta
Auto driver	25%	65%	81% (auto)
Carpool	18		
Walk to transit	15	22	
Park/ride	14	13	19 (transit)
Kiss/ride	9		
Other	19	0	

Impacts on Transit and Carpooling Use

The extent to which fringe parking per se induces transit riding has not been isolated from the impact of concomitant transit services, because the transit services predate or must be implemented concurrently with the parking. Nevertheless, the importance to certain types of transit operations of fringe parking can be inferred from the proportion of transit riders who gain access by auto, as well as from the prior mode of fringe parkers. The relative use of auto for access is listed below for five suburban commuter and rapid rail services (192*, 509).

	Auto Driver	Auto Passenger	Dropped Off
Lindenwold Line - New Jersey Suburbs	57%	6%	20%
C&NW Railroad - Chicago North Suburbs	33	24 1/	--
Milwaukee RR - Chicago North Suburbs	39	30 1/	--
Skokie Swift -Chicago North Suburbs	32	24 1/	--
BART - San Francisco and Suburbs	48	4	20

1/ Includes passengers dropped off.

Park/ride lot oriented bus services receive 50 to 90 percent of their patrons from parked autos and another 5 to 30 percent from auto drop-offs. See Table 21 for further details on bus passenger access.

Where bus feeder or collector service is not feasible or cannot be made adequately attractive, it is certainly reasonable that the provision of park/ride lots at least enhances express transit usage and may be necessary for its operational success. This is especially the case where surrounding land use activity precludes the option of parking on the street and using transit service or where the volume of autos parked would overwhelm on-street parking and result in prohibitively long walks for prospective patrons.

Because carpoolers are not constrained by the locations of transit stops, they would seem less likely to be influenced by the availability of formal lots. It is interesting in this light to consider the 20 percent of lot-using carpoolers in the Dallas/Fort Worth area who stated they would not be carpooling without fringe lots (17). Respondents were not questioned further, but possible reasons for their response may have been safety/security concerns, the presence of the lot serving as the impetus to start a carpool, or the suspicion that the survey takers were considering terminating the lot they used.

Impacts on VMT, Energy and Environment

Park/ride fringe parking VMT savings are influenced by the prior travel mode of users, lot distance from the CBD, and the energy efficiency of the connecting transit service. A matter still open to some question is how detrimental is the increased local auto travel associated with the 15 to 20 percent of all park/riders on average who previously walked to transit, and who now connect by auto.

Some indication of the energy impacts of fringe parking facilities may be gained by examining express transit and ridesharing that is heavily dependent on auto access. Extreme caution must be exercised, however, in interpreting results that only partially pertain to the fringe parking user. Those using an auto in some way for access to the extensively studied Shirley Busway transit service in Washington and the San Bernadino Busway service in Los Angeles constitute 33 and 72 percent, respectively, of all riders. The energy savings and emissions reductions attributable to these express operations are presented in the "Express Transit" digest under "Impacts on VMT, Energy and Environment." The annual energy savings, excluding any obtained from traffic congestion reduction, is estimated at 775,000 gallons of fuel annually for the Shirley Busway service and 875,000 gallons for the San Bernadino Busway service. The proportion attributable to park-and-ride patrons has not been isolated (148#).

A very park/ride dependent rail transit operation is the Philadelphia-Lindenwold High Speed Line, with about 83 percent auto access. The park/ride lots are within the service area of pre-existing commuter bus services. About half of the initial High Speed Line ridership previously used energy efficient bus or commuter rail. Estimates of the auto VMT savings afforded by the total park/ride and rail transit operation range from 66,000 daily work trip VMT (16,500,000 work trip VMT annually assuming 250 work days per year) to 28,000,000 annually for all trip purposes (77, 192*). Two independent energy evaluations, which specifically noted the indirectness of the combined auto access/rapid transit mode, produced partially conflicting results. One concluded that the total operation produced an average peak period energy savings equivalent to approximately 800 gallons of gasoline, and the other calculated that there was a 600 gallon net energy loss[e/] (77, 148#). Neither study calculated possible energy savings from congestion reduction. Opening of the Lindenwold Line was associated with a 3 percent traffic volume reduction on the parallel Benjamin Franklin Bridge into Philadelphia (192*).

Many smaller park-and-ride operations may well be typified by 6 shopping center lots in Milwaukee, which have removed some 400 cars from radial highways, less than one percent of the auto trips to the CBD. Such a number is small, but pertains to peak

e/ For daily one-way travel to work, which should be roughly equivalent to one peak period of commutation.

hour travel, and it is arguable that the traffic and carbon monoxide reduction may be of contributory significance at major CBD congestion points (192*). Table 25 gives energy analysis results for six park-and-ride lots in the Dallas-Fort Worth area, five of which were found to provide net energy savings. The estimated period required to "pay back" the indirect energy cost of lot construction ranged from one to 6.6 years. Prior transit mode use and indirectness of routing questions were apparently not applicable to the fringe lots in question (131).

VMT savings attributable to corridor parking facilities for carpoolers were determined from a survey of 150 selected sites in Connecticut, Michigan, Missouri and California. Median facility size was under 40 spaces. The grand total net VMT savings were equated to 1,435,000 gallons of fuel conserved annually. A formula developed from the survey results gives the following estimates of annual VMT savings per lot space provided, as a function of site distance from the primary destination (207):

Distance from Primary Destination	Annual VMT Reduction per Lot Space
10 mi.	2,800
20	4,300
30	5,700
40	7,200

Peripheral lots may not reduce VMT. Athough they tend to serve larger volumes of autos than remote lots, their proximity to the traveler's destination and attraction of users from all around the metropolitan area probably result in a negligible reduction in travel, or even a slight increase. A survey of peripheral lot users in Fort Worth revealed that approximately one quarter passed by the CBD in order to park at the lot. Another quarter deviated significantly from the straight line route to the CBD (16*). On the other hand, it can logically be assumed that the 3,700 autos parked at two large peripheral lots in Cleveland and the 4,200 autos at the Fort Worth lot would cause increased core area congestion and carbon monoxide concentrotions in the absence of peripheral parking (207, 192*).

Impacts on Bus System Costs

Park/ride allows cost-effective provision of trunk-line bus service where residential densities are insufficient to support an adequate feeder or collector mode operation. Trips made from remote park/ride lots are overwhelmingly peak period work trips by riders from outlying suburban areas of above average income and high auto ownership. This type of rider need not be dependent on local bus access and would be very unlikely to use it if low residential densities necessitate long headways and circuitous routing. One analysis of the residential densities required to support express bus service indicates that the density must be 5 to 6 times greater if collector service is to be provided instead of relying on park/ride (721). (See "Implications of Travel Patterns" in the digest "Express Transit" for additional detail.) A 1979 estimate of the annual cost to provide feeder service in a Dallas/Fort Worth region suburban community, to obtain ridership comparable to fringe parking, was $25,000-$50,000 (16*).

The availability of free or low cost joint use parking versus construction of a lot specifically for park/ride use naturally affects the economic attractiveness of feeder or collector service vis-a-vis fringe parking. Indeed, there is always a cost and service

Table 25

Energy Impact of Dallas-Fort Worth Area Lots, 1979
(131)

Lot	Number of Spaces	Miles to CBD	One Way Person Trips	Direct Energy Savings Per Year (Gallons)	Years to Pay Back Indirect Energy Use 2/
Garland 1/	627	18	710	200,000	1.0
Las Colinas	170	12	75	- 3,800	3/
North Central	356	11	550	38,000	3.2
Pleasant Grove	710	9	170	700	4/
Redbird	100	7	140	6,100	6.6
Ridglea	150	6	85	7,400	4/

1/ Combination of two lots.

2/ Energy used in lot construction only

3/ Payback not realized.

4/ Joint use lots -- no construction cost.

trade-off to be considered, in that bus service at a park/ride lot is never as attractive as truly equivalent service within close walking distance. Figure 11, based on 1975 costs, estimates the costs at which construction of a fringe facility is more economical than feeder service. The technique and assumptions used in deriving the figure are detailed in the appendix of the source. Although some of the cost assumptions are outdated, the trend illustrated in the figure is informative (357).

Additional References

"Change of Mode Parking - A State of the Art" and the accompanying appendix prepared by ITE Technical Committee 6H-A (286) provides an extensive compilation of park/ride lot usage data. For further information on Pool/Transit Fringe Parking consult references:

6, 11, 14, 16*, 17, 18, 35, 43, 45*, 70, 77, 78, 80, 87, 88*, 101, 102, 114, 131, 136, 140#, 148#, 158, 162, 172, 191, 192*, 207, 217, 243, 250, 258, 282, 286, 292#, 316, 329, 357, 377#, 394, 397#, 401#, 406, 416, 427, 433, 440#, 441, 452, 462+, 481, 486, 509, 522, 526, 527, 563#, 572, 573, 575, 593+, 595, 604, 605*, 611, 627, 628#, 675#, 677, 684, 685, 687#.

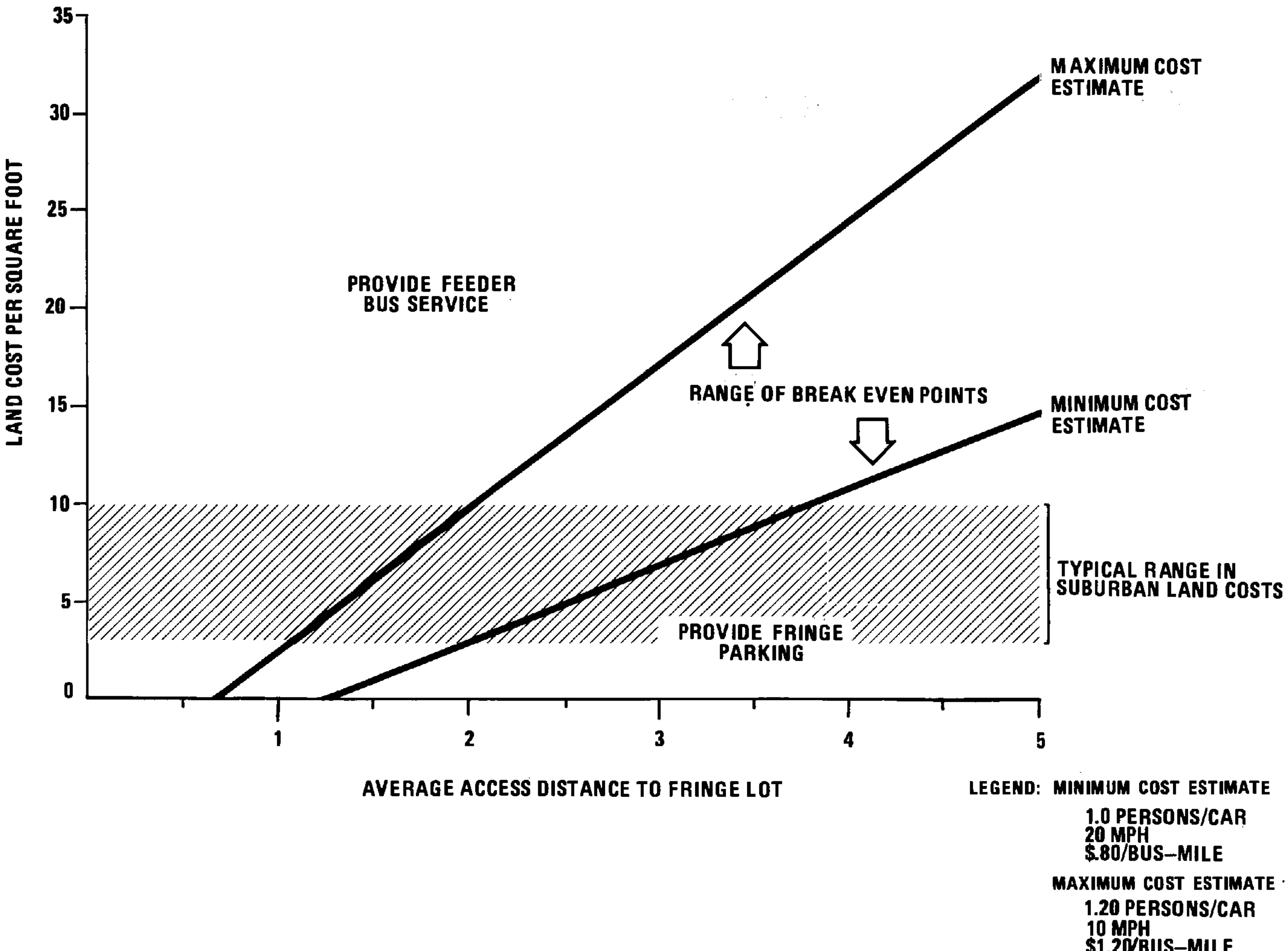

Figure 11
Economic Comparison of Feeder Service vs. Construction of Fringe Lots
(357)

16. Allen, Douglas A. Estimating the Service Area for Park-and-Ride Operations. North Central Texas Council of Governments. April, 1979. 32 pages. POOL/TRANSIT FRINGE PARKING*. OBSERVED STATIC SITUATION. TRAVEL CHOICE.

Characteristics of the service areas of three types of park/ride lots in the Dallas/Fort Worth region were analyzed to determine the distance and time commuters are willing to travel to access the lots. In addition, the shape of the shed from which the park/ride lots draw users is examined with reference to the orientation of the ultimate destination of park-and-riders. This study covers 9 remote lots, 4-30 miles from the CBD; 3 local service lots, 4-10 miles from the CBD; and 1 peripheral lot, 1.5 miles from the CBD. The remote lots were formally designated as park/ride lots, contained 150-600 spaces and were served by express buses. The local service lots were served by local buses and were not designated as park/ride lots by the bus operator. The peripheral lot was served by special shuttle transit service.

Origins of cars using the park/ride lots were obtained by matching license plate numbers of a sample of cars at each lot to addresses supplied by the Department of Motor Vehicles. This technique captured only the origins of auto drivers and no attempt was made to sample patrons traveling to the lot via other modes. Possible contributing factors to lot usage such as differing residential densities, freeway versus arterial access and service attributes of transit service were not examined.

Listed below are the meon and distribution of travel time and trovel distance for users of the three lot types.

Lot type	Trovel time in minutes (cumulotive distribution) 3	6	9	12	15	18	21	Average travel time (minutes)
remote	13%	38%	58%	94%	98%	100%	100%	9.0
local	20	47	63	90	90	100	100	8.6
peripheral	0	5	16	68	84	94	98	12.7

Lot type	Trovel distance in miles (cumulotive distribution) 1	2	3	4	6	8	10	12	Average travel distance (miles)
remote	14%	39%	58%	72%	88%	97%	100%	100%	3.6
locol	20	47	63	80	90	90	100	100	3.4
peripheral	0	5	15	34	52	79	88	96	6.3

The shape of the service oreas for remote and local pork/ride lots were similar, with the distance from the lots to the origins of 90% of the drivers being 4-5 miles for remote lots and 3-4 miles for local service lots. There oppeored to be little resistance to bocktracking up to 2-2.5 miles to park at both remote and local service lots. These distances are straight line distances, not trovel distonces. The shape of the peripherol lot service area wos vastly different. Fully one quarter of the users bypassed the CBD to reach the lot ond opproximately another quarter traveled circuitous paths to the CBD by using the lot. Whether these travel patterns were due to downtown congestion, porking charges or other reosons was not explored.

45. Barton-Aschman Associates, Inc. Commuter Parking at Highway Interchanges. Prepared for Bureau of Public Roads, U.S. Department of Transportation; Project No. FH-11-6956. March, 1970. 112 pages. NTIS PB 192-006. POOL/TRANSIT FRINGE PARKING.* OBSERVED STATIC SITUATION. TRAVEL CHOICE.

The incidence of parking near highway interchanges for the purpose of mode shifts to carpools or transit, in both designated and unsanctioned locations, was investigated to determine the level of fringe parking and the characteristics of parkers. At the time of this study little fringe parking was identified outside of the Northeast Corridor and information in the report is from Pennsylvania, New Jersey, Connecticut and Massachusetts. In addition, many of the interchanges surveyed were along toll facilities. As a result, comparatively longer trip lengths, higher commute costs and more severe congestion associated with larger, older cities should be acknowledged in applying the conclusions to other regions. The study also examined whether unsanctioned parking results in unsafe or inefficient conditions and analyzed the economic, legal, engineering and social implications in providing public facilities. In addition, the possibilities for joint use parking and the potential demand for and benefits of fringe parking were investigated.

Information in the study was obtained from a literature review, questionnaires sent to state highway departments, toll road authorities and transit agencies, and on-site investigations. Questionnaires seeking the characteristics of fringe parkers were placed on 1,426 vehicles at 36 locations and an additional 351 cards were distributed at interchanges in New Jersey and Connecticut. A 30% response rate was obtained.

On the highways surveyed, carpool fringe parking was more widespread, but in smaller quantities than transit fringe parking. Two transit lots had 340 and 410 parked autos while no carpool fringe area had more than 60 autos. Because carpoolers are not constrained by transit service attributes, carpool parking location may be more dependent on convenience and less susceptible to outside planning than is transit parking, except where parking space is scarce. The authors cite the flexibility of carpool parking in the low usage of the one fringe lot that charged a parking fee. Whereas almost all transit fringe parkers were destined for downtown areas, only 10% of carpool parkers had downtown destinations, with 11% bound for non-downtown areas of cities and 79% destined for suburban and outlying areas. The authors conclude that due to cost considerations and flexibility in scheduling, fringe parkers prefer transit to carpooling if it is available. Reasons for using fringe facilities in order of importance are listed below. Results were similar for toll and non-toll routes, while CBD destined carpoolers ranked parking cost at destination as the primary inducement.

Carpoolers	Transit Riders
trip cost	congestion
trip length	parking cost at destination
companionship	trip cost
congestion	parking shortage at destination
parking shortage at destination	trip length
parking cost at destination	companionship

Cumulative access distance for carpoolers and transit riders is given below. Access distance represented 20% of total origin to destination distance for both groups. Approximately 30-40% of carpoolers used the major highway to reach the fringe location while 60-70% used arterial crossroutes.

Cumulative Access Distance	Carpoolers	Transit Riders
2 miles	12%	19%
5	48	59
10	72	80
15	88	90
20	93	94

In the cases studied, fringe parking and carpooling or transit riding had no appreciable effect on highway volumes. The authors suggest that moderate park/riding or park/pooling can reduce congestion at interchanges near large suburban employment sites and reduce parking shortages in CBD's.

88. Brown, Gerald. "Influence of Park-and-Ride Factors in Modal Shift Planning." Transportation Research Record. Transportation Research Board, Washington, D.C. Number 557. 1975. Pages 12-20. POOL/TRANSIT FRINGE PARKING*, EXPRESS TRANSIT, CONSUMER PREFERENCE ANALYSIS. OBSERVED RESPONSE. MODE CHOICE, ACCESS MODE CHOICE.

A park-and-ride lot and associated bus service were inaugurated in March 1972 to serve one of the most heavily traveled corridors in Vancouver, British Columbia. The lot, 5 miles from the center of the CBD, provides users with access to buses on 5 and 10 minute headways during peak periods. The buses operate express for 3 miles then distribute riders for the remaining 2 miles, reversing the process on the return trip.

In April 1972 an on-board survey of park/ride users was conducted to obtain existing and prior travel attributes and reasons for using the park/ride lot. A second survey was taken of auto commuters in a corridor not served by park/ride service to ascertain what factors would influence their decision to travel by auto or to park-and-ride. Basic ingredients of the hypothetical park/ride service were assumed to be similar to the existing park/ride operation in that the lot would be remote from the CBD, users would walk from their auto to a sheltered bus stop, use an express bus, be deposited within two blocks of their destination and be guaranteed a seat. Results of the two surveys were analyzed to determine factors affecting park/ride service usage.

Patronage grew steadily on the park/ride service, reaching 900 daily AM inbound passengers by July 1973. Over 600 cars parked at the lot during this period. An express bus route implemented in the park/ride lot service area after the park/ride service began operating did not noticeably affect ridership. Prior mode and access mode for surveyed patrons is given below:

Prior mode			Access mode		
auto driver	-	38%	auto driver	-	77%
auto passenger	-	8	auto passenger	-	11
bus	-	21	walk	-	10
park/ride, other	-	33	bus, other	-	2

At least 12% of all patrons previously made the trip exclusively by bus, then switched to auto driver and park/ride with the advent of the lot, indicating that park/ride operation can induce auto travel in addition to replacing it. The degree to which this shift influenced overall VMT was not reported. The cumulative distribution of access times to the lot is given below:

percent of patrons within	5 minutes	-	10%	20 minutes	-	65%
	10 minutes	-	30	30 minutes	-	85
	15 minutes	-	50	40 minutes	-	93

Analysis of data from former auto drivers revealed that overall travel time increased only 1% (42.7 to 43.1 minutes) and average out-of-pocket expenses declined 39% (82¢ to 50¢). On a scale of 1 (very unimportant) to 5 (very important) auto drivers listed the following reasons for changing modes:

parking cost	-	4.07	trip time/speed	-	2.67
driving strain	-	3.82	more frequent buses	-	1.97
traffic congestion	-	3.63	less walking	-	1.89

The survey of auto commuters in the corridor not served by a park/ride lot revealed that frequent bus service and minor travel time savings would be required to induce large shifts of auto drivers to park/ride service. Based on the two surveys, the author concludes that 5 minute headways, express service, a guaranteed seat and costs at or below out-of pocket driving costs are necessary for successful park/ride operation.

192. Ellis, Raymond, J. Burnette and P. Rassam. Fringe Parking and Intermodal Passenger Transportation: Operational Experience in Five Cities. Peat, Marwick, Mitchell and Company. Sponsored by Federal Highway Administration, U.S. Department of Transportation. November, 1971. 256 pages. POOL/TRANSIT FRINGE PARKING*, EXPRESS TRANSIT. OBSERVED RESPONSE. TEMPORAL DISTRIBUTION, MODE CHOICE, ACCESS MODE CHOICE, AUTO OCCUPANCY. REVENUES/DEFICITS.

Operational characteristics and impacts associated with remote park/ride lots in Milwaukee, Seattle and Philadelphia and peripheral park/ride lots in Atlanta and Cleveland were examined to determine the factors in their success or failure. All the facilities were paved and lighted and all but Atlanta provided shelters. The two peripheral lots employed attendents to watch the lots while Philadelphia used television surveillance. Little or no feeder bus service was provided to the lots. Freeway express buses in Milwaukee operated from 6 shopping centers 10-14 miles from the CBD. Between 4 and 11 bus trips were made from each center during the AM peak two hour period with headways ranging from 5 minutes to 30 minutes throughout the peak. Local buses provided off-peak service. Freeway express buses in Seattle served a specially constructed lot 9 miles from the CBD. Peak headways were 15 minutes, off-peak headways were 30 minutes and evening service was provided by local buses. Travel time savings of 5 minutes are realized through use of an exclusive bus ramp in the CBD. Park/ride lots in Philadelphia are associated with the Lindenwold High Speed rapid transit line. Six outlying stations 6-14 miles from the CBD were served by trains on 5 minute peak and 7.5 minute off-peak headways. Both Atlanta and Cleveland operated shuttle buses to 2 peripheral lots adjacent to freeways less than 1 mile from the CBD. Cleveland off-peak headways were 9 minutes, with peak headways less, while Atlanta had 10 minute peak headways and no off-peak service. The number of parking spaces and autos parked daily is given below:

	Milwaukee	Seattle	Philadelphia		Atlanta	Cleveland
			Pay	Free		
Parking spaces	800	475	3,771	4,442	1,250	4,100
Autos parked	400	475	2,214	4,340	400	4,100
Facility type	remote	remote	remote		peripheral	peripheral

Park/ride service was successful at diverting former auto travelers with 40-60% of remote park/riders and up to 80% of peripheral park/riders being former drivers and an additional 5-10% being former auto passengers. About 20% of park/riders formerly walked to a transit stop indicating that although park/ride diverts CBD traffic, it may induce auto travel in outlying regions. The remaining 10-30% of park/riders who had previously used transit did so via park/ride, kiss/ride and transit feeder access modes. Although the net effect on VMT was not quantified, the proportion of users switching from walk access to park/ride access and the relatively short access distances indicate that net VMT reductions were still significant. In total, 30-50% of remote lot users and 20-35% of peripheral lot users were former transit patrons. Kiss/ride access accounted for 15-20% of remote lot users while walk and transit access varied depending on lot location and availability of feeder service. In general, 50-80% of patrons drove to the lot with auto occupancies of 1.06-1.20 for remote lots and 1.30-1.35 for peripheral lots. Eleven percent of Atlanta lot users and 63% of those in Cleveland walk to their destination rather than ride the CBD bus shuttle. Distance traveled to the lot is given below for all patrons in Philadelphia and Seattle and for auto drivers in Milwaukee:

Distance traveled	Philadelphia	Seattle	Milwaukee
under 2 miles	56%	47%	53%
under 4 miles	78	69	86
under 6 miles	85	82	94

There were no significant differences in travel attributes among the stations on the Lindenwold Line despite the varying distances from the CBD. Cost savings (1968-70 dollars) over auto driving based on tolls, parking charges and transit fares and time savings over walking to public transit are presented below.

	Milwaukee	Seattle	Philadelphia	Atlanta	Cleveland
Daily cost savings	1.25	1.05	2.30	.53	1.00
Daily time savings (min.)	50	N/A	35	22	20

A survey of users of the peripheral facilities revealed that cost and convenience were the two prime factors influencing their decision to park and ride. Congestion was cited frequently by users in Atlanta. Of the 5 case studies, only Atlanta was judged unsuccessful while Philadelphia was said to be the most successful. It appears that relative cost savings is the primary reason for the failure of the former and the success of the latter although congestion in the Lindenwold corridor makes the High Speed Line attractive from a time standpoint.

605. Thompson, R. Patton. Evaluation of Three Demonstration Parking Facilities in California. Sponsored by California Department of Transportation. June, 1980. 60 pages. POOL/TRANSIT FRINGE PARKING*, EXPRESS TRANSIT. OBSERVED RESPONSE. MODE CHOICE, AUTO OCCUPANCY, ACCESS MODE CHOICE. ENERGY, AIR QUALITY.

Three demonstration park-and-ride lots were opened in 1978 to evaluate the influence of fringe parking facilities on carpool formation and transit ridership. The Manzanita lot, 8 miles north of the San Francisco CBD, was served by express buses on 5-minute headways that used a contra-flow bus lane to the Golden Gate Bridge. Carpools did not have access to the priority lane, but they did receive toll-free passage across the bridge. The Fruitvale facility was located about 4 miles from the Oakland CBD and 9 miles from the San Francisco CBD. Buses on 10 minute peak headways served the lot which was the last collection stop on San Francisco bound routes. Carpools and buses to San Francisco had access to priority toll approach lanes on the San Francisco-Oakland Bay Bridge and were granted toll free passage. The San Pedro fringe parking lot was 20 miles south of Los Angeles and served by peak period express buses on 20-30 minute headways in addition to local service.

Information was obtained from visual inspection of the sites and mail back questionnaires placed on parked cars in each lot. No attempt was made to survey travelers not driving and parking at the lot although the volume of people accessing the lot via other modes was noted. Survey response rates were 57% at Manzanita, 30% at Fruitvale and 60% at San Pedro.

Although approximately 100 cars were observed parking in the vicinity of the Manzanita lot prior to its construction, only a 76-space facility was provided. The lot thus filled to overflowing and, combined with often crowded buses, may have impeded transit patronage and carpool formation. Nevertheless, within 5 months of its opening, 150 autos were parking in the area and 80 transit riders and 100 carpoolers departed from the lot during the AM peak period as compared to the 110 parked cars, 45 transit users and 60 carpoolers 2 weeks after the lot opened. The degree of pooling induced by the lot is speculative as at least 2/3 of the carpools had formed before the lot was opened and some no doubt would form even if no lot was provided. Little or no prior commuter parking was identified as such near the Fruitvale facility prior to its opening. The 164 space facility was used by 60 parked autos during the AM peak period after 6 months, up from 30 parked autos after 2 weeks. The lot was used by 95 bus riders, 10 carpoolers and 25 people who walked to their destination, up from 75 bus riders, no carpoolers and 10 pedestrians. It was noted that some people walking from the lot boarded local buses 2 blocks away. Fifty percent of the transit patrons were destined for San Francisco with 23% each bound for Oakland and Livermore Laboratory, 35 miles away. Crowded bus conditions forced some lot patrons to stand, perhaps inhibiting ridership. Prior to using the lot, 45% of lot users had driven to their destination. The 106-space San Pedro lot provided parking for 45-50 cars 8 months after opening, not significantly different from opening day usage or the number of cars parked in a nearby drive-in theater prior to the lot's construction. The number of lot users increased from 65-70 to 80-90 and transit ridership grew slightly, probably due to an increase in the number of users dropped off at the facility by vehicles which did not park. Although commuter parking in the area increased only slightly, 63% of express bus survey respondents indicated they had previously driven alone, and only 33% of all parkers indicated they had parked at the theater. According to the survey, five of seven carpools using the lot formed after the facility was provided.

Mode of access data was stratified differently for each lot. At Manzanita, 56% arrived by single passenger auto, 36% by carpool, 6% by walking and 2% by bus while at Fruitvale 48% arrived in an auto that parked, 5% by kiss/ride, 21% by walking and 26% by bus. At San Pedro 62% arrived by single passenger auto, 31% by kiss/ride, 3% by carpool, 3% by walking and 1% by bicycle. Average access distance was 3.1 miles at Manzanita and 3.5 miles at San Pedro. The fuel shortage in the summer of 1979 significantly increased usage at the Fruitvale and San Pedro facilities, although the long term effects are unknown. The three lots combined reduced annual VMT by an estimated 600,000 miles annually.

VANPOOLS/BUSPOOLS

Types of Programs

Vanpooling and buspooling programs fall within the overall transportation system management category of "Actions to Reduce Vehicle Use in Congested Areas." Vanpooling and buspooling programs are primarily for home to work travel and include:

1. Vanpool programs in which commuters whose residences are geographically grouped travel to and from work in 8 to 15 passenger vans driven by a member of the pool with organizational and maintenance responsibilities. Riders generally pay a weekly or monthly charge (295, 335, 507, 591). There are three primary vanpooling organizational strategies:

    a. Employer-sponsored vanpool programs, in which an employer purchases or leases vans for employee use and/or subsidizes the cost of program operations and administration. The driver usually receives free passage, and limited personal use of the van for a fee. Scheduling is within the employer's purview, and rider fares are normally determined on the basis of vehicle cost and operating cost (291*, 467*, 507, 581, 637, 696#).

    b. Third-party programs, run by an organization such as a non-profit corporation, employees credit union, or transit district. The third-party organization enters into an agreement with the driver similar to that of employer programs. User fares normally cover vehicle cost, maintenance, fuel and insurance and may cover program administration costs (176*, 200, 254, 507, 556, 637).

    c. Owner-operator vanpools, often viewed as a "big carpool," where the individual owner or lessor takes all financial risks and has complete control except for non-profit requirements imposed by some regulatory commissions (507, 637).

2. Buspool programs in which commuters are offered personalized, door-to-door or neighborhood-based service to their workplace; usually a large, single employment center. Riders are offered a single bus trip that matches work schedules, or a series of peak period trips. The fare is either handled by means of weekly or monthly subscriptions for service, or else is a trip-based fare (14, 333, 629*). The two primary buspooling organizational modes are:

    a. Management and operation by the principal local transit operator, as an adjunct to traditional public bus service. Examples implemented experimentally in the past averaged less than 10 one-way miles in length, but services currently provided are mostly in the 10 to 30 or more mile range (24*, 283*, 328, 333).

    b. Management by commuters who have joined together to form one or more buspools, or by commuters in close cooperation with a private corporation formed for the purpose, or by an employer. These operations most often use chartered buses, and typically operate in the 15 to 60 mile range of one-way trip length (215, 333, 385).

Vanpool and buspool operations which form a part of an overall transportation brokerage strategy are examined in the multi-modal high occupancy vehicle context in the "Transit Marketing/Brokerage" digest. Carpooling itself is covered within the "Carpooling Encouragement Activities" topic area[a].

Traveler Response Summary

Vanpools and buspools provide an attractive and generally effective paratransit mode for home to work commuters not well served by conventional transit. Vanpooling doubled each year in the 1974 to 1980 period, but remains a relatively new form of commuter transportation of unknown ultimate proportions. In 1981 over 600 organized vanpool programs sponsored nearly 12,300 vans total in the U.S.A. and Canada, serving some 125,000 commuters. The number of owner-operator vanpools is unknown.

The majority of employer-sponsored vanpool programs serve less than 5 percent of the company workforce, typically 1 or 2 percent. However, over 20 percent of programs surveyed in 1976-77 served 10 to 58 percent of the on-site workforce. The top 15 "most successful" employer sponsored programs operated 20 to 120 vans each by 1979. Average program trip length ranges from 7 to 75 miles one way. Third-party vanpool programs are in their infancy, but at least 5 such programs were sponsoring 50 to 140 vans each in 1979. There are successful exceptions, but most vanpool programs do best where one-way trip lengths exceed 15 miles, where work schedules are fixed and regular, where employer size is sufficient to allow matching of 10 to 12 people from the same residential area, where public transit is inadequate, and where some congestion or parking problems exist.

Buspools require higher densities of travel demand than vanpools, but otherwise the indicators of likely success are comparable. Buspool systems with average route lengths of less than 10 miles have failed except where the residential density of eligible employees approaches one such employee per every four households. Long haul buspools, in the 10 to 60 mile range of route length, apparently have a very low failure rate. Single-employer oriented buspool systems, perhaps one-tenth as common as vanpool programs, serve up to around 10 percent of the on-site workforce. Two suburban Washington services oriented to the central business district are used by as many as one or two out of every three commuters traveling between the passenger pickup and discharge areas. Buspool services may work with as little as one scheduled bus, but there are over a half dozen systems in the U.S.A. that operate buspool fleets in the 20 to 50 bus range.

Excepting certain CBD oriented programs, slightly over half of new vanpool and buspool riders formerly drove an automobile to work. The majority of buspools and

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a/ A "Carpooling Encouragement Activities" digest was provided in Edition I of this Handbook (510). For "Carpooling Encouragement Activities" references see Chapter III of this current edition. In particular "Evaluation of Carpool Demonstration Projects, Phase I Report", by F.A. Wagner, provides comprehensive and recent carpool program information (674).

vanpools serve white collar workers on regular work schedules, but a number of significant operations oriented to blue collar workers exist. Van/buspool commuters appear more than willing to tolerate some extra time spent in picking up and discharging passengers in order to gain door-to-door or neighborhood pickup convenience in conjunction with savings in travel cost and stress. However, once this extra time approaches and exceeds line-haul travel time, the vanpool or buspool service is not as attractive and normally fails to draw much of the potential market.

Program Objectives

The primary focus of vanpool and buspool programs is provision of an attractive door-to-door or neighborhood-based paratransit alternative to the private automobile for home-to-work travel. Vanpool/buspool service may be designed to provide an intensive form of ridesharing where conventional transit service does not exist and is unlikely to be cost-effective. It may equally well be designed to supplement existing, but relatively unattractive or costly line-haul transit services.

The general objectives are to satisfy travel requirements more efficiently than can be done with low-occupancy auto usage, but to do so without severely restricting personal mobility or incurring unduely high operating subsidies. Specific intended benefits to employers and the general public include reduction of automobile congestion around major employment centers, reduction of parking requirements at employment sites, conservation of energy, and reduction of air and noise pollution. Intended user benefits include low costs, acceptable travel time, and convenience for the journey-to-work trip (14, 176*, 200, 215, 291*, 333, 467*, 505+, 696#).

Extent of Vanpooling

Vanpooling is increasing in popularity year by year but remains a relatively new form of commuter transportation of unknown future proportions. Many feel the potential for the sustained growth of vanpooling is quite large. Others view it as having significant potential only in special situations (291*, 591). Descriptors that may help define the potential vanpool market are discussed in the section "Indicators of Market Potential."

The geometric growth in acceptance of vanpooling is demonstrated by the doubling in number each year of employer sponsored, third-party and other organized program vanpools in the 1974 to 1980 period. This growth is shown for the U.S.A. and Canada in Figure 12 and in the following table (507):[b/]

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b/ Includes information obtained from Office of Transportation Programs, U.S. Department of Energy.

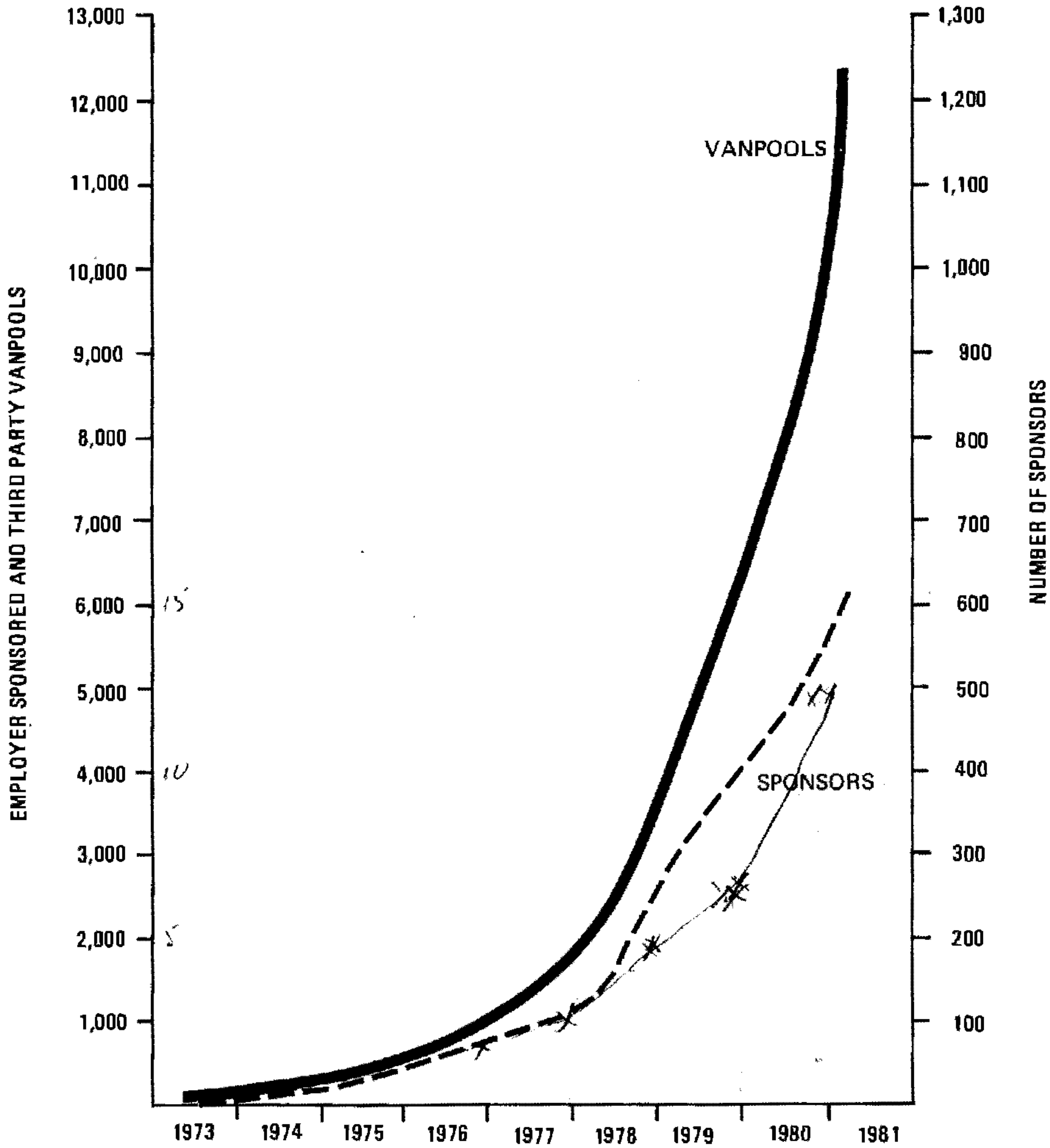

Figure 12
Growth of Sponsored Vanpools
(507)

Growth of Sponsored Vanpools	Number of Sponsors	Number of Sites	Number of Vanpools
April 1973	1		6
April 1974	15		125
April 1975	25		240
April 1976	56		643
April 1977	86		1,100
February 1978	122	163	1,986
April 1979 1/	308	372	4,382
June 1980	458	618	8,105
March 1981	603	864	12,268

1/ Some data for subsequent months.

In early 1981 organized programs had nearly 12,300 vans serving some 125,000 commuters. On the other hand, the relative infancy of vanpooling is demonstrated by statistics compiled by the Golden Gate Vanpool Demonstration Project whose 30 vans at the time (April 1978) comprised well over one percent of North America's sponsored vanpools. These vans carried one half of one percent of the commuters between San Francisco and its northern suburbs, and one tenth of one percent of the commuter trips confined within the northern suburban counties of the San Francisco Bay Area (176*). Three states had no organized-program vanpools in 1981 and another ten states had less than 25. The top ten states had 60 percent of the sponsors, 58 percent of the vanpooling sites and 72 percent of the organized-program vanpools in the U.S.A. as shown in the following listing:[c/]

Top Ten States	Number of Sponsors	Number of Sites	Number of Vanpools
Texas	111	140	2,248
California	47	71	1,922
New Jersey	98	125	1,288
Virginia	15	16	597
Minnesota	19	30	591
Connecticut	21	42	584
Tennessee	9	27	540
Michigan	19	21	438
Maryland	8	9	301
Washington	10	16	277
Subtotal	357	497	8,786
U.S.A. Total	597	853	12,183

There is no inventory of owner-operator vanpools. One 1979 estimate was that there might be 3,000 to 5,000 in the U.S.A. The number of individually owned and operated

c/ U.S. Department of Energy, op. cit.

vanpools using the Washington Area Shirley Highway bus and carpool lanes daily increased from 80 in October 1978 to 250 in April, 1980. At the military-industrial complex in Norfolk, VA, over 60 were known to be in operation in 1979 (507). Also in Virginia, on the order of 200 owner-operator vanpools carry 15 percent of all 12,750 AM peak hour person trips entering the core area of Newport News, dominated by the Newport News Shipyard and Drydock Company. Another 10 percent are carried in some 30 privately operated buspools.[d/]

Response to Employer Sponsored Vanpool Programs

The longest established major vanpool program, and the largest with employer sponsorship, was started in 1973 at the 3M company in St. Paul, Minnesota. By 1979, 3M had 115 vanpools operating at the 3M Center, serving 13 percent of the work force. When surveyed in 1974, the average 3M van carried 11.36 persons for an average one-way line-haul distance of 17.2 miles. Line-haul distances ranged from 5 to 48 miles. As of 1976, 93 percent of 3M vanpoolers reported having accepted an increase in travel time in order to vanpool. Average commute time after vanpooling was 38 minutes compared to 28 minutes before. The percent of vanpoolers in each travel time change category is shown below for both 3M and State of Michigan employee vanpoolers (467*, 507, 637):

Travel Time (vanpooling vs. prior mode)	Percent of Vanpoolers	
	3M	Michigan
10+ min. savings	2%	2%
0-10 min. savings	4	5
no change	17	20
0-10 min. increase	37	20
10-20 min. increase	27	26
20+ min. increase	13	27

The University of Washington in 1976-77 examined 58 employer sponsored vanpool programs scattered across the U.S.A. and operating a total of 616 vans at the time. Table 26 characterizes these programs by employer size, employee participation, and program average one-way trip length. Although work force participation rates as high as 58 percent were encountered among these programs, almost half were at the 1 or 2 percent level. Program average trip length ranged from 7 to 75 miles one way with a broad distribution of trip lengths within programs. Although half the firms were in manufacturing, the programs tended to concentrate on office locations, and three quarters served predominantly white collar workers.

Employer sponsored vanpool programs are dependent on management support, or at least approval. Of the 58 programs covered in Table 26, 86 percent received employer subsidies for administration; 76 percent for publicity; and 67 percent for absorption costs (expenses related to having a vanpool fall below minimum ridership). Of the programs deemed most successful on the basis of market penetration and growth, a key element of success was a high level of management commitment frequently

d/ Information obtained from the City of Newport News, Virginia.

Table 26
Characteristics of 58 Employer Sponsored Vanpool Programs in 1976-77 (291*)

Employer Size		Employee Participation		Average Trip Length	
Thousands of Employees	No. of Programs	Percent Vanpooling	No. Of Programs	One-Way Miles	No. of Programs
0-1	17	1	20	2-7	1
1-2	12	2	8	7-12	2
2-3	8	3	6	12-17	6
3-4	6	4	5	17-22	12
4-5	2	5	1	22-27	14
5-6	3	6	3	27-32	7
6-7	0	7	0	32-37	7
7-8	1	8	1	37-42	3
8-9	1	9	1	42-47	3
9-10	1	10	0	47-52	1
10-11	2	11	3	52-57	0
11-12	0	12	2	57-62	1
12-13	1	13	1	62-67	0
13-14	1	14	1	67-72	0
14-15	0	23	1	72-77	1
15-16	0	25	2		
16-17	0	37	1		
17-18	1	42	1		
18-19	1	58	1		

motivated by parking problems. Table 27 lists the 15 "most successful" programs and their characateristics as of 1976-77. The 12 "least successful" programs had 3 or less vans and 2 percent or less of employees riding after a year or more. Lack of vanpooling success was frequently associated with pre-existence of employee carpooling programs that may have had the affect of competing for riders (291*).

Although vanpool success is most frequently associated with the long distance commutes and low job turnover rates associated more with white collar workers, several programs have been adapted to production worker needs. The Polisar, Ltd. Commuter Van Cooperatives of Sarnia, Ontario (technically a third-party operation) have a unique system of multiple drivers and manual demand responsive routing to cope with shift changes and rotation. Each of the 16 vans transports 30 to 35 members daily by serving three shifts (507).

Response to Third-Party Vanpool Programs

Certain single-employer oriented vanpool programs are technically third-party programs because van financing and program administration is handled independently of the employer's organization. Examples are the Polisar, Ltd. Commuter Van Cooperatives mentioned above and the 32 van Pantex Vanpool Program in Texas. The Pantex vans are financed by the Amarillo Pantex Federal Credit Union and otherwise represent owner-operator vanpooling with company guidance and incentives (507, 637).

Third-party vanpooling programs independent of one-on-one employer involvement began to emerge in the 1976-78 period and represent a small but fast growing element of vanpooling (176*, 507). A prototypical example and one of the larger of these programs is Maryland's VANGO, Inc., which evolved out of the Maryland State Ridesharing Program. Actual operation began in November, 1977, and 139 vans were in service after 30 months (June, 1980). Eligible drivers sign a three-party lease agreement with VANGO and their leasing company that provides the driver a van, vehicle registration, vehicle backup, insurance coverage, protection from possible termination costs, and assistance in maintaining ridership. VANGO has so far concentrated on the suburban Baltimore and Washington markets, and does not furnish vans for trips under 10 miles one-way commute distance. Other examples of third party programs fully underway by mid 1978 include, along with VANGO, the following (176*, 200, 507, 586*, 637):

Agency, State	Start Date	Initial Growth	Vans Apr. '79
Commuter Computer Los Angeles, CA	April '76	85 vans in 24 months	137
Gold Gate Bridge District, CA	Oct. '77	25 vans in 8 months	56
Knoxville Commuter Pool, TN	Jan. '76	51 vans in 16 months	65
Rides for Bay Area Commuters, CA	March '78	63 vans in 12 months	70
VANGO, MD	Nov. '77	44 vans in 16 months	107

Table 27
Characteristics of 15 "Most Successful" Employer Sponsored Vanpool Programs
(291*, 507)

Category I Employers 1/	No. of Employees 3/	Start Date	Number of Vans 4/	Ridership Percent 3/
3M, St. Paul, MN	9,500	4/73	6 - 92 - 115 5/	11
Cenex, S. St. Paul, MN	700	10/73	2 - 20 - 17	23
General Mills, Minneapolis, MN	1,700	1/74	5 - 18 - 22	12
TVA, Knoxville, TN	3,000	3/74	6 - 70 - 71 5/	25
Ralph Parsons, Pasadena, CA	3,500	4/74	3 - 28 - 35	8
Winnebago, Forest City, IA	3,700	12/74	12 - 21 - 30	11
CONOCO, Houston, TX	1,400	3/75	10 - 37 - 67 5/	25
Prudential, Newark, NJ	980	7/75	2 - 57 - N.A. 5/	58
Category II Employers 2/				
Erving Paper, Brattleboro, VT	300	3/73	1 - 6 - 6	42
Voorhees, McLean, VA	100	4/74	1 - 1 - 1	14
Nabisco, Hanover, NJ	975	10/75	13 - 13 - N.A.	13
Sou. N. Eng. Tel., New Haven, CT	600	2/76	6 - 6 - 18	11
Aramco, Houston, TX	450	3/76	2 - 5 - 34	12
Laminating Corp., Eatontown, NJ	150	7/76	3 - 4 - 5	37
Zenith, Chicago, IL	400	10/76	1 - 4 - 6	9

1/ Those out of 58 programs surveyed in 1976-77 with at least 9 vans more than at program inception and with work force participation rates (ridership percent) of 8% or more.

2/ Those programs at firms with less than 1000 employees on site with a smaller gain in vans but with work force participation rates of 8% or more.

3/ As of 1976-77.

4/ At program inception, as of 1976-77, and as of 1979 (1979 data may not be exactly comparable)

5/ Nationwide in 1979: 3M, 130; TVA, 399; CONOCO, 189; Prudential, 202.

It is too early to judge third-party vanpool market penetration potential. An early assumption of Maryland planners was that 25 percent of all employees of the Baltimore Region who worked for employers of over 200 people and commuted over 9 miles one way were prime candidates for vanpooling. This would equate to 350 vanpools. After 17 months of VANGO operation, 72 vanpools (employer and owner-operator included) were registered in the Baltimore Region, leaving a large but not insurmountable gap between performance and objective (200, 586*).

The average VANGO, Commuter Computer and Golden Gate one-way trip length is in the 30 to 40 mile range, longer than the median employer-sponsored program average (176*, 200, 291*, 507). Interestingly, only 19 percent of Maryland vanpoolers (predominantly VANGO) are picked up at home, and the average morning pick-up point access distance is 3.6 miles. In good weather 26 percent of Golden Gate vanpool passengers are picked up at their door, as compared to 44 percent in bad weather. An auto trip of 2.9 miles on average is the access mode of another 33 to 39 percent, and the remainder walk an average of 2 blocks. Average Maryland and Golden Gate van occupancies are 9.6 and 14.2 persons, respectively. Golden Gate and Maryland vanpooler characteristics and attitudes that can be directly compared include (176*, 586*):

	Golden Gate	Maryland
Average Age	40 yrs	41 yrs
Sex	63% male	57% male
Marital Status	78% married	72% married
Average Income	$25,000	$30,000 (family)
Occupation		
Professional, Technical	55%	58%
Manager, Administrator	16%	15%
Clerical, Sales	18%	19%
Crafts, Operators, Laborers	8%	2%
Service	1%	0%
Other	2%	6%
Overall Satisfaction (good/adequate or better)	99%	91%

The Golden Gate and Maryland data, and comparisons with overall service area demography, indicate a predominantly middle to upper-middle income, white collar market for third party vanpooling. The market is characterized by stable employees traveling long distances who work fairly regular hours (176*, 586*). Unfortunately, these examples are not fully representative on all counts. For instance, examination of the owner-operator vanpooling associated with the Norfolk and Newport News, VA shipyards would undoubtedly identify another end of the potential market spectrum, at least in terms of percentage blue collar worker involvement.

Response to Short-Haul Industry-Oriented Buspools

The results of operating subscription buspools in a local, short-haul environment are mixed. Three examples are provided by Mass Transportation Demonstration Projects run in the Midwestern cities of Peoria and Decatur, IL, and Flint, MI. In Peoria, buspool service was successfully established as a permanent element of the local transit operation and continued for half a decade until the private operator went out of business. In Decatur and Flint, demonstration project revenues did not grow to meet expenses (under 1965 - 1970 conditions) and the experiments were terminated. In each case the door-to-door transit service took commuters from their in-city homes to the large industrial complexes where they worked. The basic service parameters were as follows (24*, 283*, 333, 629*):

	Decatur	Peoria	Flint
Service Dates	9/65 - 6/66	12/64 -1970	9/68 - 1/71
Length of Runs (Miles)	6 - 14	5.7 - 13.5	1 - 16
Time of Runs (Minutes)	28 - 33	27 - 41	25.1 average
Number of Buses	2	17	32
Daily Ridership (round trips)	60	500	325

In Decatur and Peoria, where the subscription buspools primarily served large Caterpillar Tractor Company plants on the edge of the city, increases in city-wide peak period transit ridership of 7 and 13 percent, respectively, were obtained. The market share achieved among Caterpillar employees living within the city limits and working shifts served was 9 percent in Peoria (another 7 percent used regular transit routes) and 4 percent in Decatur (no conventional service available). In Flint, where the buspools primarily served that city's auto manufacturing industry, they accounted for 17 percent of Flint's total adult transit ridership. However, total systemwide ridership continued to decline throughout the life of the Flint buspool project (24*, 283*).

Lack of greater usage was partially attributed to the large amount of unscheduled overtime which occurred in the manufacturing plants, making it difficult for commuters to subscribe to a fixed schedule service. The service was found to be most popular among office employees who worked on a regular schedule (283*). Short-haul buspool services are also difficult to operate with an acceptably low ratio of passenger pickup time to express run time, a factor discussed further with respect to "Indicators of Market Potential." Minimization of passenger pickup time was aided in the uniquely successful Peoria operation by the fact that the concentration of employees from the plant served was one employee per four households in the service area (509).

Response to Short-Haul CBD-Oriented Buspools

Short-haul, door-to-door subscription buspools oriented to Central Business Districts are apparently not attractive when they must compete directly, at a premium fare, with a comprehensive, conventional transit system. Such buspools were attempted as part of the Decatur, Peoria, and Flint demonstration projects mentioned above, and all failed (24*, 283*).

In Decatur and Peoria, the downtown buspool service carried only about one percent of the total CBD travel market potential. The radial, line haul bus system simply provided better service to CBD-oriented trips than the buspools and the buspool amenities were not enough to compensate (283*). In marked contrast is the apparent viability of long haul CBD-oriented buspools operating within large metropolitan areas from suburbs with poorly developed transit service. This type of buspool is among those discussed next.

Response to Long-Haul Commuter Buspools

Long-haul buspools have a fairly good success record. Most have attracted sufficient home-to-work ridership to become established paratransit services, connecting residential and employment centers 10 to 60 or more miles apart. In many cases, these buspools have been formed by a group of residents in a community, or a group of employees at an employment center, who have maintained a significant role in management of the operation. Where buspool service has superseded infrequent, traditional commuter-bus operations, as in Columbia, MD, large increases in transit ridership have been obtained. Marginal or failed buspool routes have had their lack of success attributed to such factors as excessive passenger pickup time, work schedule changes, employee layoffs and problems with the local transit authority (14, 385, 498, 505+, 629*).

The Reston Commuter Bus is the preeminent example among buspools connecting suburban growth centers with downtown employment. In 1980 the service from suburban Reston, VA, to Washington, DC, was carrying about 1,400 inbound commuters daily on 38 peak period bus trips. Reston Commuter Bus ridership and Reston population have grown together from the early stages of community development, as shown in Figure 13 together with market penetration data. The buspool mode share first stabilized at 17 percent of Washington commuters and then restabilized at 23 percent[e/] after buses gained exclusive Reston ramp access to the high speed Dulles Access Road. Although line haul travel time was indeed saved, the beneficial effect of gaining entry to the Dulles Access Road may have been as much or more due to changes it made practical in passenger collection procedures. Buses now collect passengers along 4 residential pickup routes, make a transfer stop, and then distribute passengers along 5 employment area routes, halving the previous 30-minute north Reston passenger collection process. Some 12 percent of all passengers avail themselves of the transfer. (See "Indicators of Market Potential" for further discussion of passenger pickup time impacts and related Columbia, MD buspool mode share data.) It should be noted that the Reston Commuter Bus is not a subscription service. It is run by a community-based nonprofit corporation, but collects fares on a trip-by-trip basis (215).

COM-BUS of Southern California is the counterpart example among long-haul buspools connecting residential areas with suburban employment centers. The employment areas in the COM-BUS case are primarily aerospace industry oriented, and one way trip lengths for the luxury buses used range from 20 to 70 miles. As of 1976 the private, for profit operation had stabilized at 47 one-trip routes serving approximately 2,000 passenger subscriptions, paid weekly in advance. There is no market penetration data, but it is relevant to note that only a quarter of Southern California aerospace employees travel over 20 miles to work, and less than 5 percent travel over 40 miles -- the average COM-BUS trip length. COM-BUS minimizes passenger pickup time: 70 percent of all riders park and ride within two miles of their residence and another 25 percent gather at central pickup points for express service. COM-BUS originally evolved out of employee action. In a manner similar to the Reston service, COM-BUS uses volunteer "Bus Captains" on each route who ride free and perform route administration/payment collection functions (385).

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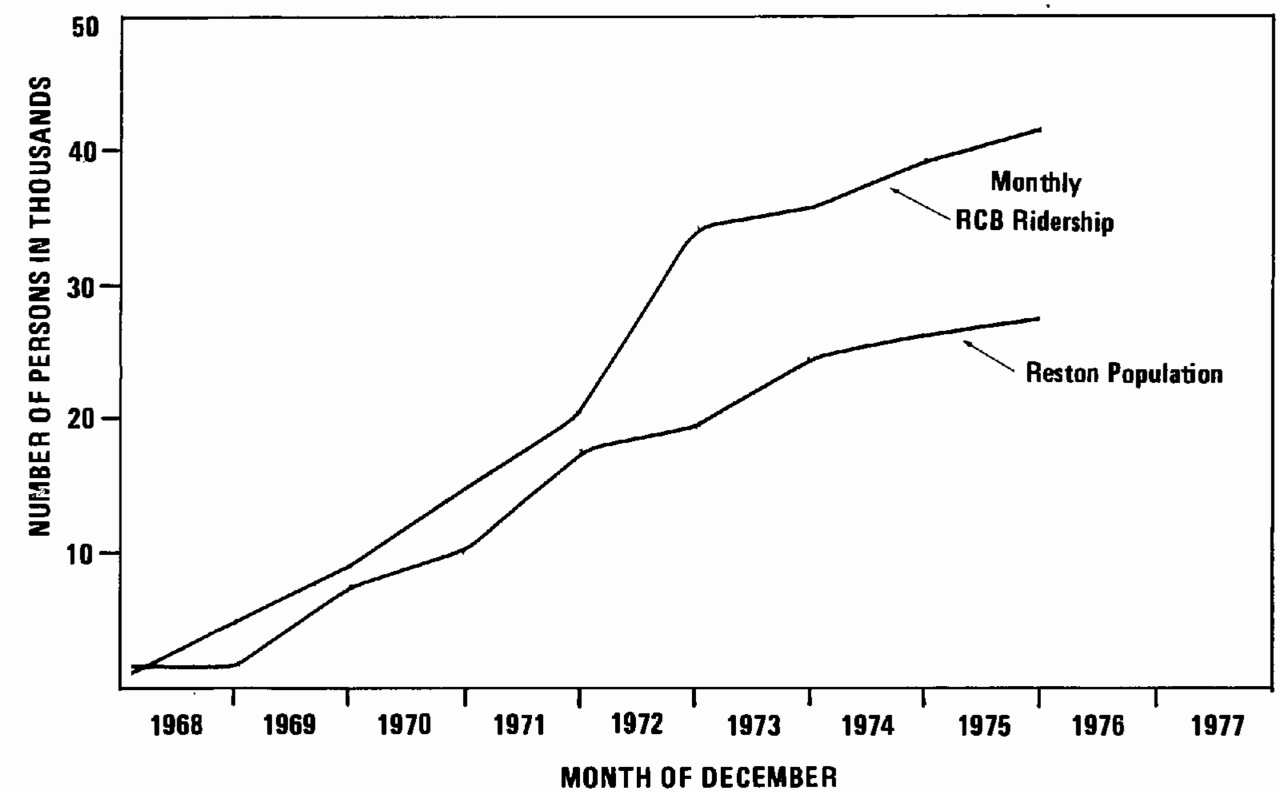
e/ A 1970 survey indicated that the market penetration to employment areas directly served may be 2 to 2½ times greater than for Washington commutation as a whole.



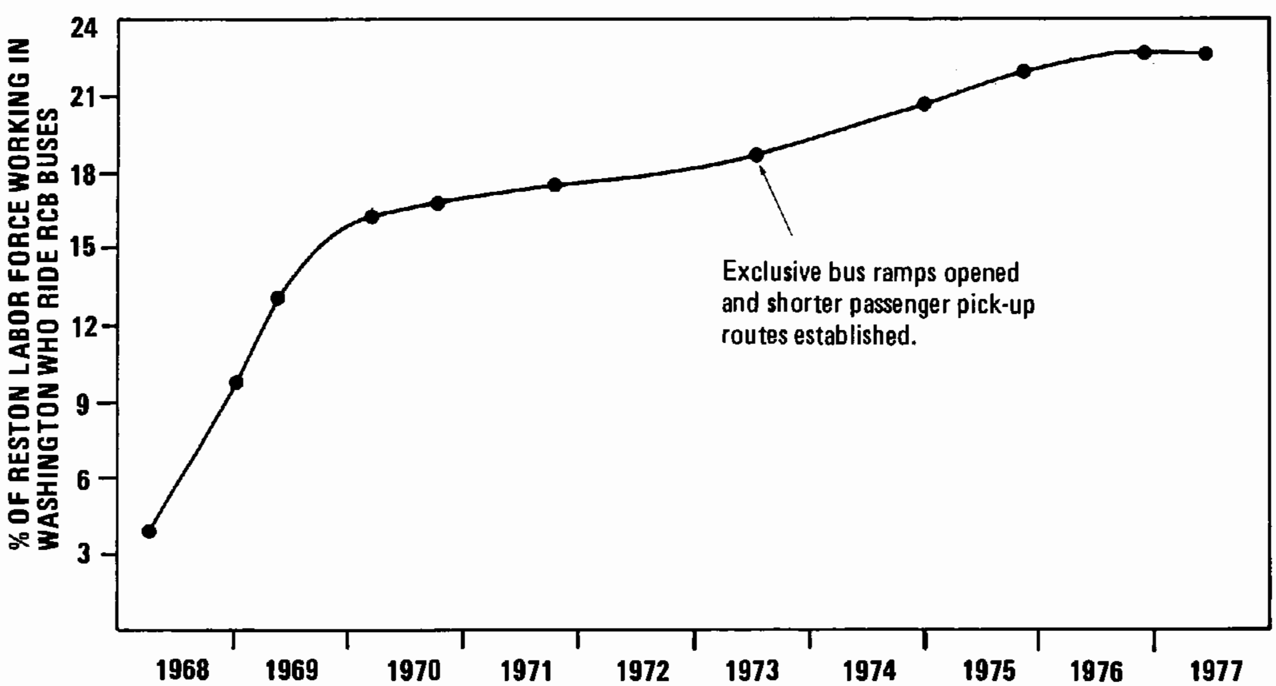


Figure 13
Reston Commuter Bus Ridership and Market Penetration

Two significant private operator buspool systems, in Bremerton, WA, and near St. Louis, MO, are industry oriented like the Peoria operation described earlier. However, the minimum one-way route distance is 9 miles. The majority of riders are blue collar workers. Costs are kept low by using plant employees as part-time drivers of older full size transit or school bus equipment. Each system operated 24 1-run routes as of 1976 and 1974 respectively, serving surrounding rural areas and communities. Comparative market and usage data are given below (333, 328):

	Bremerton-Charleston Transit Company	Specialty Transit Company
Industry	Naval Yard	McDonnell Douglas
Employees	10,000	30,000
Daily Users	1,120	700-850
Percent of Employees	11%	2-3%
Route Length	20 mi. avg.	9-52 miles

The National Geographic Society provides an example of an employer-sponsored buspool program. The need for the subsidized service was the result of a move of the Society's 1,200 employee bindery plant from Washington, DC, to a location 20 miles out in the suburbs. Chartered buses are used on 11 routes, most serving reverse commute riders. Daily patronage on the 8 Washington routes is roughly 850 round trips, mostly originating 10 to 25 miles from the plant (333). Trip distance, fare, and financial performance data for the buspool programs given here as examples, and others, are provided in the "Revenue/Cost Considerations" section, Table 29.

Underlying Traveler Response Mechanisms

The transportation service attributes offered to the commuter by vanpools and buspools lie in general between the attributes of carpooling and conventional transit. Of concern to the potential van/buspooler are cost, convenience, other intangibles and the individual components of travel time. For van/buspooling these individual components include wait time, pickup time or trip circuity, and line haul time (467*, 591, 629*).

Most vanpool programs do not exhibit significant diversion from transit, the exception being programs oriented toward CBDs with good transit service. The 50 percent of Golden Gate third-party vanpoolers who formerly used public transit saved an average of 9 minutes per one-way trip by vanpooling. The average former auto commuter among Golden gate vanpoolers, and the average Maryland vanpooler (typically a prior auto user), have accepted 11 to 12 minute one-way travel time increases compared with their former commute. This is essentially the same as the 10 to 11 minute increases on average reported by the 3M and Michigan State Government employer-sponsored vanpool programs, and the 10 minute average extra travel time of COM-BUS subscription buspools as compared to comparable Southern California auto commutes (176*, 385, 467*, 586*, 637). Clearly van/buspoolers are trading off travel time for other travel attributes.

Auto-like (door-to-door) convenience is often associated with vanpools and buspools, but caution must be exercised in this regard. Although many programs are structured on the assumption that passenger pickup will be door-to-door, the Reston, VA, commuter bus service uses standard bus stops and a number of programs are reporting significant percentages of non-home pickups, as follows (176*, 215, 385, 586*, 591, 637*):

Pickup Point	COM-BUS Buspools Sou. Cal.	Golden Gate Vans 1/	Knoxville Brokered Vans	All Maryland Vans	Michigan Employee Vans
Home	5%	44%	36%	19%	62%
Intersection	70 3/	17 2/	10 2/	11	5 2/
Parking Lot		39 3/	54 3/	57	33 3/
Other	25 4/	--	--	13	1

1/ Under bad weather conditions.
2/ Walk access
3/ Auto access
4/ Central pickup points (access unspecified)

Convenience of door-to-door service was the overriding reason given for program participation in surveys of buspool and vanpool program users in Flint, MI, Decatur and Peoria, IL, Columbia, MD, and St. Paul, MN (24*, 283*, 467*, 629*). Golden Gate and Maryland vanpoolers identified cost savings as being more important than any other individual reason for vanpooling (176*, 586*). In an analysis based on the premise that vanpoolers are simply trading off time for cost, the value of time at which the average vanpooler would switch to single occupant auto under 1974 3M vanpool program conditions was calculated to be $5.83 an hour (467*). Other reasons frequently given for the decision to use buspool or vanpool service are the avoidance of driving, saving auto wear and tear, ability to leave the car at home for others and saving energy (24*, 176*, 283*, 467*, 586*, 629*, 637). Apparently at least 15 to 20 percent of new vanpoolers either sell an existing auto or postpone the purchase of a new one (176*, 586*, 591).

An important intangible affecting vanpooler and buspooler response is personalities, or grass roots public relations. It has been stated that for a vanpool to become permanent, it must establish its own social identity and pattern of personal relationships. The driver is a key to the success of a long-lived vanpool, with commitment, affability, leadership and driving skills being cited as prerequisite characteristics (591). While buspools normally have professional drivers, several successful programs have found that placement of a "Bus Captain" (COM-BUS), "Busmeister" (Reston, VA) or service representative (Peoria Demonstration Project) on each bus provides a significant element of responsive service. Vanpool drivers and buspool aides perform a marketing function in the broadest sense, including keeping tabs on needed service adjustments (215, 283*, 385).

Indicators of Market Potential

Vanpools and buspools are almost exclusively oriented to serving work purpose trips. Vanpools are normally most successful where one-way trip lengths exceed 15 miles, where work schedules are fixed and regular, where employer size is sufficient to allow matching of 10 to 12 people from the same residential area, where public transit service is inadequate, and where extenuating conditions exist such as congestion or a shortage of parking. Nevertheless, strong employer commitment in the case of employer-sponsored programs can overshadow factors such as trip length. Although most vanpools serve primarily professional and clerical personnel on regular hours, some programs serve primarily production workers and even shift workers. The University of Washington study of 58 programs concluded that employer size has minimal effect on project outcome, and several programs are obviously using park-ride as a successful means to collect riders too dispersed for door-to-door pickup. One transit district has deliberately and successfully instituted vanpooling in direct competition with its own extensive transit service and another assists vanpool formation in lieu of providing express bus service from suburban locales. Exceptionally long commute distances will overshadow lack of other extenuating circumstances favoring vanpooling (176*, 291*, 467*, 507, 586*, 591, 637).

The Minneapolis Ridesharing Commuter Services Demonstration, which sponsored formation of carpools and third-party vanpools, attributed its failure to attract and maintain projected ridesharing levels to three major factors: multi-employer sites with large numbers of employees on different work schedules, favorable driving conditions and easy parking, and relatively short commuting distances (556). The least successful employer vanpool programs appear to exhibit less management support and more problems with management approvals than the norm (291*). The most notable buspool project failures have been those having to cope with short line-haul trips and industrial, multiple-shift work schedules (24*, 283*). The major, heavily patronized buspool services such as those to Washington, DC, and Southern California employment centers are long-haul and serve daytime worker concentrations (215, 385, 629*). The successful, short-haul, industry-based buspool in Peoria was afforded an extremely high employee concentration: approximately one central-plant Caterpillar Tractor Company employee per every four households in the service area (509).

The ratio of maximum passenger pickup and delivery time to line-haul travel time is apparently a useful rule of thumb measure with which to judge the attractiveness of individual vanpools and buspools. This "service ratio" describes the travel time quality of the vanpool/buspool trip while also serving as an indicator of how much faster standard auto travel would be. Although users accept longer vanpool and buspool travel times, there appears to be a limit to the time spent picking up and dropping off passengers, relative to driving time with a full load, that will be tolerated. In the original 3M pilot vanpooling program, vanpools with a ratio of residential pickup time to line-haul time of up to 1.0 proved successful. However, problems were encountered with forming vanpools in areas where the ratio would be greater than 1.0. Subsequent experience at 3M is that many vanpools, even a majority, are now operating with a service ratio in excess of 1.0 (467*). However, this development may well reflect nothing more than the uniquely intense management interest in 3M vanpooling.

Other evidence, provided by Maryland vanpooling and buspooling experience, tends to corroborate the 1.0 service ratio as a useful indicator of the normal limit for most van/buspooling. The total time spent picking up and dropping off passengers is 14.0 minutes for the average Montgomery County vanpooler compared to 40.1 minutes enroute time; an average service ratio of 0.35. The corresponding figures for other Maryland vanpoolers are 22.6 minutes pickup/dropoff and 37.4 enroute, for an average service ratio of 0.60 (586*). Although the service ratios for individual vanpools assuredly vary significantly around these mean values, it is easy to imagine that most lie below 1.0. The Columbia to Washington buspool service captured a much larger share of its potential market (81 percent[f]) than the Columbia to Baltimore service (8 percent)-(629*). The service ratio for the Washington service was 0.8, compared to 1.4 for the Baltimore service [g]. Of course, other factors have undoubtedly had an influence on the Columbia results, especially the higher parking costs prevalent in downtown Washington.

Work Scheduling Implications

Vanpool users normally must adhere to a fixed commutation schedule, and users of even the largest buspools are typically provided only peak period or work start and finish arrival/departure time options. The worker who must stay overtime is thus in difficulty. Even if work schedule aberrations are anticipated in advance, the only available travel choice is to forsake the vanpool or buspool mode for the occasion. This is probably a major reason, along with work absences, why the "attendance factor" is typically 80 to 90 percent. Golden Gate vanpoolers ride 4 out of 5 days on the average. The 3M average use by all vanpool members (presumably excluding those on vacation) is 70 percent daily, 25 percent four days a week, and 5 percent three days or less a week (176*, 467*).

The requirement that vanpoolers pay for days that they miss as well as days that they ride has been cited as a detriment to vanpooling, especially during vacation periods. The two-van program of the Provo, UT, Mountainland Association of Governments did not survive its first summer for this reason. Work schedule changes and irregularities have been cited as a contributing factor in the majority of the buspool service terminations which have been reported (14, 24*, 283*, 291*). The effect of variable work hours programs is less clear. Roughly one in ten employers approached about employer-sponsored vanpooling have felt that their variable work hours programs preclude instituting vanpool programs (291*). On the other hand, 3M instituted staggered work hours concurrent with vanpooling, and flextime appears to support high occupancy vehicle use in general (see "Impacts on Mode Choice" within the "Variable Work Hours" digest).

There are successful instances of coping with irregular vanpool/buspool usage. One method used is to over-subscribe; allowing lower monthly rates and assuming one or more persons will be away each day. Another is the use of trip-based pricing in conjunction with a low monthly base cost. Flexible scheduling was adopted for two executive vanpools formed at 3M. (Nevertheless, less than half of the 42 management-type vanpool members at 3M report daily use.) A "straggler bus" is run after the regular Reston Commuter Bus evening service, picking up late passengers between 7:00 and 7:26 PM. Actual ridership varies between 15 and 20 passengers each evening,

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f/ The literature notes that this percentage may be overstated by a factor of 1.5 or 2.0 due to lack of specificity in the survey data.

g/ These service ratios are calculated on the basis of the 3/6/73 Washington schedule and the 2/11/72 Baltimore schedule (629*) by the handbook authors, omitting isolated on-line stops.

but addition of this bus in 1970 attracted more than 80 new riders to the system as a whole. These riders need the assurance that they will not be stranded at their workplace by a late meeting or other delay (14, 215, 467*, 591).

Sources of New Ridership

When vanpools serve central area employment in corridors with heavy transit service, a substantial proportion of the vanpoolers may be drawn away from transit use. The effect can be seen in the first two entries of Table 28, which shows the prior mode of vanpoolers and buspoolers in various programs. Both Montgomery Ward Chicago vans and those Golden Gate Vanpool Demonstration Project vans oriented to the San Francisco commute attracted over half their riders from conventional bus or rail services. The Golden Gate van-versus-bus competition was a deliberate attempt to head off further expansion of the deficit financed bus service without sacrificing highway lane productivity (176*, 295).

Most vanpool and buspool operations tap a predominantly new travel market as compared to more traditional mass transit. It is a market shared to a degree by carpooling, however. The intra-suburban Golden Gate, 3M, licensed Maryland and Michigan state employee vanpool examples and the buspool examples in Table 28 illustrate what are apparently typical results with respect to ridership sources. Prior solo drivers constitute a quarter to a half of the vanpoolers and buspoolers in these examples. Total prior auto drivers, counting in carpool drivers, are in the 45 to 65 percent range (24*, 176*, 283*, 467*, 586*, 637). Long-haul commuter buspools are probably similar to the short-haul buspools of Table 28 with respect to the prior and alternate modes of buspoolers. A 1975 survey of Reston Commuter Bus riders showed negligible evidence of transit captivity, with a median rider household income of $25,000 per year and 60 percent owning 2 or more cars (215).

The previously cited investigation of 58 employer-sponsored vanpools found that while 40 percent of vanpoolers in the more successful programs were prior carpoolers, 70 percent in the least successful were. This was ascribed to frequent preexistence of major carpooling programs in the latter case (291*), but it may also be that it takes the characteristics of a successful vanpool program to attract the higher prior solo driver percentages. There is some limited evidence that increased carpooling is a spinoff of successful vanpool programs (291*, 467*, 507).

Impacts on Energy, VMT and Environment

Vanpooling is the least energy intensive of four-or-more-wheeled urban transportation modes, which is to say that vanpooling is estimated to consume the least propulsion energy per passenger mile. Urban energy intensiveness estimates for various urban transportation modes are given below in BTU's per passenger mile (1975)--(636):

Single occupant auto	11,000	Old rail rapid transit	2,540
Average auto	7,860	New rail rapid transit	3,570
Carpool	3,670	Light rail transit	3,750
Bus	2,610	Commuter rail	2,625
Vanpool	1,560	Dial-a-ride bus	9,690

Buspools probably have an energy intensiveness similar to conventional bus service, except that buspool buses parked so as to minimize non-revenue mileage may approximate the lower energy intensiveness of vanpools.

Table 28
Prior Mode of Vanpoolers and Buspoolers
(24*, 176*, 283*, 295, 467*, 586*, 637)

	Wards	Golden Gate Vans		3M	Maryland Vans		Mich.	Buspools	
	Chicago Vans 1/	S.F. Dest's.	Suburban Dest's.	St. Paul Vans 2/	Van Drivers	Van Riders	Employee Vans 3/	Peoria IL	Flint IL 4/
Drove car alone	15%	10%	25%	49%	34%	38%	45%	43%	50%
Carpool	29	23	74	46	55	47	48	29	34
Drop off/other	2	—	—	3	1	4	6	—	12
Regular transit	53	62	1	2	4	6	1	28	15
Buspool	—	5	—	—	6	4	—	—	—

1/ Carpool breakout is 7% driving with passenger, 10% rotating carpool, 12% carpool passenger

2/ Carpool breakout is 8% driving with passenger, 22% rotating carpool, 16% carpool passenger

3/ Carpool breakout is 33% two occupant, 21% three occupant, 23% four occupant, 23% five or more

4/ Totals 111% because of multiple answers

Energy intensiveness measures do not take into account prior or alternate travel modes, mode of access, circuity of travel, or construction energy, subjects about which there are varying degrees of controversy (636, 673). Information in the preceeding section indicates that the percentage of prior auto drivers among persons attracted to vanpooling and buspooling is comparable to the percentages obtained with the most attractive among other options. When all possible energy requirements are taken into account, it is fairly clear that vanpooling remains the most energy efficient per passenger mile. No comparable estimates have been made for the buspool mode.

Among available estimates of total VMT, energy and emissions savings attainable through vanpool programs, the least speculative appear to be those that have lumped vanpooling and carpooling together for analysis purposes. One such estimate is given in Table 15 of the "Pool/Bus Priority Facilities" digest in comparison with other programs for a large prototypical urban area (171). Separate examination of the carpooling and vanpooling elements of this estimate (5.0 percent work trip VMT reduction, 11,600,000 gallons annual fuel savings) produces the following results:

	Carpool	Vanpool
Pool participation rate (new poolers only)	2.5%	0.5%
Average work trip length	16 mi.	25 mi.
Average occupancy	2.9	11
Net VMT reduction (employment of 1,153,000)	446,600	211,400
Proportion of program VMT reduction	68%	32%

The overall estimated vanpool participation rate of 0.5 percent (new vanpoolers) assumes a participation rate of 3 percent in firms of over 1000 employers and none in smaller firms (171), and would require some 500 to 800 vans[h/] in a city of 1,153,000 employees. This number of vans is a little less than twice the number of vanpools reported to be operating in Houston in 1979 (507). The vanpooling element in this theoretical analysis would save about 0.3 percent of total regional, annual, automotive fuel consumption.

Another study that estimated vanpool program potential in conjunction with carpooling assumed that vanpooling could occur in any firm of over 250 employees, but would not

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h/ Range approximated by the Handbook authors based on the requirement of the assumptions of the cited source on the one hand (524 vans -- prior vanpooler mode 100% auto, 1.2 prior auto occupancy (171) and the prior modes reported in Table 28 for Golden Gate suburban, 3M, Maryland, and Michigan employee vans on the other hand.

attract any trips under 10 miles in length. Vanpool work trip mode share potentials of 2, 4 and 4 percent were estimated for Denver, Fort Worth and San Francisco, respectively. The combined program work trip VMT reductions modeled were 4.2 to 10.1 percent. Over 80 percent of the VMT reduction was ascribed to vanpooling in these estimates (590#).

Revenue/Cost Considerations

Vanpooling and buspooling generally emerge as comparatively cost-effective para-transit options. Although a wide variation is possible in vanpool expenses, including program administration costs in particular, the lack of a requirement for a specially paid driver helps to hold costs down. Most employer-sponsored vanpool programs have been priced so as to recover vehicle and operating costs, but typically provide a private subsidy covering costs of program administration and support. Some third party programs have attempted to cover all costs, but most have elected to use public subsidies for certain program administration, overhead and promotional costs (591). Owner-operator vans are normally supported by user charges alone, although the owner may choose to absorb certain costs if the vehicle has other, personal value. The table below gives monthly user charges and related data for selected vanpool programs (176*, 200, 467*, 507, 637). Only the first listed is from the large category encompassing private company, employer-sponsored programs; the fares for such programs are said to be typically in the $20 to $30 monthly range (591).

Vanpool Service	Date	One-Way Dist. (miles)	Monthly Fare Range	Fare per Passenger Mile
3M Company St. Paul, MN	5/73	5-32	$19.50-29.50	2.3¢ (average)
MI State Employees	12/78	32 (average)	$36.75 (average)	2.7¢ (average)
Pantex, Amarillo, TX	12/78	35 (average)	$36.75 (average)	2.5¢ (average)
Golden Gate, CA	6/78	10-70	$28-$76	2.5-6.7¢
VANGO, MD	6/79	13-73	$29.30-73.60	1.7-7.8¢
Rides, Bay Area, CA	12/78	37 (average)	$42.00 (average)	2.7¢ (average)
Commuter Computer, CA	4/79	15-50	$58-$79	4.8¢ (average)

It is apparently easier but more costly to set up vanpool programs than was initially anticipated. The driver and passenger contacts required in a third-party program can be particularly labor intensive. One estimate of organizational startup costs (1977) for an employer-sponsored program is $30,000, representing administrative resources that are normally obtained through diversion from other corporate priorities. The Commuter Computer vanpool operation in Southern California estimates that third-party startup costs are $50,000 and that normal program support costs are $50 to $70 per van per month. The Golden Gate, CA, startup phase subsidy totaled $1.94 per one-way, 40-mile passenger trip (equal to $37 per van per day) compared to a stabilized $1.65 subsidy per conventional bus passenger trip of comparable length. The 1979 VANGO administrative and program support costs were approximately $36.00 per van per month, excluding certain overhead expenses, but the VANGO subsidy per commuter was nevertheless smaller than for any other transit mode in Maryland.

Vanpool subsidies, particularly within employer-sponsored programs, must be taken in context with benefits. A number of expanding companies report savings in parking space requirements and reduction of localized traffic congestion. ARCO in Southern California subsidizes its employees who use the Commuter Computer third-party vanpool program to the extent of the company's parking subsidy savings, which they estimate to be $22.00 per employee per month (176*, 200, 295, 591, 637).

Although some buspool programs have not generated enough revenue to meet capital and operating expenses, practically all have fared better than conventional bus routes, and many operate without subsidy. In Decatur, IL, and Flint, MI buspool program revenues failed to reach a level that would cover costs, and operations were terminated, although it was felt that the Decatur service would have met expenses if part-time bus drivers could have been hired (629*). The short-haul buspool operation in Peoria was able to break even for 5 years with fares comparable to the Decatur program (under 1966 conditions), thanks to a higher residential density of employees served and the correspondingly greater bus occupancies and directness of routing (283*, 333). The Bremerton, WA, and St. Louis, MO, buspool operations have been able to hire plant employee buspool members as drivers, and have operated profitably for more than 15 years (328, 333). In the new towns of Columbia, MD, and Reston, VA, the services to Washington, DC, have normally shown a small profit. The buspool service from Columbia to Baltimore operated at a slight loss, and could not support more than one bus. The Columbia-Washington service has incurred a brief period of losses each time a new bus has been added (215, 629*). The COM-BUS service in Southern California minimizes new route losses by using large vans with volunteer drivers on an interim basis. COM-BUS has evolved into a for-profit, private corporation (385). Table 29 summarizes buspool fare and profitability data.

What little is known about the sensitivity of vanpool and buspool usage to user charges presents a varied picture. A 20 percent fare increase for Commuter Computer vanpoolers in Southern California led to a 14 percent drop-off in vanpooling among those not receiving the ARCO subsidy. The drop-off among the directly subsidized vanpoolers was only 3 percent (591). Although a survey of Peoria's buspool riders indicated that convenience, timing, speed, and reliability were more important than price, a subsequent 21 percent increase in fares, accompanied by a reduction in passenger amenities, resulted in a 21 percent decrease in ridership (283*). There is no evidence that incremental fare increases to cover increased costs had identifiable impact on ridership in any of the long-haul commuter buspool operations.

Table 29
Buspool Distance, Fare and Financial Performance Characteristics
(24*,215, 283*, 328, 333, 385, 629*)

Buspool Service	Date	One-way Dist. (miles)	Average Fare	Fare per Passenger Mile	Financial Performance
Decatur, IL	6/66	6-14	$8.05 per month	6.3-15¢	loss
Peoria, IL	2/66	6-14	$9.90 per month	4-6.5¢	break even
Flint, MI	2/70	1-16	$9.00 - $18.00 per month	15¢	loss
Reston, VA	8/69	22	$1.00 one way	4.5¢	small profit
to	7/73	22	$1.20 one way	5.4¢	small profit
Washington, DC	4/77	22	$1.50 one way	6.8¢	small profit [1/]
Columbia, MD	11/70	25	$1.25 one way	5¢	small profit
to	1975	25	$1.50 one way	6¢	
Washington, DC					
Columbia, MD to Baltimore, MD	6/73	20	$1.00 one way	5¢	small loss
Specialty Transit, St. Louis, MO	2/74	9-52	$4.00 - $7.50 per week	1.4-4.4¢	profit
Bremerton, WA	3/76	20 (avg.)	35-50¢ round trip	1¢	profit (0.8 C/R ratio)
COM-BUS, Southern CA	5/77	20-70	$11.50 - $15.00 per week	2.1-5.8¢	small profit
National Geographic Society, MD	2/74	10-25	$30 per month	2.5¢	3.8¢ per passenger mile subsidy

[1/] The Reston service required a $.20 subsidy per passenger throughout 1975 (at a $1.50 one way fare) but eliminated the subsidy by changing to a private carrier able to hire part-time drivers.

Additional References

An overview of vanpool findings to date and an extensive bibliography is provided in Vanpool Research: State of the Art Review by J. H. Suhrbier and F. A. Wagner (591). Case studies and operating guidelines for buspools are provided in Guidelines on the Operation of Subscription Bus Services by R. Kirby and K. Bhatt (333). Additional material on vanpools and buspools may be found in references:

4, 5, 14, 24*, 27, 34, 48, 54, 96, 97, 99, 125, 142, 154, 155, 171, 176*, 181, 200, 211, 215, 238, 242, 254, 283*, 287, 291*, 295, 301, 320, 328, 330, 332, 333, 335, 371, 385, 407, 417, 419, 425, 438, 467*, 480, 498#, 505^{+}, 506, 507, 514, 552, 556#, 571, 581, 586*, 590#, 591, 602, 621, 629*, 636, 637, 638, 644, 649^{+}, 650, 660, 665, 676#, 697, 711.

24. American Academy of Transportation. Final Project Report: Maxi-Cab Commuter Club. Sponsored by Urban Mass Transportation Administration, U.S. Department of Transportation; Project No. MICH-MTD-2. 1972. 93 pages plus appendices. NTIS PB-220-903. VANPOOLS/BUSPOOLS,* TRANSIT MARKETING/BROKERAGE. OBSERVED RESPONSE. VOLUME.

From January 1968 to January 1971, a large scale subscription buspool demonstration program was carried out in Flint, MI. Flint is a heavily industrial city of 196,000 people with its employment concentrated in the manufacture of automobiles and related products. Flint was experiencing a long term decline in mass transit ridership and had been losing money on its system since 1958. In 1970 Flint residents made 8.9 annual trips per capita via transit.

The concept demonstrated, called the Maxi-cab service, featured door-to-door pickup and delivery routes that were established to serve work trip passengers having commonality of residence location, destination location, and shift start and end times. Fares were distance-based and ranged between $9.00 and $18.00 per month. The cost was estimated to lie somewhere between the regular bus service fare of 35¢ one-way and the average fully allocated automobile cost, then 12¢ a mile. The initiation of any new Maxi-cab route by the Flint Transportation Authority was dependent on advance subscription sales. $42,000 was spent on individual newspaper, radio, and direct mail campaigns and careful attention was given throughout the project to public relations.

Between September 1968 and March 1969 the number of Maxi-cab routes (runs) increased from 2 to 26, with 230 subscribers. Ridership declined to 170 during the summer months when conditions peculiar to the auto industry, such as changing models, caused temporary disruption in employment. Subsequently, the Maxi-cab service reached a peak of 32 runs serving 325 round trips daily, an annualized average of 165,000 one-way revenue passenger trips per year. Regular line haul bus service in Flint at the time was carrying approximately 1,000,000 adult revenue passengers per year, so Maxi-cab riders comprised an additional 17%. Nevertheless, the grand total system ridership continued to decline throughout the life of the project.

A consumer survey of Maxi-cab passengers indicated that only 15% of those riders sampled had previously used the regular bus service to get to work. The other previous modes reported (multiple survey responses were allowed) were: drove own car alone (50%), drove in carpool (22%), dropped off (12%), taxi (3%), walked (2%), and other (7%). The survey revealed that the primary reasons people decided to start using Maxi-cab were the door-to-gate service, avoidance of driving in traffic, freedom from dependence on someone else for transportation, ability to leave the car at home for use by others, and avoidance of having to leave their car in the company parking lots. The primary difficulties encountered centered on bus driver reliability problems attributable to high driver turnover, the multiplicity of employee shift change times which lowered effective passenger residence location densities below the original forecast, the large amount of unscheduled overtime in the auto manufacturing plants which made afternoon scheduling difficult, the frequent shifting of employees from plant to plant which frustrated regular scheduling, and equipment availability. In September 1970 a strike against General Motors forced a massive reduction in Maxi-cab service, and the buspools were not continued beyond the January 1971 conclusion of the demonstration Project.

176. Dorosin, Edith, Peter Fitzgerald and Bruce Richard. Golden Gate Vanpool Demonstration Project. Crain & Associates. Prepared for Urban Mass Transportation Administration, U.S. Department of Transportation; Contract DOT-TSC-1081. July 1979. 320 pages. NTIS PB 300-685. VANPOOLS/BUSPOOLS,* TRANSIT MARKETING/BROKERAGE. OBSERVED RESPONSE. MODE CHOICE. REVENUES/DEFICITS.

The Vanpool Demonstration Project grantee, the Golden Gate Bridge, Highway and Transportation District, is a multi-modal transportation agency that operates buses and passenger ferries, sponsors club buses, and controls the Golden Gate toll bridge. The project area is a single congested corridor with an exclusive, toll-free HOV lane leading via the toll bridge into the San Francisco employment center. The project was initiated in hopes of decreasing vehicle demand on the bridge without requiring further expansion of the deficit financed District transit service. A demonstration objective was to test the feasibility of "seeding" owner-operator vanpool groups via transition from initial third-party operation. The project began operations in October 1977 and the report provides an interim evaluation of activities through June 1978. Conclusions are based on preexisting data bases (more complete for corridor travel than for intra-suburbs travel), bridge vehicle and occupancy counts, vanpool application form data, initial (at time of joining) and supplementary vanpooler surveys, and on-board trip logs.

A variety of methods were used in a promotional campaign launched at the beginning of the project to attract vanpooling applications. Toll booth handouts proved the most cost-effective at $11 per application generated, followed by bus handouts ($13), employer contacts ($17) and downtown street demonstrations ($17). The least cost-effective strategies were fair booths (no applications), community meetings ($710), free rides ($304), newspaper advertising ($215), take-one holders in public places ($211), and shopping center demonstrations ($100). Not measured were the effect of news releases and synergistic effects. Of 1350 applications for vanpool membership received, 287 (21%) became active vanpoolers. Driver incentives included no more than a free commute and limited personal use of the van for 11¢ per mile.

Thirty vanpools were formed, with an average occupancy of 9.6 persons. Five of these were terminated because of inability to achieve full ridership (3 vans), inability to replace riders transferred to another work site, and end of school year (State College destination). Luxury vans with airline type seats were in greater demand than bench seat vans, despite a 60 mile round trip monthly fare of $44 versus $36. Demand split into two markets, the San Francisco commute (20 vans less 2 terminations) and intra-suburbs (10 vans less 3 terminations). Of 40,400 inbound 6-10 AM Golden Gate Bridge commuters 59.4% used 1 or 2 occupant autos, 26.6% used public transit, 13.5% carpooled and 0.5% used project vanpools in May, 1978. Project vanpoolers comprised 0.1% of the intra-suburbs market. Although exactly half of the vanpoolers previously used public transit, Golden Gate transit bus ridership increased in parallel with the vanpool project. (See Table 28 for vanpooler prior mode data). A comparative socio-economic passenger profile is given below:

	Marin-SF Bus	Larkspur Ferry	Vanpools
Income under $15,000	30%	24%	14%
$15,000-$24,999	31	24	40
$25,500 or over	29	52	45
Male/Female	63/37	73/27	63/37
No auto	0	2	0
1 auto	47	41	33
2 or more autos	53	57	67

The average round trip for the San Francisco commute was 79 miles for bench seat vans and 93 miles for luxury vans. The corresponding intra-suburbs averages were 70-73 miles. For the user, vanpooling was found always less expensive than one or two occupant auto commuting, less expensive than bus or 3 occupant carpool commuting for round trips of over 30 miles or so, and occasionally less expensive than 5 occupant carpool commuting. These cost comparisons take into account that the average vanpooler was found to ride only 4 out of 5 days, thus increasing the effective vanpool user cost. Travel time averaged only a minute longer than for prior modes, but former transit riders saved an average of 9 minutes while former auto commuters added nearly 11 minutes. Thirteen percent of all vanpoolers sacrificed 20 minutes or more. Of all vanpoolers, 8% deferred replacing an auto, 7% avoided buying an auto, 1% sold a vehicle and 4% planned to. The short-term vanpool public subsidy was $1.94 per passenger, versus a stabilized $1.66 subsidy per transit bus passenger. Little progress was made toward shifting van ownership/operation to the individuals involved.

283. Illinois, University of. Mass Transportation Demonstrations Projects ILL-MTD-3, 4. Sponsored by the U.S. Department of Housing and Urban Development. 1968. 160 pages. NTIS PB-183-192. VANPOOLS/BUSPOOLS,* TRANSIT MARKETING/BROKERAGE, TRANSIT FARE CHANGES. OBSERVED RESPONSE. MODE CHOICE.

The Premium Special Service demonstration project of 1964-66 in the cities of Peoria and Decatur, IL, was designed to test the feasibility of peak-hour, door-to-door, contractual (subscription) bus service in medium-sized cities. In each city, the experimental Premium Services were oriented to both the principal industrial center and the Central Business District (CBD). Peoria is an industrial city of 126,000 in which the Caterpillar Tractor Company is the dominant employer. The Caterpillar plant is across the Illinois River from the CBD. In Decatur, population 90,000, the main industrial plants are concentrated in an area on the fringe of the city.

The Premium Service operated on routes that were adjusted from week to week in accordance with the requests for service. Passengers contracted for service on a monthly basis and rode with an automatically renewed monthly pass. Passengers were picked up within a half block of their door and place of work. Service representatives saw that highly personalized service was offered, and the service was extensively promoted. The monthly charge for service depended upon commuting distance, with the average monthly fare being $9.90 in Peoria and $8.05 in Decatur (1965 dollars).

In Peoria, total citywide peak period transit ridership increased 13% by the end of the project. In Decatur, the increase was approximately 7%, discounting the runs which showed no promise. At the Caterpillar plant in East Peoria, 4,870 Peoria residents worked shifts for which Premium Special Service was provided. Of these, approximately 9% were riding the Premium Service after 14 months, and another 7% were riding regular bus routes. At the Caterpillar plant in Decatur, where there were 1,500 employees living in Decatur and working shifts for which the service was provided, approximately 4% were riding after 6 months. There was no regular bus service to the Decatur plant. In both cities the downtown Premium Service carried only about 1% of the total CBD market potential. The services to the CBD's were thought to have failed because of the greater dispersion of employees and employee work hours involved, the shortness of the routes (which led to schedule times nowhere near competitive with the auto), and the fact that all the regular transit routes were already concentrated on the CBD. The primarily industry-oriented services in Peoria (but not Decatur) were retained by the private bus operator after the end of the experiment, 16 one-bus routes in all. Fares were raised 21% and special amenities were dropped, then partially restored. After an initial 21% decline, ridership stabilized. {The Peoria service was continued until 1970, when the private operator went out of business.}

In Peoria, where the large Caterpillar plant was already served by regular bus routes, 72% of the Premium Service riders were prior automobile commuters (43% own car, 9% carpool, 20% passenger in car) and 28% were prior bus riders. Compared to regular peak hour transit riders, the ex-auto Premium Service riders had a 35% higher average household income and all had an alternative mode to the bus, instead of only 1 out of 3 having an option. The first choice reasons for liking the service were convenience, timing, speed, reliability (71%); avoids driving, traffic, parking (17%); lower transportation cost (7%); and other (5%).

291. Jacobson, J. O. Employer Vanpool Programs: Factors in Their Success or Failure. University of Washington. Sponsored by Urban Mass Transportation Administration, U.S. Department of Transportation. June 1977. 73 pages. Contract Number UMTA-WA-11-000578-3. NTIS PB 276-955. VANPOOLS/BUSPOOLS.* OBSERVED RESPONSE, BACKGROUND INFORMATION. MODE CHOICE, VOLUME.

This study surveyed 58 employer-sponsored vanpool programs in the U.S. with the objective of identifying those characteristics of each program which led to its success or failure. Half of the programs were operated by manufacturing firms, probably due to the large land areas needed by such firms and hence their location outside of city boundaries where transit service is often inadequate. The remaining half of the programs were fairly evenly divided among public agencies/services, finance/insurance, construction/engineering and wholesale/retail trade. Although manufacturing was the primary employer type, the majority of vanpoolers surveyed were white collar workers. This was attributed to the long commute trips and low job turnover more characteristic of higher income white collar workers, which is thought to be condusive to vanpooling, and to the orientation of the majority of the programs toward professional offices within each employer type. Of all the programs surveyed, 57% were in suburban or rural areas or small towns. The number of employees at each site ranged from 100 to 18,000; with 50% of the sites employing under 2000 and 20% under 500. The average one-way trip length for surveyed programs ranged from 7 to 75 miles, with 45% between 17 and 27 miles, 80% between 12 and 37 miles and 5% under 12 miles.

Information was obtained from a 26-question survey mailed to vanpool operators identified through a literature search and by referral. Follow-up on-site and telephone interviews were conducted as warranted to gather additional information or clarification. Input was also received from employers who had rejected or terminated vanpool programs. "Most successful" programs were defined as those with 8% or more employee participation and, in large firms, where 9 or more additional vans had been added since program initiation. "Least successful" programs were defined as those with 2% or less employee participation and 2 or fewer vans added since the start of the project.

The surveys revealed that between 1% and 58% of site employees rode in vanpools with 26% of surveyed firms reporting greater than 8% participation and 48% reporting less than 2% participation. By the criteria mentioned above, 26% of the vanpool programs were considered most successful and 21% were judged least successful. Analysis of most successful and least successful applications revealed that employer characteristics (type, size, location) and trip length have little influence on project outcome, but that employee residential densities and management committment are significant influencing factors in the success or failure of vanpooling programs. Eighty percent of the most successful versus 50% of the least successful programs indicated that management was the most important factor in developing original interest in the program while 73% of the most successful versus only 33% of the least successful programs stated there was no problem with management during implementation.

Poor transit service and rising gasoline prices were cited as the most important factors for creating employer interest in vanpooling. When asked when they first considered vanpooling 35% of employers stated the 1974 fuel shortage. Parking problems, long employee commute distances and environmental concerns (congestion, pollution, energy) were also frequently cited as important considerations. Over 80% of employers subsidize administrative and parking costs associated with vanpooling while 76% subsidize publicity and 67% subsidize costs of pools dropping below minimum ridership. Subsidies range as high as $2,100/van/year. About 1/3 of all programs stated that other area vanpool programs helped create vanpool interest at their site. The major impediment to vanpooling for employers who had rejected vanpooling was size of the workforce, although the survey revealed that programs were successful at many small sites. Discontinuance of vanpools was frequently a result of summer vacations disrupting normal ridership patterns and making monthly fare payments uneconomical.

467. Owens, Robert D. and Helen L. Sever. The 3M Commute-A-Van Program: Status Report. 3M Company, St. Paul, MN. Reprinted by the U.S. Department of Transportation, Federal Highway Administration. May 1974. 50 pages. Also Status Report II. 3M. January 1977. 100 pages. VANPOOLS/BUSPOOLS.* OBSERVED RESPONSE. VOLUME.

The 3M Company, St. Paul, Minnesota, in 1973 began an experimental vanpooling program for employees not conveniently served by transit. The 3M Center involved consists of 20 buildings housing approximately 10,000 administrative and laboratory employees, and is located on a 400 acre site at the eastern edge of St. Paul. The center has facilities to park 8,000 vehicles. The 1970 Home-Work Travel Survey showed only 43 persons using transit, and a 1.24 average auto occupancy.

Standard 12-passenger vans were purchased by the 3M Company and provided to vanpools formed on the basis of a special pilot program questionnaire. Drivers were 3M employees willing to pick up and drive at least 8 other employees to and from work. Vehicle maintenance and preferential parking for the vans were provided by 3M Company. The driver's responsibilities included picking up and delivering passengers on a set schedule, arranging for service and maintenance of the van, keeping at least 8 paying passengers in the vanpool, and providing for standby drivers. In exchange for his responsibilities, the driver was not required to pay the approximately $20 to $30 monthly fare charged other passengers, was given personal use of the van during non-work hours for a reasonable mileage rate, and was given the right to keep the fares for any passengers over the minimum of 8.

The 3M vanpooling endeavor began as a 6 van pilot project in April, 1973. As a result of the success of the original experiment, the number of vans was gradually increased to a total of 86 carrying over 800 riders as of January 1977, the date of the second status report. When surveyed in 1974 each van was carrying an average of 11.36 persons for an average monthly fare of $23.72 and an average round trip distance of 49 miles. The operating ratio (total operating costs divided by operating income less amortization) was 0.88. The 86 vanpools recorded in 1977 reduced the demand for parking by 735 spaces and saved well over 2,250,000 vehicle miles of travel and 190,000 gallons of gasoline per year. Further growth in the vanpooling program was anticipated on the basis of employee requests.

In April 1974 and August 1976 survey questionnaires were given to all participants in the Commute-A-Van program. Responses were obtained from 437 and 566 users respectively. Responses were virtually identical for both surveys. Of those who responded, 49% previously drove to work alone, 7% drove with a passenger, 23% were in a rotating carpool, 16% were a carpool rider, 4% were dropped off at work, and 1% rode transit. Eighty percent of the respondents found the vanpool more convenient than their former means of getting to work and 97% intended to continue using the vanpool on a permanent basis. The average travel time for vanpoolers before using the van was 28 minutes compared with 38 minutes afterwards. One quarter traveled over 20 minutes longer after joining the vanpool. Vanpool program benefits were numerous and well distributed. Participating commuters saved money, reduced the tensions associated with commuting and freed a car for use by other family members. Non-users benefitted from the reduction in congestion and parking demand in and around the 3M Company. The Company itself was able to expand without adding more roadway and parking capacity. For use in vanpool planning a Utility Ratio was derived, defined as the passenger-pickup time divided by the line-haul time. It was anticipated that the larger the ratio, the more difficult it would be to form and operate a vanpool. Some problems were encountered in forming vanpools where the utility ratio was greater than 1, but ultimately many operating vans fell into this category. In 1974, when 52 vans were operating, the average Utility Ratio was 1.18 and the following Utility Ratio breakdown was recorded:

Utility Ratio	Average Pick Up Time	Average Line Haul Distance	No. of Vans
0.35-0.75	15.9 minutes	21.5 miles	10
0.76-0.99	26.6	22.2	7
1.00-1.20	25.8	16.4	14
1.21-1.60	29.0	14.8	11
1.61-2.40	33.4	13.2	10

586. Stevens, K.B., Mark K. Soronson, John J. Clark, Louise R. Rainone. "Characteristics of Vanpools and Vanpoolers in Maryland." ITE Compendium of Technical Papers 1980. Institute of Transportation Engineers, Arlington, VA. Pages 204-214. VANPOOLS/BUSPOOLS,* TRANSIT MARKETING/BROKERAGE. OBSERVED RESPONSE. TRAVEL CHOICE, ACCESS MODE CHOICE.

Legislation enacted in May, 1976, exempts vanpools from Maryland Public Service Commission regulation but requires all vanpools to have a special license plate. This makes it easy to monitor vanpooling in Maryland, as well as to allow special privileges, such as use of "bus only" lanes in Baltimore and Washington, DC. The majority of Maryland vanpool activity has been under the umbrella of VANGO, Inc., a "third party" leasing program. VANGO is state and federally funded, and began operation in 1977 after evolving as an element of the State Ridesharing Program.

In January, 1980, questionnaires were mailed to the drivers of all third party, individually-owned-and-operated, and company sponsored vanpools registered in Maryland. An 87% response rate was obtained for driver questionnaires with a 72% rate for passenger questionnaires. The 1980 mix of Maryland vanpools was 139 VANGO (third party), 45 individual, and 48 company sponsored. The two primary centers of vanpooling were in and around the Baltimore metropolitan area and the Montgomery County sector of the Washington metropolitan area, including interstate vanpooling into the District of Columbia. The average vanpooler proved to be 41 years of age with a family income of $30,000 in each area, despite $18,000 Baltimore County (Baltimore suburbs) and $43,000 Montgomery County family income averages for the total area population. Compared to a 62% male labor force, 87% of all vanpool drivers and 55% of passengers were male. A handicap of some sort was reported by 5%, and 1 in 4 of the handicapped were influenced to join a vanpool because of it. Occupations were as follows compared to 1970 overall occupational statistics:

	Drivers	Passengers	Balt./Wash. Suburbs
Prof'nal./Tech.	66%	57%	40%
Manager/Admin.	23	15	7
Clerical, Sales	8	19	22
Blue collar	1	2	23
Service, Other	2	7	8

Almost half of all vanpool drivers report driving "because someone had to volunteer" and many Maryland vanpools report 3-5 qualified (chauffeur license) drivers, suggesting driver rotation. Bus service is within reasonable access of only 14/18% (drivers' responses given first, passengers' second). Reasons for joining a vanpool were 52/34% to save money, 0/24% to avoid driving, 15/17% to save energy, 14/13% to reduce wear and tear on own auto, and 7/3% to leave car at home for others. (See digest, Table 28, for prior travel mode data.) Of the cars left at home, 7% were used for new trips of 15-18 miles median weekly trip length. Vanpooling extended the life of the current family auto for 54/52%, alleviated the need to buy an additional auto for 13/6%, and led to sale of a vehicle for 9/2%, with another 18/37% planning to sell off a vehicle. Employer encouragement to vanpool is received by 91/83%. When present, this encouragement includes preferential parking in 70/51% of all cases, free parking in 42/27%, flexible hours in 44/40%, administrative leave in 35/19%, and reduced parking fee in 6/4%. Changes in average travel time compared to the prior mode were:

	Driver		Passenger	
Increase	70%	+18 min.	50%	+30 min.
Decrease	5	-24	10	-24
Same	25	0	40	0
Average Net Change		+11 min.		+12 min.

The average Maryland vanpool carries 14.2 people, including driver, for a $43.00 monthly passenger fare and travels 59 minutes to get to work. Of total travel time, 37% is spent picking up and dropping off passengers. Only 19% of vanpoolers are picked up at home, compared to 33% at shopping center lots, 11% at intersections, 10% at roadside parking, 8% at a park-ride lot, 7% at a church lot, 2% at the driver's home, and 10% at other pick up points. The average distance to the AM non-home pickup point is 3.6 miles. The location of the PM pickup point is 65% work site, 23% parking location, and 12% other points.

629. Truby, T. J. Door-to-Door Buspools: Recommendations for Public Policy. Consortium of Universities/Urban Transportation Center, Washington, DC. Sponsored by the Urban Mass Transportation Administration, U.S. Department of Transportation; Project No. UMTA-DC-11-0003. November 1973. 57 pages. NTIS PB-231-136. VANPOOLS/BUSPOOLS,* BUS ROUTING/COVERAGE, TRANSIT SCHEDULING/FREQUENCY. OBSERVED RESPONSE. VOLUME.

In late 1970 a group of residents in Columbia, MD, joined together to begin a buspool service connecting Columbia with Washington, DC, 25 miles to the south. Two years later a similar buspool connecting Columbia with Baltimore, 20 miles to the east, was initiated. Columbia is a developing new town which after 7 years of growth had a predominantly affluent population of 26,000. Prior to initiation of the buspool operation, the only public commuter transportation to Baltimore and Washington was provided by Trailways Bus Company in the form of 2 morning and evening buses to Baltimore and a single bus to Washington.

The Columbia buspools operated, in effect, as a partnership between the riders (consumers) and a privately-owned bus company. The consumers provided overall management, determined schedules and routes, sold tickets, collected fares, and promoted the service. The bus company provided the buses and drivers. The buspool services were routed throughout Columbia's neighborhoods and the downtown areas of Washington and Baltimore, thereby minimizing the need for transfers. Fares were initially $1.25 per ride to Washington and $1.00 per ride to Baltimore, but were later raised to cover increased operating costs.

At the start in November 1970, there was a total commuting labor force of 3,850, of which 4% (150) regularly commuted between Columbia and Washington. Of these, 39% (60) took the buspool. By May 1973, because of the rapid growth of Columbia, the total commuting labor force had increased to 8,650 and there were still approximately 4% (350) commuting to Washington. However, those taking the buspool had increased to 81% (280). (The estimates of total commuters to downtown Washington may be 25% to 50% low due to lack of specificity in the survey data.) In January 1973, when the Baltimore buspool was begun, about 8% of the labor force (600) commuted to downtown Baltimore, and 7.2% (44) of these were taking the buspool. By May 1973 the number of commuters to Baltimore was still approximately 8% (650), and of these 9.6% (62) took the buspool.

A problem peculiar to the one-bus Columbia/Baltimore service was the long ride through Columbia for riders living in Columbia-West. The extra 23 minutes riding time to pick up passengers in Columbia-East seemed to work against any increase in ridership in Columbia-West. The extra time was citied, in a questionnaire given to all riders, as the major problem with the schedule. A second Baltimore bus was added for a time, but revenues did not cover expenses. Even with 2 buses the passenger pickup time in Columbia plus the passenger distribution time in Baltimore exceeded the 30 minute express portion of the run. Despite these problems with the Baltimore run, the door-to-door service which the buspool provided was thought to be a major factor in the large ridership increase over what the Trailways Bus Company had carried between Columbia and Baltimore, and Columbia and Washington. Other factors which contributed to the high level of service provided by the Columbia buspools included closely tailored scheduling and routing, multiple trip tickets, and the involvement of the consumers in the planning and management of the bus service. As of the date of the report, 8 buses were used in the Washington buspools and 1 bus served the Baltimore pool.

TRANSIT SCHEDULING/FREQUENCY

Types of Scheduling Changes

Transit scheduling/frequency changes are part of the overall transportation system management category "Actions to Improve Transit." Scheduling and frequency changes include:

1. Increases or reductions in the number of scheduled transit vehicles or trains; providing an increase or decrease in service frequency and correspondingly reduced or lengthened headway and passenger wait times.[a] Such changes may be concentrated in the peak or off-peak periods, or may apply overall (43, 177#, 178, 350, 377*, 440#, 509, 522+, 573, 574*, 628*, 704).

2. Lengthening or shortening of the hours or days of service provided (244).

3. Rescheduling to provide easily remembered departure times, or to match regularly scheduled activities such as shift changes, or to afford better coordi-nation at transfer points (43, 509, 628*).

4. Increasing the reliability of existing transit service to minimize platooning of buses, missed runs and other deviations from expected schedules in order to decrease passenger wait time and annoyance (1*).

Scheduling and frequency changes are, in effect, a specialized form of transit service improvement or reduction that involves no alteration of coverage or routing. Rescheduling and service frequency adjustments are typically included as elements of more extensive transit service modifications, and marketing is often packaged with improvements in frequency.

Traveler Response Summary

The traveler response to service frequency changes varies markedly, but there are underlying consistent patterns that relate to the widely varying circumstances attending individual transit route service modifications. Patronage increases exceeding 1 percent per 1 percent frequency improvement are apparently possible, as are circumstances where frequency increases fail to engender increased ridership. The average response to frequency improvements is roughly a one half of 1 percent patronage gain per 1 percent frequency increase.

Ridership is most sensitive to headway changes when the transit line involved serves middle and upper income areas, and when the prior service was relatively infrequent. When transit headways are already short, and particularly when lower income service areas are involved, ridership may be more sensitive to fare changes than frequency improvements. Otherwise, ridership is apparently more responsive to frequency changes, although the evidence is fully conclusive only in the case of commuter railroad operations.

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a/ Service frequency is the number of buses or trains per hour or day, while headway is the time interval between buses or trains. Passengers arriving randomly will have a waiting time which averages one half the headway.

The greatest concern expressed by transit riders is with dependability of service and with midday and evening service frequencies. Actual waits at the transit stop are less than random arrivals would imply when service is reliable. Easy to remember departure times, readily available schedules, and service reliability may be major factors in achieving a favorable user perception of the wait for transit service. Off-peak ridership responds more to service frequency improvements, on a percentage basis, than peak period ridership.

Frequency improvements affecting individual transit lines have the potential of diverting some riders away from other transit services. In business districts significant numbers of people who previously walked may be attracted. In general, however, one out of every two or three new riders drawn to transit service by frequency improvements would otherwise have driven an auto, as is the case with transit fare reductions.

Response to Bus Frequency Changes

Increased bus frequency normally attracts increased patronage, almost always in some amount less than 1 percent additional riders per 1 percent service increase, but occasionally more. Results of service frequency changes are not often reported independent of the impact of other service alterations. The available observations suggest that it is not appropriate to specify a single numerical relationship between service frequency changes and patronage (277). The wide variations in reported ridership responses are attributable in part to the widely varying circumstances attending individual bus route headway changes. The variables involved include the pre-existing level of transit service, the geographic and demographic environment, and the time period of the day or week (277, 384).

Headway elasticities[b/] calculated from individual Massachusetts demonstration project results (377*) are presented in Table 30 along with other reported elasticity findings (277, 384). The median headway elasticity among those derived from the Massachusetts experiments is -0.4, or -0.6 omitting depressed urban areas. There are indications that due to data limitations, these elasticities may somewhat understate the study area long term potential for ridership gains.[c/] On the other hand, other

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b/ The measure "headway elasticity" indicates the percentage change in ridership observed or expected in response to a 1 percent change in the headway. Thus a headway elasticity of -0.60, for example, indicates that a 1 percent decrease in headway has caused or is expected to cause a 0.60 percent gain in ridership. See Appendix A for a discussion of elasticity measures. Service elasticity and headway elasticity are both used to express the degree of transit ridership response. Those calculated by the authors of this handbook have been derived using arc elasticity formulae that give the same elasticity value (except for sign) for both service, expressed in bus trips or bus miles, and headway. The method of derivation of elasticities found in the literature is often unspecified.

c/ There are several reasons these elasticities may be somewhat understated. For one thing, the Massachusetts experiments were short: 3 to 12 months in duration. Also, the elasticities were calculated on the basis of revenue, "before" ridership data not having been reported. In cases where smaller fares were charged for shorter trips, there may have been more of a ridership increase than revenue increase, because indications are that service improvements attract proportionately more short trips than long trips.

Table 30
Bus Service Headway Elasticities

Massachusetts Demonstrations (377*)[1/]	Headway Elasticity	Months After Implementation
Boston-Milford suburban route (new headway approximately hourly)	-0.4	10-12
Uxbridge-Worcester suburban route (new headway hourly)	-0.2	7-9
Adams-Williamstown city route (new headway approximately hourly)	-0.6	1-3
Pittsfield city route (raised from 3 to 8 round trips daily)	-0.7	1-3
Pittsfield city route (raised from 10 to 15 round trips daily)	-0.6	1-3
Newburyport-Amesbury (depressed area) city route (new headway 30 min. peak/60 midday) 2/	-0.4	6-8
Fall River (depressed area) city service (overall 20 percent service increase)	nil	4-6
Fitchburg-Leominster city route (new afternoon headway 10 minutes, to match morning) 2/, 3/	-0.3	6-8
Boston downtown distributor, Phase 1 (new midday headway 5 minutes, to match peak) 3/	-0.8	5-7
Boston downtown distributor, Phase 2 (new headway 4 minute base, 8 minute midday) 3/	-0.6	8-10
Boston rapid transit feeder route (new midday headway 5 minutes, to match peak) 3/	-0.1	4-6
Other Reported Findings (277, 384)		
Detroit city route (new headway 2 minute peak, 3½ minute midday)	-0.2	--
Chesapeake, VA, suburban service (new headway 35 to 42 minutes)	-0.8	--
Stevenage, England (peak period/off peak; new headway 5 minutes)	-0.4/-0.3	--
Madison, WI, circulator routes (Saturday/Sunday; new headway 20/30 minutes)	-0.2/-0.6	--

1/ Arc elasticity calculated by the Handbook authors on the basis of revenue.

2/ Includes impact of minor route extension.

3/ Approximate elasticity computed for full service day by using an unweighted average of peak and off peak (or morning and afternoon) headway improvements.

analyses support the adoption of approximately -0.5 as an overall average elasticity for bus headway changes.

Separate calculation where possible of peak, off peak, and all day headway elasticities to produce 23 separate elasticity values from essentially the same case studies as those listed in Table 30 produced the averages listed below. Fourteen of the observations are from non-Massachusetts locations. The averages in this tabulation are stratified by original bus service level. The results clearly indicate a greater sensitivity to frequency changes for cases where the prior service was infrequent (384). (See "Impacts on Temporal Ridership Patterns" for stratification by time period).

Original Service Level	Number of Observations	Arc (Midpoint) Elasticity
Less than 10 min. headway	7	-0.22
10 to 50 min. headway	6	-0.46
Greater than 50 min. headway	10	-0.58
All observations	23	-0.44

The 7 observations of those above that pertain to all weekday hours give an average headway elasticity of -0.47. Theoretical studies of passenger response to increased transit service, as defined by decreased wait time, have provided the elasticities given below. The travel modeled was all CBD oriented except for the 3 cases specifically noted (34, 97).

Area modeled	Trip orientation	Change in headway	Change in ridership	Implied arc elasticity
Washington, DC	CBD	-20%	+7.2%	-0.31
Washington, DC	CBD	-40	+14.9	-0.27
Denver, CO	Area-wide	-25	+21.0	-0.66
Denver, CO	CBD	-50	+36.0	-0.44
Ft. Worth, TX	Area-wide	-25	+21.6	-0.68
Ft. Worth, TX	CBD	-50	+67.8	-0.75
San Francisco, CA	Area-wide	-25	+18.3	-0.58
San Francisco, CA	CBD	-50	+24.6	-0.32

These results, with implied elasticities averaging -0.50, are for work purpose trips only and were obtained using disaggregate logit mode choice model formulations.

The actually observed responses to bus service frequency improvements appear to be greatest when the route involved serves middle and upper income areas (277), when the prior frequency was less than three buses or so per hour (509), and when the travel market involved is predominantly comprised of short trips. The response to service frequency changes is apparently least when the improvements primarily affect lower income areas, when the prior service was already relatively frequent, and when the travel market served is characterized by long trips.

Response to Train Frequency Changes

Aside from providing new facilities or lower fares, fixed rail systems are for the most part restricted to scheduling and frequency changes as a form of service improvement. The reported results are all in the realm of commuter rail operation. Described in terms of the factors identified above as influencing response to bus frequency changes, commuter rail lines typically serve middle and upper income areas. Although they have relatively long time intervals between trains, they also predominantly serve long trips. Thus an average or somewhat above average response to service changes might be expected if there is a correlation between bus and rail service impact.

Listed below are the ridership impacts of demonstration project service changes in three Northeast applications. Marketing activities were involved in all cases, as were certain off-peak fare incentives in the Boston experiments. Fares were increased in the Philadelphia demonstration (377*, 574*).

Location	Demonstration Phase	Increase in Service	Increase in Ridership	Implied Arc Elasticity 1/
Philadelphia Reading RR	Final	9.2%	8.6%	+0.9
Boston Boston & Maine RR	II	77%	37.5%	+0.6
Boston New Haven RR	II	26%	11.5%	+0.5

1/ disregarding effects due to fare changes and marketing

In the Philadelphia demonstration, average trip length increased by 5.8 percent (574*), resulting in an arc elesticity with respect to passengers miles of +1.6. One implication is that long commuter rail trips may be more sensitive to service levels than shorter trips. The longer commuter rail lines in Boston were likewise associated with greater traveler response to headway changes than the shorter lines.[d/] In Boston, it was also observed that the ridership response was greater for the lines with the poorer pre-demonstration service levels (384).

Results obtained in the New York City area, although not directly comparable, appear to be consistent with the primary Philadelphia and Boston findings (628*). Overall,

d/ These limited observations are not in direct conflict with the apparently greater sensitivity of short versus long bus trips to headway changes. Very short trips via bus are an alternate to the walk mode and this is not the case with any normal length commuter rail trip.

these data tend to suggest that commuter rail patronage responses to frequency changes are in the same general realm as bus ridership responses.[e/]

Response to Regularized Schedules

At least one travel demand analysis has shown that while the average wait for local, often irregularly scheduled bus service can be adequately described for travel estimation purposes as one half the headway, the average wait for commuter rail service cannot. The wait for commuter trains is apparently perceived by the potential commuter as being some lesser amount.

Readily available schedules and long-term dependability of service, allowing one to minimize wait at the station, may be a major factor in this favorable perception of commuter rail scheduling. This suggests that the same type of effect might be possible to engender with the right kind of systematic, easy to remember and well advertized bus schedule (509). There is little information available on actual response to provision of easily remembered departure times, although it may be noted that many successful restructurings of small city bus service and midday commuter service have employed cardinal time scheduling as one aspect of the overall design (177#, 178, 377*, 628*).

Impacts of Transit Reliability

Somewhat akin to schedule regularization, but more fundamental, is the question of transit reliability. Attitudinal studies of commuters in Baltimore and Philadelphia have found "arrival at intended time" to be perceived as the second most important travel attribute for work trips. Only arrival without accident was judged by respondents to be more important out of over 35 attributes listed. Similar surveys in Boston and Chicago placed "arrival at intended time" above travel time, waiting time and cost measures. For non-work trips reliability was judged not as important, although it still ranked eighth on the list (226, 471).

Periodic equipment failures during initial operation of the BART rapid rail system in San Francisco led to public perceptions of undependability, and are thought to have inhibited ridership (483). There is little empirical data relating traveler behavior to transit reliability. However, reliability affects transit wait time and also in-vehicle travel time, and both are determinants of mode choice and thus transit patronage. The following table gives estimated impacts on patronage of improved schedule reliability assuming the average passenger response to wait time changes applies[f/]. Reliability is in this case measured by the wait time saved through improved maintenance of a ten minute headway.

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e/ The elasticities presented for commuter railroad service improvements are arc elasticities computed by the Handbook authors.

f/ Calculated by Handbook authors utilizing formulations for reliability impact on wait time (1*), and assuming a wait time elasticity of -0.5 and random arrival of passengers at the bus stop.

Mean headway	Standard deviation of headway	Patronage increase due to new standard deviation of	
(minutes)	(minutes)	4	2
10	6	8%	14%
10	4	--	6%

Note: A standard deviation of 4 minutes indicates that two-thirds of observed headways are within 4 minutes of the mean headway, e.g., in the case of a mean 10 minute headway, between 6 and 14 minutes.

The conceptual relationship of reliability and traveler behavior is further illustrated in Figure 14. The curves in Figure 14 represent the distribution of bus arrival times at the traveler's ultimate destination, before and after improvements in reliability. If the traveler is willing to accept a certain probability of being late, represented by the area under the curve to the right of T_L, the narrower range of bus arrival times resulting from improved reliability permits the traveler a later time of departure T_D vs. T_D. The average travel time in this example remains unchanged but the time set aside for travel decreases (1*).

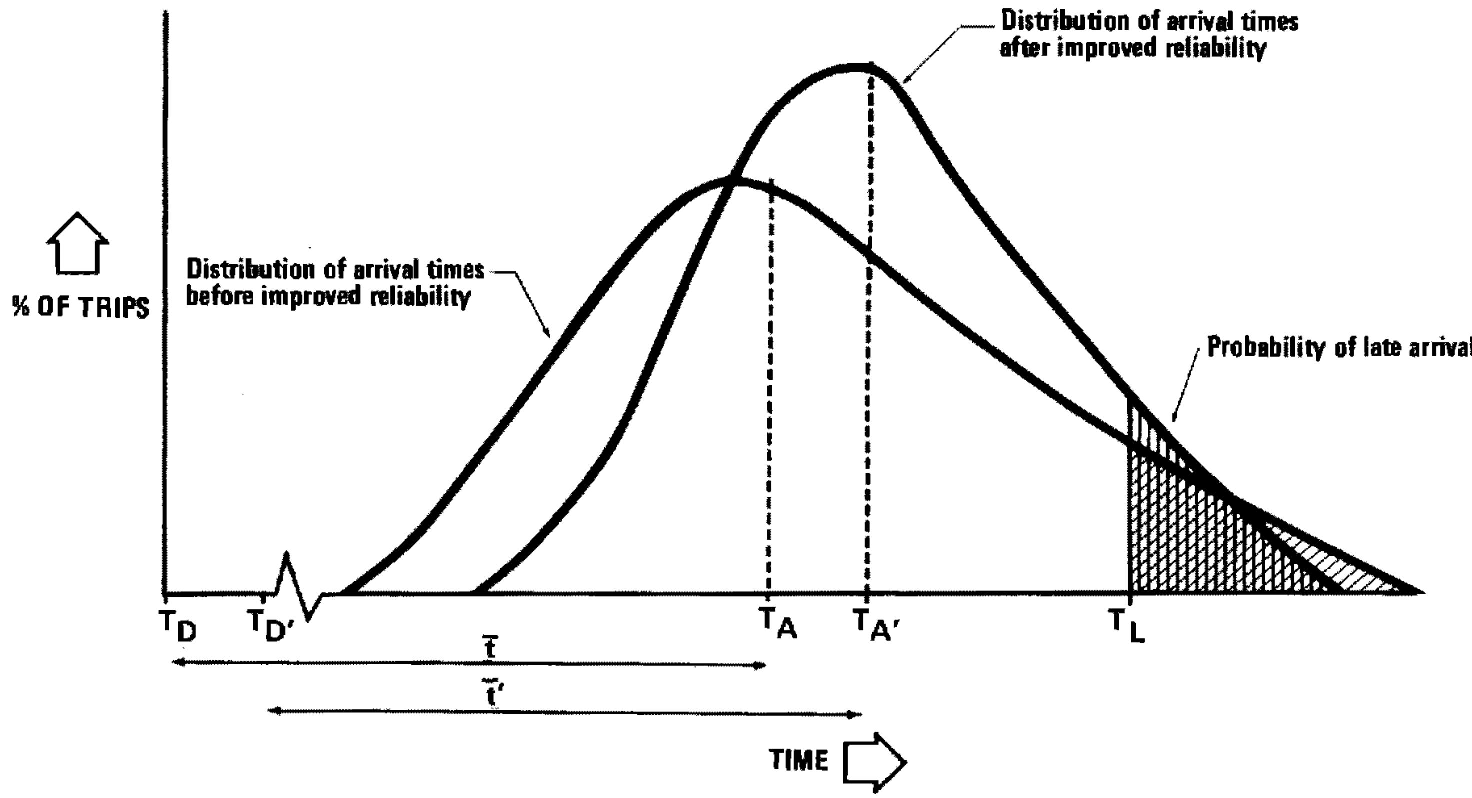
Schedule reliability is demonstrated to save regular commuters more time than the assumption of random passenger arrivals at the transit stop would indicate. A study of ten bus stops in London found that where bus arrival times were consistent, passenger waiting times tended to be less than that expected based on random arrivals. Passengers were benefiting by setting their arrival time to coincide with bus arrival times. Where service was inconsistent, waiting times more nearly approximated times based on random arrivals (297).

Response to Combined Service Frequencies

Some transit service improvement actions involve deployment of additional buses to serve a given street or closely defined corridor in an operating mode differing from the preexisting or alternative service. Overlaying express bus routes on existing local routes is an example. In such cases it cannot strictly be said that the frequency of service has been increased proportionate to the new bus runs, and some riders may not benefit from the new service. Other riders, however, obtain increased options with additional amenities such as express speed.

In situations where the provision of new or expanded express bus service has resulted in increased overall frequency of service from residential areas to the CBD, patronage increases have been on the order of 0.9 percent for each additional 1 percent increase in the number of bus trips. These findings suggest that where express service is appropriate, a combination of increased service and express runs may attract more additional patronage -- possibly half again as much -- as would a similar bus trip increase applied to local service alone. Further detail on frequency changes with express service is contained in the "Express Transit" topical digest.

When differing services are coordinated to provide a meaningful combined frequency, some passengers appear governed in the choice of their transit trip by the departure and arrival times, and others appear governed by the other characteristics of the service offered. In rural England a study was made of local transit travel having the option of a through bus trip every two hours or a trip involving a transfer every



T_D =Departure time before

$T_{D'}$ =Departure time after

$\bar{t}$ =Mean travel time before

$\bar{t}'$ =Mean travel time after

T_A =Mean arrival time before

$T_{A'}$ =Mean arrival time after

T_L =Time of late arrival

Figure 14
Effect of Improved Reliability on Transit Passenger Trip Timing

intervening hour; a combined frequency of one hour. If departure/arrival time governed, 50 percent would be expected to use the transfer service, while if other trip characteristics governed, no one would be expected to use it. In actual practice 24 percent elected the intervening hour transfer service (600).

Frequency Changes With Fare Changes

The results of bus frequency changes in connection with fare changes are inconclusive in respect to which has the greater impact. The increased ridership attracted by a bus frequency increase of approximately 25 percent in Fitchburg, Massachusetts, was effectively nullified by a 25 percent fare increase (377*). A 40 percent fare decrease accompanied by routing improvement and extensions in Iowa City led to more than a doubling of ridership despite a widening of the headway on three of the seven original routes from 20 minutes to a uniform systemwide 30 minutes. Subsequent reduction of peak period headways to 20 minutes systemwide was accompanied by a 10 percent ridership increase, small by comparison (177#).

On the other hand, overall service improvements, including both coverage and frequency improvements, have been estimated to have greater impact than fare reductions (see "Fare Changes With Service Changes" in the digest "Transit Fare Changes"). Analyses of the sensitivity of short, suburban trips to bus service levels, done with a mode choice model calibrated for the northern Chicago suburbs, indicated the middle-to-upper income population involved to be about 40 percent more sensitive to frequency than fares in the 10 to 20 minute headway range, and over two times as sensitive to frequency in the 20 to 40 minute headway range (509). Results for a lower income population could well show a lesser difference in sensitivities, or even dominance of sensitivity to fares, particularly where service is already quite frequent.

There is limited but strong indication that the typical commuter railroad patron is much more influenced by service frequency than by fares. The first phase of the Boston & Maine experiments previously citied included both fare decreases (28 percent) and service increases (77 percent). Overall Phase I patronoge rose 27 percent, but the increase on two individual lines which received only fare reductions was a mere three percent. Although most fares were raised in Phase 2, ridership continued upward. The experience on Boston area lines of the New Haven Railroad was comparable (377*), and an 11 percent fare increase as part of the Philadelphia area Reading Company demonstration similarly failed to erase positive patronage response to service frequency improvement (574*). These experiments were conducted at a time when inflation was not a significant confounding factor.

Underlying Traveler Response Mechanisms

Service frequency changes affect the time a transit patron must wait for service, both initially and at transfer points. Increasing the frequency reduces these wait times and makes transit a more attractive travel mode. Travel demand research done using modeling techniques has for some time suggested that transit wait time, transfer time, and walk time lumped together may be two to two and one half times as important in mode choice as an equal time spent in the transit vehicle (520, 561).

More recent modeling efforts afford a differentiation among these out-of-vehicle time components and indicate that, at least for work trips, the initial wait as measured assuming random arrivals has a lesser relative importance than the transfer wait. The following results from Houston mode choice model sensitivity analyses for the relative importance of trip time components, as estimated for a uniform time reduction and normalizing on running time, are fairly typical (604):

Trip Purpose	Relative Trip Maker Weighting of Running Time	Initial Wait Time	Transfer Wait Time
Home-Work	1.0	0.96	1.49
Home-Other	1.0	2.62 1/	2.62 1/
Non Home Based	1.0	2.65 1/	2.65 1/

1/ No differentiation between initial and transfer wait time.

Again the indication is that if service is reasonably reliable, passengers can reduce the impact of the initial wait time by adjusting their time of arrival to more closely coincide with the transit schedule. Since transfer waits cannot be controlled by the passenger, they remain the more onerous.

Where transit service already exists, as is always the case when service frequency improvements are being considered, those who are most dependent on public transportation (transit captives) are among the transit riders already being served. Thus the riders attracted by frequency improvements tend to be discretionary transit riders, more prevalent among middle and upper income groups (277).

Sources of New Ridership

In the reported surveys of new riders attracted by increased service frequency, "trips not made previously," reflecting changes in trip frequency or destination choice, were apparently not identified. The percentage of such trips is probably comparable to the 10 to 20 percent reported in connection with combined fare and service increases. (See "Sources of New Ridership" in the topical digest "Transit Fare Changes" for the specific data and further discussion.)

Bus riders attracted from other travel modes by increased frequency were, in various Massachusetts experiments, distributed as follows among the prior modes(377*):

own car	18 to 67%
carpool	11 to 29
train	0 to 11
taxi	0 to 7
walking	0 to 11

The prior modes percentages for patrons attracted by more frequent commuter train service in the Boston area were (377*):

own car	64%
carpool	17
bus	19

These percentages are roughly comparable to those reported for combined fare and service increases except for the introduction of competitive transit services (train and bus) as one source of "new" riders. Service frequency and scheduling improvements on individual routes do have the potential of causing shifts in transit route choice. "New" riders who have merely changed route must be discounted in assessing benefits other than whatever travel time saving the riders involved accrue.

Impacts on Temporal Ridership Patterns

The potential of transit frequency improvements for attracting additional ridership is greatest percentagewise in the off-peak periods of the day. A likely reason, in part, is the typical existence of lesser service frequencies in the off-peak hours.

Another possible factor is the off-peak prevalence of discretionary travel. In the Detroit center city Grand River Avenue demonstration, off peak elasticities were almost 100 percent above the peak hour headway elasticity of -0.13. Chesapeake to Norfolk suburban service off peak elasticities were over 50 percent above the morning peak -0.58 elasticity. Only in Stevenage, England were elasticities found to be lower in the off peak than in the peak. Bus headway observations previously discussed are stratified below by time period (384):

Time Period	Number of Observations	Arc (Midpoint) Elasticity
Peak Hours	3	-0.37
Off peak Hours	9	-0.46
Weekends	4	-0.38
All Hours	7	-0.47

Experimental train frequency increases on Boston & Maine service into Boston of 82 percent in the peak and 92 percent in the off peak induced an 18 percent Phase I ridership increase in the peak and a 60 percent increase in the off peak.[g/] These results imply peak and off peak service elasticities of +0.3 and +0.7, respectively (377*). (Data on the temporal impact of fare reductions combined with all types of service improvements are presented under "Impacts on Temporal Ridership Patterns" in the topical digest "Transit Fare Changes.")

Only 24 percent of public hearing attendees polled in St. Louis were concerned with obtaining improved rush hour service, while nearly all desired service improvements in other time periods (277). Commuters to New York City listed midday and evening

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g/ From head count data. In this experiment, "off peak" was defined as including not only midday and evening trains and patronage, but also trains and patrons moving counter to the predominant flow during the peak hours. The experiment employed off peak fare discounts, but not in Phase I.

service improvements, which involved both speed and service frequency, as the most important changes wrought by a demonstration project involving the New York Central Railroad (628*).

Impacts on VMT, Energy and Environment

For evaluation of the VMT, energy consumption and pollutant emission impacts of transit service frequency changes per se, reliance must be placed on modeled traveler response. In one study, 25 percent areawide bus headway (wait time) reductions were modeled with the following energy saving and emissions reduction results (590*).

	Weekday Areawide Percentage Change 1/					
	Transit Rides	Auto VMT	Auto Fuel	Auto Emissions HC	CO	NOx
Denver	+21.0%	-0.4%	-0.4%	-0.4%	-0.4%	-0.3%
Fort Worth	+21.6	-0.3	-0.3	-0.4	-0.4	-0.3
San Francisco	+18.3	-2.0	-2.2	-2.3	-2.4	-1.9

1/ Work purpose travel only; negative sign indicates savings/reductions in specific category.

The above estimates do not include any calculation of the increased fuel consumption or pollutant emissions incurred by public transit in providing the additional service. Another study indicates that within certain travel markets, increased transit fuel consumption may largely or completely offset the automobile energy saved by attracting trips to transit with frequency increases. For example, the impact of decreasing Chicago rail rapid transit wait time by 20 percent was estimated to be a 1.8 percent ridership gain accompanied by a net increase in urban transportation energy use equiva-lent to 0.5 percent of areawide automotive fuel consumption. The estimated impact of a similar decrease in commuter rail wait times was an 8.0 percent ridership gain accompanied by increased energy use equivalent to 0.3 percent of areawide automotive fuel consumption (511#). These are, however, examples from one end of the spectrum. Exactly comparable estimates were not made for other travel markets.

More comprehensive examination of bus frequency increases in combination with increases in service coverage have indicated that net energy savings are attainable in a number of travel markets, but not in others (See "Impacts on VMT, Energy and Environment" in the digest "Bus Routing/Coverage"). Notably, the net energy savings resulting from combining improved frequency with decreased fare is in most cases greater than the sum of the individual actions. This same synergistic effect is also evident when improved transit service is combined with auto use disincentives. In both cases the complementary actions assist in filling the additional transit vehicles required by virtue of the frequency improvement strategy, thereby increasing both transit and total energy efficiency (511#). (See also "Impacts on VMT, Energy and Environment" in the digest "Transit Fare Changes.")

Impacts on Revenues

Transit service frequency increases will attract transit trips and thereby increase gross farebox revenue, but will seldom lead to a decreased net cost of transit operation. In any case, the net cost of a carefully designed service frequency increase is often found acceptable to the operating agency involved (177#, 350, 377*, 574*). Note that schedule regularization to provide greater public convenience and easy recollection of departure times need involve only start-up costs.

The marginal cost of new off peak service may be significantly less than the average systemwide full operating cost. Peak ridership demands determine the number of vehicles and heavily influence the number of drivers needed to provide service. Off peak costs are thus largely determined by direct vehicle operating costs alone, particularly where full time drivers are not actually driving full shifts.

A 1968 evaluation of suburban Long Island bus operating costs found that it took only 6 percent as many patrons to cover the marginal costs of off peak bus operation as to cover the full costs of peak hour only (no off peak service) operation (498#). Comparison of off peak with peak hour only service exaggerates normal conditions, but it is clearly inappropriate to use a flat, all day, per mile or per hour cost in assessing the viability of off peak service improvements. Examination of the commuter railroad cost impact of a 40 percent increase in car miles spread over both the peak and off peak revealed the following operating cost increases (377*):

fuel	+40%
train crew labor	+32%
car repair	+28%
nonoperating labor	+11%

Sensitivity analysis of providing alternative frequencies to serve short (0 to 4 miles) trips in the middle to upper income northern Chicago suburbs indicated that provision of headways wider than 20 minutes would result in diminishing returns (net revenue computed per 1969 operating costs), unless a highly regular 30-minute schedule could induce improved rider reaction to the wait for service (509). This result was associated with service elasticities of over 1.0 for service changes involving headways wider than 20 minutes, as might be expected considering the travel market under study. Travel markets involving lower income groups or longer trips can be served with somewhat less frequent headways without going beyond the point of diminishing revenue returns.

Traveler Response Time Lag

The ridership response to a service frequency improvement takes time to fully develop, probably more time than the response to a fare decrease. In the case of various Massachusetts experiments, some frequency improvements elicited ridership increases that stabilized within the first month. This was particularly true of the bus service experiments oriented to urban, off-peak travel. Other frequency improvements elicited a response that grew throughout the course of the 9 to 12 month experiments. For example, a suburban route into Boston exhibited a 27 percent ridership increase over the prior year in the fourth quarter compared to 18 percent in the first, while a suburban route into Worcester showed a 16 percent increase in the third quarter compared to none in the first (377*). Commuter railroad service frequency improvements attracted steadily increasing ridership over 16 to 18 month periods (377*, 574*, 628*). (Further discussion is provided under "Traveler Response Time Lag" within the topical digest "Bus Routing/Coverage.")

Additional References

"Patronage Impacts of Changes in Transit Fares and Services", by Mayworm, Lago and McEnroe (384) provides additional case study detail with respect to Transit Scheduling/Frequency. For further information on Transit Scheduling/Frequency consult references:

1*, 6, 10, 13, 21, 34, 43, 50#, 76, 93, 96, 108, 109+, 121, 130, 145#, 148#, 156, 159, 177#, 178, 226, 229, 243, 244, 262, 274, 277, 290, 297, 318, 319, 321, 325, 350, 362, 368, 371, 377*, 384, 387, 388, 394, 414, 424, 428, 440#, 460, 471, 481, 489, 498#, 501, 509, 511#, 512, 519, 522+, 524, 545, 557, 573, 574*, 585, 590*, 600, 604, 610, 628*, 629#, 630, 632, 635, 636, 650, 675#, 676, 681, 684, 692#, 704.

1. Abkowitz, Mark, et. al. Transit Service Reliability. Transportation Systems Center, Cambridge, Massachusetts and Multisystems, Inc. Sponsored by Urban Mass Transportation Administration, U.S. Department of Transportation. December, 1978. 192 pages. Contract No. DOT-TSC-1083. NTIS PB 292-152. TRANSIT SCHEDULING/FREQUENCY*, CONVENIENCE/COMFORT/RELIABILITY ANALYSIS. OBSERVED RESPONSE, FORECAST RESPONSE. TEMPORAL DISTRIBUTION, MODE CHOICE.

An examination of empirical and theoretical studies was made concerning the impacts of transit service reliability on traveler and operator behavior. The literature search conducted by the authors discovered little empirical work investigating the relationship of reliability to mode choice and departure time considerations, resulting in a focus on underlying aspects of service reliability and the way in which these aspects may influence travel decisions.

The authors suggest that the measures most appropriate to determine impacts of reliability changes are the mean time of an activity, a coefficient of variation of time to ascertain the compactness of the response distribution, and the percentage of responses beyond a specified limit to indicate the likelihood of a major system failure. The study points out that two common measures of reliability impact, consumer surveys and deviation from scheduled time, are flawed. The former is flawed because it is subjective and can not measure intensity, and the latter because service may be reliable if its deviation from the schedule is consistent.

Surveys of travelers in four large cities found reliability to be of preeminent importance as a travel attribute. The response "arrive at the intended time" ranked higher than travel time and cost considerations in all four cities. Only "arrive without accident" ranked higher in any of the studies. Surveys in other areas reached the same conclusion. An investigation of passenger arrivals at bus stops revealed that on routes with comparatively reliable service, passenger waiting time was less than would be expected by random arrivals while on routes with comparatively unreliable service, waiting time more nearly approximated that anticipated by random arrivals. In so far as waiting time is a mode choice determinant, reliability will influence traveler response. The table below lists transit and passenger statistics for the bus stops with the most reliable and least reliable service of the 10 examined.

	Scheduled Headway	Observed Headway	Standard Deviation	Waiting time for Random arrivals	Observed Waiting time
Stop with most reliable service -	23.0	23.9	2.2	12.9	5.8
Stop with least reliable service -	20.3	23.5	10.7	14.0	13.1

Unreliable service is attributed to either environmental or inherent factors. Environmental factors include fluctuating traffic conditions, traffic signals, variations in boarding/alighting demand and availability of drivers and vehicles. Inherent factors aggrevate initial deviations from scheduled headways. Late buses encounter increased passenger loads at subsequent stops causing them to fall further behind while early buses encounter decreased loads causing them to become earlier. The authors suggest several strategies to counter the causes of unreliable service. Unreliability due to traffic congestion can be helped by bus priority facilities. Variation in demand can be countered by express service, exact fare requirements and pre-paid transit fares. Operational strategies to improve reliability include turning back before the end of the route and skipping stops (both of which may provide service disruptions for some passengers), providing more slack or layover time including mid-route control points and maintaining reserve vehicles (all of which provide lower levels of base service) and restructuring service to utilize shorter routes (possibly leading to more transfer requirements).

377. Mass Transportation Commission of the Commonwealth of Massachusetts, McKinsey & Co., Systems Analysis and Research Corp., and Joseph Napolitan & Assoc. Mass Transportation in Massachusetts. Sponsored by U.S. Housing and Home Finance Agency; Project No. MASS-MTD-1. July, 1964. 144 pages. NTIS PB 174-422. TRANSIT SCHEDULING/FREQUENCY*, BUS ROUTING/COVERAGE, EXPRESS TRANSIT, COLLECTION/DISTRIBUTION TRANSIT, TRANSIT FARE CHANGES, POOL/TRANSIT FRINGE PARKING. OBSERVED RESPONSE. MODE CHOICE, TRIP GENERATION, TEMPORAL DISTRIBUTION.

MTA Experiments. Between December 10, 1962, and March 28, 1964, the Mass Transportation Commission of the Commonwealth of Massachusetts performed a variety of mass transit service improvement and fare reduction experiments. Passenger and farebox (gross) revenue tallies were maintained throughout the experiments and compared with available data for equivalent months in the prior year. The patrons were sampled and interviewed to obtain information on rider characteristics and travel habits. The projects fall into 3 groups: the "MTA Experiments," involving the Metropolitan Transit Authority; the "Bus Company Experiments," involving bus operators throughout the state other than MTA; and the "Rail Experiments," involving the commuter railroads serving Boston. This review covers the MTA experiments, all conducted within Boston and the inner suburbs. The other experiments are reviewed on the following 2 pages. The annual transit ridership in the MTA service area in 1970 was 91.90 trips per capita.

Off peak service frequency was increased to match peak period frequency in 2 of the MTA experiments. On a 1 mile downtown bus route connecting Boston's North and South Stations, the off peak headway was changed from 25 min. to 5 min. Results: 6 month revenue up 71%, with an average of 1,441 new riders per day; post experiment off-peak headway set at 8 min. On a suburban feeder to rapid transit bus route, off-peak frequency was improved from 10 to 5 min. Results: 5 month revenues up only 3%. Among the new bus lines tried were 2 circumferential services, 3 and 5 miles from downtown Boston respectively. Each passed through 7 rail transit stations and 7-8 dense residential and retail communities. Frequency was 10 min. peak and 15 min. base. Results: 697 average daily additional passengers gained for the 3 mile radius corridor, 3347 for the 5-mile corridor; 2% and 27% increases in corridor revenues, respectively; revenues 5%-20% of costs.

Parking fees were selectively reduced from 35¢ to 10¢ at 8 out of 15 parking lots along 3 rapid transit lines. Parking along these lines increased by 48% in total, and parking loads were shifted from overutilized to previously underutilized lots. MTA concluded that a $165,000 net gain in annual parking and farebox revenue was produced. A separate, unsuccessful attempt was made to utilize 3 drive-in theaters as park'n'ride stations served by frequent express buses. The total daily parking count never reached 40.

Of the riders newly attracted to MTA by increased bus frequency between North and South Stations, approximately 2 out of 3 had previously walked and 96% of the prior walkers were making train connections. On the inner circumferential bus route 94% of the riders interviewed had previously used another MTA service; of the remainder 66% had traveled by auto, 25% had walked, and 8% were making new trips. On the outer circumferential bus route 13% formerly traveled by auto, 44% by bus, and 43% via a combination of radial MTA rail lines. Among patrons newly attracted to MTA rapid transit parking lots by reduced fees, 54% previously drove to their destinations, 18% carpooled, 7% took commuter trains, and 21% had gone by bus. The typical rush hour "park and ride" commuter was making a work trip and drove about 4 miles to the lot (10 miles in the case of the Riverside terminal); the typical off-peak user was shopping and drove 3 miles to the lot.

377. Mass Transportation Commission of the Commonwealth of Massachusetts, McKinsey & Co., Systems Analysis and Research Corp., and Joseph Napolitan & Assoc. Mass Transportation in Massachusetts. Sponsored by U.S. Housing and Home Finance Agency; Project No. MASS-MTD-1. July 1964. 144 pages. NTIS PB 174-422. TRANSIT SCHEDULING/FREQUENCY,* BUS ROUTING/COVERAGE, EXPRESS TRANSIT, COLLECTION/DISTRIBUTION TRANSIT, TRANSIT FARE CHANGES, POOL/TRANSIT FRINGE PARKING. OBSERVED RESPONSE. MODE CHOICE, TRIP GENERATION, TEMPORAL DISTRIBUTION.

Bus Company Experiments. (See "MTA Experiments" on the preceeding page for an introduction to the various Massachusetts demontration projects conducted between December 10, 1962, and March 28, 1964. This review covers bus service experiments conducted outside the MTA (urban Boston) service area. The patronage figures given are for average weekday total inbound passengers.

Several experiments involved increasing the service frequency provided on established local service bus routes. On a Milford to downtown Boston route, total suburban service area pop. 22,000, a 1 hour all day headway was provided. Results: 78% service increase, 12 month revenue up 22% (18% in the first 3 months, 27% in the last 3 months), 232 inbound passengers. A very similar service increase was provided on an Uxbridge to Worchester (population 187,000) route, total suburban service area population 28,000. Results: 9 month revenue up 5% (none in the first 3 months, 16% in the last 3 months), 111 inbound passengers. On a submarginal operation through industrial Amesbury and Newburyport, total population 25,000 and declining, frequency was improved to half-hourly in the peak and hourly in the base. Results: 67% service increase, 8 month revenue up 19%, 85 inbound passengers. The Adams-Williamstown bus route, total urban service area population 40,000 (including a college), received better than hourly frequency. Results (prior to disruption of the experiment by operator bankruptcy): 100% service increase, 3 month ridership up 48%, over 300 inbound passengers. Within the city of Pittsfield, SMSA population 74,000, service on two 3-mile long radial routes was increased to 8 and 15 round trips, respectively. Results (prior to experiment disruption): 16% and 50% service increases, 3 month ridership up 87% and 30%, 113 and 293 inbound passengers. On the Fitchburg to Leominster route through high density areas, 72,000 SMSA population, 1:40 PM to 6:00 PM bus trips were doubled to provided a 10 minute headway all day and a minor route extension was provided. There was a 20¢ to 25¢ fare increase in the 9th month which caused only a brief drop in ridership. Results: 8 month revenue up 8%; 1,561 inbound passengers over 12 months. A 20% service increase in Fall River, SMSA population 124,000, during a period of high unemployment and disruptive highway construction, halted but did not reverse a ridership decline. After 6 of these demonstrations, 30% to 60% of the added service was retained.

Most new routes attempted were unsuccessful, including service into light density suburbs of Fitchburg, short in-city routes to new developments, an industrial service, and 2 commuter railroad feeder routes. The services attempted varied from 5 bus trips a day to half hourly frequency; the average bus trip carried less than 2 passengers. An expressway service into Boston attracted 61 inbound passengers; a modest success. A rapid transit feeder service, operating through dense suburbs on a 30 minute headway, attracted 193 inbound riders at a 10¢ fare, 183 at a subsequent 15¢ fare, and was retained in full after the demonstration. Reduction of off-peak fares from 25¢ to 10¢ in Lowell, SMSA population 119,000, produced a 4 month 79% average off-peak ridership increase.

The prior travel modes for new bus riders on the Milford, Uxbridge, Fitchburg, Adams, and Pittsfield demonstrations ranged from 18% to 68% own car, 11% to 29% carpool, 0% to 7% taxi, 0% to 54% walk, and 0% to 11% train. Some 51% of all bus riders, old and new, said the bus service was a contributing factor in staying on their present job.

377. Mass Transportation Commission of the Commonwealth of Massachusetts, McKinsey & Co., Systems Analysis and Research Corp., and Joseph Napolitan & Associates. Mass Transportation in Massachusetts. Sponsored by U.S. Housing and Home Finance Agency; Project No. MASS-MTD-1. July 1964. 144 pages. NTIS PB 174-422. TRANSIT SCHEDULING/FREQUENCY,* BUS ROUTING/COVERAGE, EXPRESS TRANSIT, COLLECTION/DISTRIBUTION TRANSIT, TRANSIT FARE CHANGES, POOL/TRANSIT FRINGE PARKING. OBSERVED RESPONSE. MODE CHOICE, TRIP GENERATION, TEMPORAL DISTRIBUTION.

Rail Experiments. (See "MTA Experiments" 2 pages preceeding for an introduction to the various Massachusetts demonstration projects conducted between December 10, 1962, and March 28, 1964.) This review covers experiments conducted on the 3 commuter rail operations in the greater Boston area. These included: The Boston & Maine Railroad (B&M), the New Haven Railroad (N.H.) and the New York Central Railroad.

The B&M experiment consisted of 3 phases: Phase 1 incorporated an overall 77% increase in service (including weekends) and a 28% decrease in fares. The weekday service expansion was 92% (peak service 82% and off-peak 96%); the fare decrease varied from 12% to 72%. Phase 2 involved retention of Phase 1 service improvements, coupled with virtual elimination of the fare reductions, except for adjustments to provide an off peak fare discount. In Phase 3 service levels were adjusted, while the fare structure remained the same. The N.H. experiment consisted of 2 phases: In Phase 1, the total overall average service level was increased by 42% and fares were reduced by an average of 10%. In Phase 2 part of the N.H. operation was returned to preexperiment service levels, and fares were raised to approximately preexperiment levels except for provision of off peak fare incentives. New York Central Railroad operation was used as an experimental control; no significant changes were made to service or fares, nor was there any special advertising of the service.

Ridership increases on the B&M were immediate; ridership in January 1973, was up 30% (5,500 more weekday riders) over December. Overall patronage gains on the B&M averaged 27%, 37.5% and 44% over pre experiment levels for Phases 1, 2 and 3 respectively. The N.H. experienced ridership increases of 10% and 11.5% for Phases 1 and 2, respectively. Riding on the New York Central continued downward during 1963. The average decline was 5.9%, similar to preexperiment trends on the other 2 railroads. On 2 individual lines of the B&M which received only fare reductions, the total Phase 1 ridership increased by only about 3%. Similar results were observed on individual N.H. lines. Moreover, the Phase 2 B&M and N.H. patronage increases occurred despite fare increases. It was, therefore, concluded that service level improvements were more effective than fare reductions for increasing ridership. Nevertheless, the fare reductions were perceived: Of new train riders surveyed, 22% cited lower fares as the principal reason they used trains more often, while 14% cited the increase in train service and 6% noted both. Additional revenues earned during Phase 1 covered the loss inherent in the fare reduction but not the costs of added service; new revenues earned during the final phases were sufficient to cover the full incremental cost of the experiment, but not much of the overall operating deficit.

A 35% B&M Phase 3 increase over a preexperiment headcount reflected a 21% peak period increase and a 79% off-peak increase. (All off-peak data includes reverse commutation during the peak.) The N.H. percentage increases were similarly large in the off peak relative to the peak. Riders using commuter trains more often previously traveled 63.6% in their own car, 16.9% as a carpool member, and 19.5% via bus. Of all inbound riders, 41.0% drove and parked their own car at the station, 27.7% walked to the station, 1.8% took a bus, and 2.2% a taxi. While 83% of inbound N.H. commuters walked to their destination, 55% of B&M commuters used subway or bus (40% walked) because of the station location.

574. Southeastern Pennsylvania Transportation Authority. Sepact III: Final Report - Operation Reading. Sponsored by U.S. Department of Transportation; Project No. PA-MTD-5. June 1971. 102 pages. NTIS PB-204-065. TRANSIT SCHEDULING/FREQUENCY,* TRANSIT FARE CHANGES, TRANSIT MARKETING/BROKERAGE. OBSERVED RESPONSE. TRAVEL CHOICE.

The Operation Reading demonstration, carried out by the Reading Company and the Southeastern Pennsylvania Transportation Authority between May 1965 and October 1966, was designed to evaluate the ability of revised fare and service schedules, advertising and promotion, facility improvements, and new managerial techniques to reverse the declining commuter rail patronage trend. Reading's commuter operation lies primarily north of Philadelphia, serving approximately 44,000 daily commuters with 100 community stations located along 259 miles of trackage.

The demonstration was performed in 5 consecutive phases. Service adjustments and promotional campaigns were included in all phases; fares were rationalized in Phase I and raised in Phase III. Market surveys of 4,402 households were conducted in May 1965, January 1966, and October 1966, coinciding with project Phases I, III, and V. These were accompanied by ticket lift counts and smaller intermediate surveys. February-April 1965 served as a preexperiment base period for comparison of annualized train miles, ridership, and revenue.

In Phase I (May-July 1965) 48 additional off peak trains were placed in service, and zonal fares were extended to cover the entire system. Service was reduced in Phase II (August-October 1965), and then selectively restored in Phase III (November 1965 to April 1966) in connection with fare increases averaging 11.1%. At this point there were 22 off peak trains more than in the base, a 7.8% increase over the base in annualized train miles. Phase III annualized ridership was 4.1% over the base despite the fare increase. The increased revenue together with modest operational improvements resulted in a 13.1% reduction in the deficit. In Phase IV (May-September 1966) and Phase V (October 1966) there were further service adjustments facilitated by electrification of the Fox Chase line. As compared to the base, Phase V train miles were up 9.2%, the average fare paid was up 11.4%, overall ridership was up 8.6%, the average length of ride was up 5.8%, and the deficit was down 21.5%. The increase in off peak ridership was 13.3%, versus 4.9% for peak period riding.

On the basis of mapping work trip origins and destinations, it was concluded that the Reading 1965 work purpose ridership represented 65% "saturation" of the rail commuter market. A series of followup surveys consistently showed that only 45 to 50% of the passengers commuting to and from work via the railroad in any given month had used it in a prior month. Reasons given for this fluidity of travel choice were chiefly related to employment, including change or relocation of the employer, temporary unemployment, vacation, illness, and retirement. Change of residence, affecting about 20% of households each year, was also a factor. The January 1966 Survey showed that 20% of both the commuters and the general public thought that raising fares was a good idea; they associated the increased fares with increased service. Public recall of Operation Reading publicity ranged from 10 to 15% of actual rail users and from 4 to 42% of potential rail users over the life of the project. Newspaper articles, editorials, and advertising proved to be the superior media for promotion, and accounted for roughly half of the public awareness.

590. Suhrbier, J.H., and W.D. Byrne. Analytic Procedures for Urban Transportation Energy Conservation: Summary of Findings and Methodologies - Final Report - Volume I of 5 Volumes. Cambridge Systematics, Inc. Prepared for Office of Conservation and Advanced Systems Policy, U.S. Department of Energy; Contract No. EC-76- C-01-8628. April, 1979. TRANSIT SCHEDULING/FREQUENCY*, TRAFFIC OPERATIONS IMPROVEMENTS, CARPOOLING ENCOURAGEMENT ACTIVITIES, VANPOOLS/BUSPOOLS, AUTO FACILITY PRICING, AUTO FACILITY SUPPLY, TRANSIT FARE CHANGES, RESEARCH TECHNIQUES. FORECAST RESPONSE. MODE CHOICE, VOLUME. ENERGY, AIR QUALITY.

Separate methodologies were utilized in this study to analyze the energy conservation potential of traffic and transportation policy strategies. Selected results of the various policy strategies as modeled for Denver, Ft. Worth and San Francisco are presented here. The transportation policy impact estimation methodology utilized a system of disaggregate qualitative choice travel demand models linked to automotive fuel consumption and pollutant emissions models. Gross automotive fuel savings were calculated. (Changes in public transit energy consumption were not examined). For carpooling encouragement strategies, promotion efforts by employers of 50+ and 250+ employees were tested. The vanpool option was limited to employers of 250+ employees and to work trips of over 10 miles one-way trip length. Results for selected strategies are tabulated below in terms of percentage impacts on weekday work purpose travel and related gross automotive fuel consumption:

		Change in Work Trip Mode Share 1/				Change for Work Trips 1/	
Policy	City	Drive Alone	Shared Ride	Transit	Van-pool 2/	Auto VMT	Auto Fuel
25% headway reduction (areawide)	Denver	-0.5%	-1.1%	21.0%	--	-0.4%	-0.4%
	Ft. Worth	-0.4	-0.8	21.6	--	-0.3	-0.3
	San Francisco	-2.3	-3.9	18.3	--	-2.0	-2.2
50% headway reduction (CBD only)	Denver	-4.6	-7.8	36.0	--	-3.6	-4.1
	Ft. Worth	-4.9	-5.9	67.8	--	-4.2	-4.4
	San Francisco	-18.0	-20.5	24.6	--	-15.0	-16.3
Improve CBD express bus frequency	Denver	-1.9	-2.1	12.5	--	-1.8	-1.9
Carpool Promotion (50+ employee firms)	Denver	-2.9	13.0	-10.1	--	-1.4	-1.2
	Ft. Worth	-3.2	14.7	-10.1	--	-1.9	-1.6
	San Francisco	-3.4	11.5	-6.2	--	-1.5	-1.2
Carpool Promotion (50+) with Vanpool Promotion (250+)	Denver	-4.4	11.1	-11.1	(2%)	-4.2	-3.2
	Ft. Worth	-7.0	9.1	-11.6	(4%)	-10.1	-7.3
	San Francisco	-7.1	5.4	-9.4	(4%)	-9.6	-6.4
50% Transit fare subsidy	Denver	-0.1	-0.3	5.4	--	-0.1	-0.1
	Ft. Worth	-0.1	-0.3	5.7	--	-0.1	-0.1
	San Francisco	-0.5	-1.5	5.3	--	-0.8	-0.7
100% Transit fare subsidy	Denver	-0.2	-0.7	11.3	--	-0.2	-0.3
	Ft. Worth	-0.2	-0.7	11.7	--	-0.1	-0.2
	San Francisco	-1.0	-3.1	10.9	--	-1.6	-1.6

1/ Values given for CBD oriented strategies (50% headway reduction; improve express bus frequency) are percentages of CBD work trips only (involving 7.5%-11.3% of areawide fuel consumption).

2/ Percentages given are new mode share.

The higher initial level of transit service in San Francisco is crucial to the effectiveness of the transit headway improvement and fare subsidy strategies as compared to Denver and Ft. Worth where the initial transit mode shares were only 2% and 3% respectively. Some program packages had no synergistic effects because of competition among strategies. Combined carpool, vanpool and fare subsidy programs gave a 10.1% VMT reduction compared to 10.4% for the sum of the individual strategies. Combining transit improvements and ridesharing incentives with auto disincentives was more synergistically effective.

628\. Tri-State Transportation Commission. Suburban Service Adjustment Experiment. Sponsored by U.S. Housing and Home Finance Agency; Project No. INT-MID-5. February 1966. 75 pages. NTIS PB 210-929. TRANSIT SCHEDULING/FREQUENCY,* POOL/TRANSIT FRINGE PARKING, COLLECTION/DISTRIBUTION TRANSIT, TRANSIT FARE CHANGES. OBSERVED RESPONSE. VOLUME.

A 28 month demonstration was conducted on the Harlem Divison of the New York Central Railroad, starting July 1, 1964, to test the efficacy of improving rail service to an outlying suburban area. The 14 stations north of White Plains, N.Y., were primarily involved. To decrease running times, 6 of these stations were designated as local stops and actually received service reductions. Improvements were concentrated on the remaining 8 stations. Off-peak service frequency was increased by approximately 50%, to provide hourly off peak headways at the express stations. Local stops south of White Plains were eliminated on the hourly trains (85% to 90% of all project area passengers were destined to New York City proper). Terminal-to-terminal running time, formerly about 81 minutes via express and 2 hours via local, was shortened by 5 to 14 minutes for peak period trains and up to 24 minutes for off peak trains. Parking was increased at the 8 express stations. Concurrent with the demonstration project, coaches and motive power were upgraded. A 25% reduction in off-peak, 1-day, round trip tickets predated the demonstration project. In the second year of the project, an additional 25% discount on off peak, round trip Manhattan tickets was instituted. Local bus services were augmented and synchronized with train scheduling at the White Plains stations with the particular objective of providing alternative transportation to certain local station service areas.

A preexperiment survey at the stations to be designated "local" revealed that 40% of all patrons drove to the station, 30% were dropped off, 24% walked, and 6% rode buses. It was thus felt that the majority of local station patrons would shift to driving or riding the expanded bus service to nearby express stations. In practice, citizen opposition caused local station peak hour service levels to be restored to nearly the original service frequencies by the end of the project. Fluctuations in ridership were measured by both ticket sales data and by train count surveys. In addition, various limited interview surveys were conducted.

Ridership increased 3.0% in the first year of the project, 13.2% in the second year, and 16.8% in the first 6 months of the third year, all as compared to the corresponding months of the pre-project year. Of these increases 91% were attributed to project improvements (9% to population gains), and 58.4% reflected increased travel on off peak trains. Off peak reduced fare ticket use was up 52% in the first year. After introduction of the Manhattan ticket discount, second year off-peak ticket sales rose 119% over the first year level. Total off peak ticket sales increased by 28.8% during the course of the project. The most frequent opinion survey comments, among those favorable to the demonstration, referred to the midday and evening service improvements.

The number of cars parked at stations increased by some 27% during the project period. It was concluded that most of the new riders drove cars to get to the station. The station parking lots most utilized were not necessarily the cheapest but instead were those providing easy highway access and the shortest walk. The feeder bus phase of the experiment was unsuccessful. An average of 6 to 12 passengers per day used the new service to transfer to trains. This result was ascribed to the high auto ownership (85% with 1 or more cars) in the area.

BUS ROUTING/COVERAGE

Types of Routing Changes

Bus routing/coverage changes are an element of the overall transportation system management class "Actions to Improve Transit." Bus routing and coverage changes include:

1. Introduction of bus service where there was no transit system previously, or, conversely, bus service abandonment or temporary closure due to a strike (482*, 642+, 675*).

2. Major systemwide extension and addition of bus routes, or service retrenchment, such as to markedly alter system coverage[a/] (109+, 188, 322, 325, 384, 509, 546, 656, 673, 675*).

3. Extension or addition of individual, primarily radial bus routes to provide service (coverage) to new development and other previously unserved areas (47, 82, 112, 177*, 178, 280, 377#, 440*, 522+, 524, 689).

4. Initiation of special purpose bus routes to serve specific, inadequately served, existing or potential travel demands; for example, provision of a route connecting an area of high unemployment with a major suburban employment concentration (32, 40, 82, 120, 145*, 244, 408, 498*).

5. Restructuring of a bus system to rationalize service, to accommodate new travel patterns and to reduce circuity and the number of transfers required for bus travel, including through routing of separate bus routes, reconnection and realignment of routes, and provision of crosstown and express lines (13, 177*, 178, 280, 440*, 479, 608, 691#).

Note that this list does not include provision of feeder bus or downtown shuttle routes, express service (except as part of an overall restructuring), or nonstandard operations such as subscription bus service. While these types of services can legitimately be considered among bus routing possibilities, they are assigned in this Handbook to the separate topics "Collection/Distribution Transit," "Express Transit," and "Vanpools/Buspools," respectively.

Traveler Response Summary

The middle range of estimated ridership growth in response to overall expansions of bus transit is an 0.6 to 0.9 percent increase per 1 percent increase in regional bus miles of service. Much wider variations have been reported including individual instances of ridership increase proportionally in excess of service increase. The degree of systemwide ridership response to changes in service is greater in small cities, in suburbs, and in the off-peak.

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a/ Coverage is a measure of the proportion of a metropolitan area or population served by transit, irrespective of service frequency. A rule-of-thumb indicator of coverage is the presence or lack of transit service within 1/4 mile.

Roughly three fifths of the radial, crosstown, and low income area bus routes tried in the Mass Transportation Demonstration Projects of the 1960's[b/] were sufficiently attractive to be retained after the experimental period of operation (excluding feeder routes and express routes serving fringe parking lots). Routes serving multiple functions have fared best. There is also evidence that packages of improvements, including not only better routes but also improved schedules and buses, and possibly fare reductions, do particularly well in attracting increased ridership. New bus routes have been found to take 1 to 3 years to reach their full patronage potential. Ridership development on entirely new transit systems may take even longer.

The attractiveness of individual new or modified bus routes is very much a function of how they relate to local travel patterns and other elements of the transit system. The majority of ridership on new bus lines, other than transfer passengers, comes from homes within one to three blocks of the route. Nevertheless, a major component of the patronage on individual new bus routes may be prior riders of other transit routes; percentages as high as 60 to 94 percent have been reported. This phenomenon plus the need to match new routes with trip densities sufficient for their support both argue for examining routing changes in a system context.

The results of transit strikes show many existing riders to be dependent on transit service for mobility. A reported 15 to 20 percent of all work purpose trips and 40 to 60 percent of non-work trips normally made via transit were suppressed during strikes. Increases in vehicular traffic on the order of 6 to 16 percent have been observed on the affected approaches to the central city during transit strikes. Otherwise, variations in auto traffic in response to bus transit routing and coverage changes have usually been too small or gradual to be measured. Short term urban VMT reductions of two-tenths-of-one-percent or less have been estimated for implemented comprehensive bus service expansion programs.

Response to Comprehensive Service Expansion

The degree of systemwide ridership response to overall expansion of transit service varies markedly from case to case, but typically is somewhat greater than the route ridership response to frequency changes alone and somewhat less than the commuter corridor ridership response to express service introduction. On average, service

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b/ It should be noted that most of the comprehensive service expansions available for study occurred during the 1970's when large transit subsidies were supported, while most of the route specific changes investigated individually occurred under the lower subsidies of the 1960's. Many of the earlier changes might have been "successful" under a policy of greater subsidization and, conversely, many comprehensive changes would not have been feasible under a policy of covering most or all operating costs with fares collected.

elasticities[c/] calculated for response to increases in bus miles operated are in the +0.6 to +0.9 range, although individual results lower than +0.3 or higher than +1.1 are not uncommon. In contrast, changes in frequency alone result in average elasticities of +0.4 to +0.6 (toward the lower end of the scale found for overall expansion) while changes in service accompanying the introduction of express operation result in average elasticities of +0.8 to +1.0 (toward the upper end of the scale). (See the topical digests "Transit Scheduling/Frequency" and "Express Transit" for related information). Within the systemwide service expansions, in addition to new routes and expanded coverage, a portion of the bus mileage increases is attributable to increased frequency and expansion of service hours. The route expansions into previously unserved or poorly served areas have been observed to account for a proportionally higher increase in passengers than the increased frequencies of service (82, 656).

Table 31 lists elasticities for systemwide service expansions in eleven North American cities. Little or no change in transit fare occurred during the analysis periods resulting in the actual decrease of real fares due to inflation. No attempt was made to adjust the data for inflation related effects. On average, the large metropolitan areas exhibit lower service elasticities than do the smaller cities. The average value for urbanized areas under 500,000 population is +0.98 and for areas over 500,000 population is +0.83. This may result in whole or in part from the better initial coverage in historically more transit-oriented large cities, which results in lesser additional patronage attraction as the larger systems expand (322, 384, 656, 675*).

Regression analysis of time series data has been used in several instances to separate out the impact of service expansion from other factors. Service (bus-mile) elasticities calculated for 1972 service expansion in Atlanta and 1973 service expansion in San Diego were +0.3 and +0.7 to +0.8, respectively, after subtracting patronage gains associated with concurrent fare decreases (322). Analysis of 17 bus systems in the United States between 1960 and 1970 resulted in a bus-miles/per capita service elasticity of +0.76, again after correcting for fare changes and inflation (188). An examination of ten bus operations in New York State between 1964 and 1973 produced a range of service elasticities from +0.24 to +1.26, with an average of +0.73 (384). Three separate studies of transit vehicle-mile elasticities in several British cities yielded average values of +0.44, +0.63 and +0.71 (188, 384). Figure 15 summarizes the ridership response to comprehensive transit service changes identified in these studies plus the studies covered in Table 31.

Analagous to the large city/small city dichotomy, suburbs with their traditionally poorer transit service achieve greater ridership response to service increases than

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[c/] The measure "service elasticity" indicates the percentage change in ridership observed or expected in response to a 1 percent change in service, normally described in terms of bus miles operated. An elasticity of 0.80, for example, indicates that a 1 percent service increase has caused or is expected to cause a 0.80 percent gain in ridership. See Appendix A for a discussion of elasticity measures. The elasticities given here are arc elasticities (logarithmic formula) or, in the case of most of the regression analyses, point elasticities.

Table 31
Service Elasticities for Individual Comprehensive System Expansions
(656, 675*)

City	1970 Urbanized Area Population	Years	Increase in Bus Miles	Increase in Ridership	Service Elasticity
Minneapolis, MN*	1,700,000	1971-1975	47.3%	39.6%	+0.87
Seattle, WA	1,240,000	1974-1975	9.6	8.3	+0.87
Miami, FL*	1,220,000	1972-1975	12.5	10.9	+0.88
San Diego, CA	1,200,000	1974-1975	20.1	13.3	+0.68
Portland, OR*	820,000	1971-1975	42.5	36.4	+0.88
Vancouver, BC*	740,000	1971-1975	77.6	56.8	+0.78
Salt Lake City, UT*	480,000	1971-1975	117.8	118.4	+1.00
Madison, WI	210,000	1974-1975	7.6	8.9	+1.16
Bakersfield, CA	180,000	1974-1977	50.8	49.0	+0.97
Raleigh, NC	150,000	1976-1977	28.6	10.9	+0.41
Eugene, OR*	140,000	1972-1975	166.5	271.3	+1.34
Average					+0.89

Notes: (1) Service elasticities are arc elasticities calculated by the Handbook authors from the reported data using the logarithmic formula.

(2) No attempt was made to adjust the data for service restructuring, changes in peak/off peak ratios, senior citizen/student rates, fare zone redistricting, or decrease in real fares due to inflation.

(3) Asterisk denotes period including 1973-74 oil embargo.

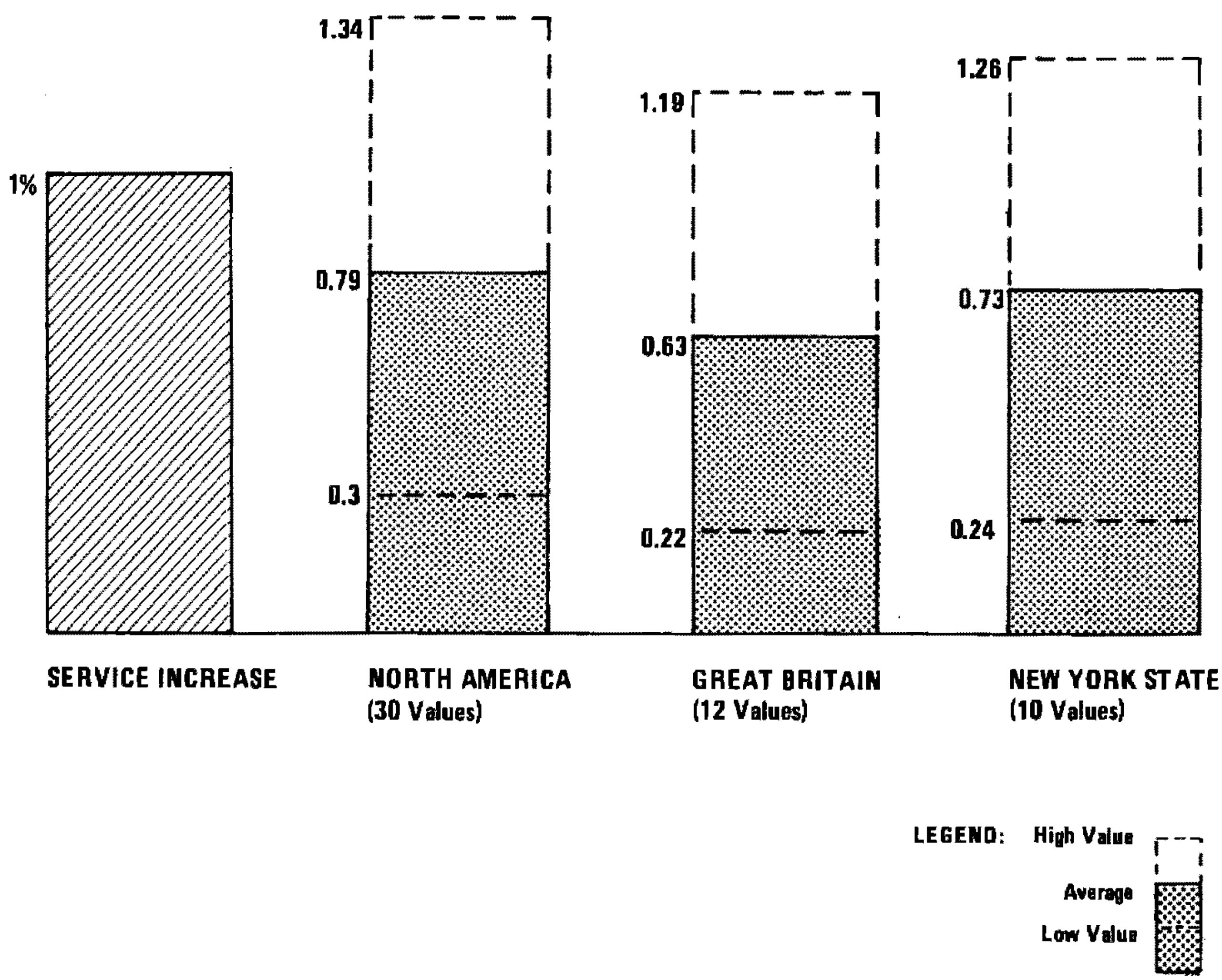

Figure 15
Elasticity Values for Comprehensive Service Changes
(188,322,384,675*)

cities and commuting corridors with their traditionally better service. Calculation of service elasticities by route type in San Diego gave the following results (384):

Radial routes to CBD	+0.65
Central city routes	+0.72
Suburban routes	+1.01

Similiarly, in an examination of 30 British cities, off-peak service increases were found to affect off-peak ridership more than peak service increases affect peak ridership. Off-peak service elasticities averaged +0.76 versus +0.58 for peak period service (384).

Response to New Transit Systems

The following table gives ridership data for the first full year of operation for four areas previously unserved by transit, except for Chapel Hill, NC, where the data is for the second full year (675*):

Location	Year	Service area population	Peak buses	Annual bus miles	Annual riders	Passengers/ bus mile
Orange Co., CA	1975	1,900,000	88	6,560,000	7,953,000	1.08
Chapel Hill, NC	1975	32,000	21	908,000	1,902,000	2.09 1/
Bay City, MI	1975	78,000	8	329,000	255,000	0.78
Greenville, NC	1977	24,000	3	134,000	107,000	0.80

1/ A large student population combined with a student pass program may account for the relatively high utilization in Chapel Hill.

The passengers per bus mile rates obtained are for the most part lower than the national average of 2.06 for urbanized areas of less than 500,000 population. The table below indicates that new system usage as measured by passengers per bus mile continues to grow for several years after service initiation (675*):

Location	1975	1976	1977	1978	1979	1980
Chapel Hill, NC	2.09 1/	n/a	2.25	2.69	2.35	2.40
Bay City, MI	0.78	0.87	n/a	n/a	n/a	n/a
Greenville, NC	--	--	0.80	0.99	1.23	1.41

1/ Second year
n/a = not available

Response to New Coverage

The ability of an individual new or modified bus route to attract patronage is so strongly a function of how the route in question relates to the local development, transportation system, and travel patterns that impacts can be generalized only in qualitative terms. Formal estimation of likely ridership requires recourse to either full scale or shortcut travel demand estimation techniques (82, 92, 112, 126, 251, 546, 557, 567, 577).

Bus service expansion to provide coverage in areas previously unserved normally takes the form of new or extended radial routes, oriented toward downtown.[d/] To the extent that a new route of this type employs the same equipment, operating procedures, fare structure, transfer rules, and service frequency as other radial routes in the same city, the ridership per capita served should ultimately build up to about the same level as that obtained in previously served neighborhoods of similar socioeconomic background and downtown orientation (258). The service area of a conventional bus route is narrow; more than half the ridership on new radial routes in Nashville and St. Louis came from homes within one and three blocks, respectively (522).

Eleven out of 13 all-new, CBD-oriented Mass Transportation Demonstration Project routes penetrating previously unserved suburban areas in greater Boston, St. Louis, Memphis, Nashville, and Providence (excluding routes primarily serving park/ride facilities) were successful enough to be retained, some with service reductions, after the 1960's experimental period (522+, 524). Average weekday patronage at the end of the demonstrations, on the routes retained, ranged from 160 to 560 rides (377#, 691#). Of five new radial routes in the smaller cities of greater Fitchburg, Newburyport, and Pittsfield, MA and New Castle, PA, none were retained, although certain route extensions in New Castle proved viable (377#, 440*).

An examination of 10 late 1970's route extensions in Albany and Rochester found that although household density and service area population were rough indicators of patronage attraction, specific local conditions appeared far more important in determining impacts. One route experienced significant ridership loss despite no change in operations aside from the extension, indicating that exogenous factors can overshadow the impacts associated with increased coverage. Of the five route extensions that were able to cover increased operating costs with revenue generated by new riders, two were extensions to suburban employment sites on the reverse leg of park/ride routes, supporting the contention that reverse commute service is marginally profitable (See "Impacts on Costs/Revenues" in the "Express Transit" topical digest). The three other extensions able to cover costs served residential areas; including one with a large public housing complex and another with a hospital. On one route, headways were widened at the same time coverage was extended, resulting in an overall decrease in vehicle miles operated. Ridership increased on the route, indicating that patronage was more sensitive to coverage than to frequency, at least in this particular instance (82).

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d/ Extended coverage can also be provided with feeder routes or segments of crosstown routes connecting with trunk line bus service. Such coverage requires a transfer to reach CBD destinations and thus is potentially less attractive.

Response to Special Routes

A number of special purpose but otherwise conventional bus routes have been instituted to connect areas of high unemployment, mostly in-city, with suburban job sites. When no other purposes are served, service on such routes is provided only at shift changes, and ridership is typified by the 26 to 166 daily one-way rides recorded on Long Island demonstration project routes after 18 months. When the route is designed to serve multiple user groups, more patronage can be attracted. On Long Island, a multipurpose route carried 256 riders per weekday. In Los Angeles, one multipurpose route had only 160 weekday riders, but the Century Boulevard line through Watts was carrying 3,000 riders per weekday, 1,700 per Saturday, and 700 per Sunday after 22 months (498*). Reverse commute express services from high unemployment urban districts to suburban work sites carried 300 to 400 total daily riders on 6 routes in Washington, DC and on 4 routes in Baltimore (408). (See "Response to Reverse Commute Service" in the "Express Transit" digest for related information).

Of the Federal dollars spent from 1966 through 1969 to foster low income area bus route development, about three-fifths went toward routes that achieved permanent operating status. The multiuser routes were the more successful. Productive functions provided in addition to the low income-area-to-workplace linkage were (145*):

Los Angeles (Watts) Century Boulevard Line	general crosstown and airport service
Long Island multiuser route	service to shoppers and other user groups
Washington, DC Maryland lines	suburbs to CBD commuter service on return trips
Twin Cities	suburbs to CBD commuter service on return trips
Kansas City Sunflower Arsenal Line	general interurban service to Sunflower, KS
Chicago O'Hare Express	rapid transit terminal to airport express service

The low density of inner city to suburban workplace travel inhibits the development of conventional bus routes, and alternate approaches to serving such travel should be explored and evaluated (145*). (Refer to the "Flexible Paratransit" topic in the bibliographic cross-reference lists, and to the "Vanpools/Buspools" digest for references and discussion concerning alternative high occupancy vehicle modes.)

Response to Service Restructuring

Demand elasticities describing ridership response to overall transit service expansion (with some service restructuring) were presented in the discussion "Response to Comprehensive Service Expansion." The impacts of restructuring existing service to more effectively accommodate travel demand, as distinct from the effects of service expansion per se, have not been isolated for large North American cities. A study of the 1968 Washington, DC, all-bus system, involving simulation of alternative routing networks, estimated that an operation restructured to better match the surveyed travel patterns of existing riders would (13):

- Reduce door-to-door travel time for about 25 percent of all riders.
- Lengthen travel time for only 8 to 9 percent of all riders.
- Reduce the number of trips involving transfers by 12 to 17 percent.
- Reduce the number of trips involving two or more transfers by 37 percent.
- Lower operating costs by 1.7 percent.

Some elements of the recommended system were later implemented, but the ridership impact was not studied.

The reported response to restructuring of bus service in small cities ranges from negligible impact to a tripling of patronage in one instance where restructuring was combined with increased coverage and a fare reduction. In New Castle, PA, public reaction was favorable to various routing changes, specifically including the creation of combination radial/crosstown routes or two-way loop routes by joining two or more preexisting radial lines at their downtown terminal or at their outer ends. Revenues did not significantly increase, however, even with other amenities such as new buses (440*). Improved bus routing in Peoria, IL, together with new buses, better seating, and improved fare collection, increased patronage by 53 percent (277). In Iowa City, IA, the total system of three radial routes with 20 minute headways and four radial routes with 30 minute headways was completely redesigned in 1971. The new system provided five through-routed radial route pairs with moderately expanded coverage, new buses, a 15¢ instead of 25¢ fare, and a universal 30 minute headway. In the fifth month, the systemwide headway was changed to 20 minutes in the peak periods to alleviate crowding. Based on prior experience in Iowa City, the fare decrease alone should have produced a 57 percent ridership increase. Actual total patronage for the first 6 months averaged 165 percent over the same period for the prior year, and in the sixth month itself, weekday ridership was 6,000 compared to 2,000 before service improvements (177*, 178, 280).

System restructuring that forces existing transit riders to change their familiar patterns runs the risk, according to conventional wisdom, of driving away patronage. No evidence of such patronage defection was reported, however, except in the case of one very ill-conceived substitution of express for local service (187†). Although it never increased much, ridership held fairly steady in the New Castle demonstration project despite an experimental design that caused transit lines to be rerouted at programmed intervals throughout a 27 month period (440*).

Restructuring of bus service in Delhi, India, to cut down on routes meandering through the city by emphasizing corridor line haul and crosstown ring road service with interchange stations increased paid patronage 25 percent in four months and 40 percent in little over half a year. Bus mileage increased less than 1 percent and the number of buses in use decreased 14 percent. Significant improvement in schedule keeping was also noted (608).

Response to Crosstown Routes

Institution of crosstown routes is an element of service restructuring designed to enhance service to nonradial travel and sometimes to increase coverage as well. Two 1960's Mass Transportation Demonstration Project crosstown routes in Boston attracted substantial numbers of riders. However, all but a fraction were diverted from other transit routes, and the service was not retained (377#). An in-town crosstown route in Nashville attracted new riders to the system and was recovering about one fourth of operating costs by the end of the third quarter. A suburban route in Nashville was a total failure, while an outlying route in St. Louis that connected older, matured suburbs and shopping attracted enough patronage (560 on the average weekday) to be retained by the operator (522+, 691#). The Century Boulevard crosstown line in Los Angeles, discussed earlier under "Response to Special Routes," became very heavily used.

The division of a diametric route[e/] into two radial routes in Chatham, England, to improve schedule reliability resulted in a drop in patronage on the affected route, particularly at stops near the central terminus. To what degree riders switched to other radial routes after transfer-free crosstown travel was eliminated as opposed to supressing travel or changing modes was not examined. Crosstown travelers were further hampered by a de facto fare increase associated with the additional transfer payment required (479).

Underlying Traveler Response Mechanisms

A new or revised bus line may provide a better route where some degree of transit service already existed, or it may provide transit service where there effectively was none before. An improved routing may serve to shorten the walk necessary to reach bus service, or it may reduce the number of transfers (and transfer time) necessary to make a trip, or it may reduce the time spent on the bus. Any of these results will help make transit a more attractive modal alternative. Applied research in the realm of travel mode choice modeling indicates that transit walk time and transfer time may on the average be one-and-one-half to two-and-one-half times more important to the potential rider than an equal time spent in the transit vehicle (520, 561, 604). Obviously, a service retrenchment or poorly designed route change may lengthen walk, wait, or ride times and detract from transit usage.

Bus usage is most prevalent among households with no car, and next most prevalent among one-car households. In that low auto ownership and transit captivity[f/] are predominantly, although not exclusively, associated with lower incomes, lower incomes and greater use of bus service also tend to go together (249, 277, 396, 561). Transit captives have few options other than using transit or forgoing desired travel. These relationships suggest that attention should always be given in planning new service to the location of low auto ownership or low income population groups (277).

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e/ A through-routed radial line passing through the CBD (diametric to the city as a whole) and thus providing radial, crosstown and downtown distribution service.

f/ The concept of transit captivity is discussed in Chapter I.

Expansion of bus service coverage per se is in particular directed at shortening the walk time required to reach transit service, or at bringing service to more people. The shorter the walk is to transit service, the higher the probability that transit will be used. A 1968 survey of the Buffalo metropolitan area showed that among workers residing 1/10 of a mile from a bus, 20 percent used transit, while among those 1/8 of a mile from a bus, 10 percent used transit (277). Similarly in St. Louis the patronage of new radial routes (express routes in this case) came 35 percent from the adjacent blocks, 17 percent from the next tier, 12 percent from the third, and 7 percent from the fourth (691#).

Comprehensive service expansion and restructuring is directed at providing attractive transit service to an increased proportion of total travel requirements. The degree to which urban activities in general can be reached within a reasonable time via public transit has been shown to influence transit usage in somewhat the same way as income does (409, 604), indicating that overall service presence may affect auto ownership decisions and the proclivity to use transit.

Implications of Travel Patterns

For patronage to be attracted to a bus route or system, the operation must first of all connect points between which there is a significant demand for travel. Travel to and from the central business district is the traditional mainstay for transit patronage. Significant factors in the previously cited strong response to restructured and enhanced bus service in Iowa City were undoubtedly the fact that the CBD of that small city attracted over 25 percent of all urbanized area trips, together with the adjacent university campus and hospital complex, and the fact that the central area could be served by all of the redesigned bus routes (177*).

The increasing dispersion of urban activity and related travel in most urbanized areas suggests the need to critically examine existing systems and specifically investigate crosstown and reverse commute bus routes along with extension of existing routes (277). At the same time, finding nonradial or reverse-commute travel corridors of sufficient trip density to support conventional bus service can be difficult (145*). Reverse commute service is most likely to be viable when land use and travel demand patterns allow it to be operated as a complement to normal commute service (82, 408). Insufficient concentration of travel demand presumably contributed to the failure of individual crosstown and reverse-commute experimental bus routes such as the suburban crosstown Mass Transportation Demonstration Project route in Nashville (522+) and individual industrial service routes in Los Angeles, Long Island, and Massachusetts (377#, 498*).

Sources of New Ridership

Ridership attracted to new or revised bus routes comes as the result of changes in trip frequency, destination choice, mode choice, and route choice. New or revised routes have even greater potential for inducing shifts in transit route choice than do frequency changes. Thus a major patronage component may be riders diverted away from other routes, as shown by the following available examples of new ridership sources for specific new bus lines:

Source of New Riders	Radial Routes to Suburbs St. Louis (691#)	Circumferential Route @ 3 Miles Boston (377#)	Circumferential Route @ 5 Miles Boston (377#)
Other Transit Routes	60%	94% 1/	87% 2/
Auto	28 3/	4	13
Walk and Other Means	12	2	4/
New Trips	4/	less than 1%	4/

1/ 81% of this diversion was from other routes on the same streets.

2/ 44% other bus routes and 43% rail rapid transit.

3/ 16% single auto driver and 12% carpool.

4/ Not reported.

In the case of the experimental Boston crosstown lines in particular, many former riders of other transit lines made the switch to the new routes in order to minimize travel time and transfers (377#).

The examples given may exhibit atypically high diversion from other transit due to the particular circumstances involved, but the implication is valid: The impact of new routes should be examined in a system context in order to ascertain the net impact. (For sources of riders newly attracted systemwide by combined service improvements and fare decreases see "Sources of New Ridership" in the topical digest "Transit Fare Changes.")

Impacts of Strikes

Transit strikes serve as an indicator, albeit imperfect because of their temporary nature, of the transportation functions provided by urban transit. The majority of all trips normally made by transit shift to other travel modes, but a very significant proportion are suppressed for the duration of a strike. Such reduction in trip generation undoubtedly reflects the lack of alternative travel modes among transit "captives." Table 32 shows the proportion of transit trips suppressed, and the alternative modes used by those who did travel, for both the 1966 New York City transit strike and the 1974 A.C. Transit strike in the Oakland/East Bay suburbs of San Francisco (482*).

Trip suppression was specifically identified in the 1974 A.C. Transit strike as being most prevalent among the young and elderly. Normally these groups comprised 65 percent of all non-work trips on A.C. Transit buses. During the strike, elderly transit riders, a bare 21 percent of whom either had a car or a drivers license, suppressed 55 to 60 percent of all trips. Approximately half of all trips by the young were suppressed (482*).

Table 32
Transit Strike Impacts on Transit Riders
(482*)

	New York City	A.C. Transit
Population served by suspended service	8,000,000	1,000,000
Daily patronage	5,000,000	200,000
Number of working days during strike	9	45
Percentage of work trips suppressed	15-20%	9-21%
Percentage of non-work trips suppressed	41%	49-59%
Alternate modes used for trips not suppressed		
Auto (driver or passenger)	51%	68%
Chartered bus	11	0
Taxi	12	4
Commuter train/BART train	7	15
Walk	10	8
Hitchhike, bike, etc.	2	5
Stayed all night near work	7	0

The percentage of transit riders turning to driving an auto during a transit strike is apparently significantly less than the percentage of new riders attracted by transit improvements who are prior auto drivers (see "Sources of New Ridership" and "Characteristics of New Riders" within the topical digest "Transit Fare Changes"). This is reasonable, in that newly-attracted transit patrons would tend to be discretionary riders with access to an auto, while the body of captive riders would be among those already using transit. Among bus transit trips normally made to downtown Oakland, only 7 percent were made as auto driver trips during the A.C. Transit strike. Of bus trips normally made transbay to San Francisco, 26 percent shifted to single-occupant automobiles and 60 percent shifted to carpools (482*).

The impact on vehicular volumes of major transit strikes is nevertheless readily evident. During the A.C. Transit strike daily vehicular traffic on the three principal bridges across the San Francisco Bay rose 6 to 16 percent and AM peak congestion on the San Franciso-Oakland Bay Bridge stretched from the normal 30 minutes duration to 120 minutes, despite an increase in the average peak period Bay Bridge auto occupancy from 1.44 to 1.75 persons (482*). During a 1969 transit strike affecting the easterly half of the Northern Virginia suburbs of Washington, D.C., the 6 to 11 AM vehicle count across the impacted Potomac River bridges was up 13 percent while average auto occupancy rose from 1.56 to 1.68. Four miles south into Virginia, however, the vehicle count was up only 2 percent with occupancy up from 1.38 to 1.50 (642+).

Impacts on Traffic Volumes and VMT

Discernable traffic volume changes thought to be associated with modification of bus transit routing and associated improvements have only been observed in one reported instance other than when transit systems are closed due to strikes. Normally the proportion of urban travel using transit service and the impact of service changes are small enough at any one time that auto traffic impacts cannot be seen and isolated from other events. It was in the case of the previously noted Iowa City combined fare reduction, routing changes, schedule regularization and equipment improvements that downtown parking revenues dropped by 11 percent over the prior year in the first 6 months of the new bus system (177*). This impact presumably reflects the increase from 3 percent to 11 percent in the proportion of all downtown-oriented trips using transit.

Table 33 provides estimates of the effect of new and expanded bus service on vehicle miles of travel in ten cities, assuming that from a congestion standpoint a bus is equivalent to two passenger cars. The reduction in equivalent VMT as a result of the improved transit service is minimal, averaging 0.13 percent in large cities and 0.03 percent in smaller cities. The average transit service (bus mile) increases in these same cities were 21 percent and 63 percent, respectively, exclusive of new systems. Three of the smaller cities showed increases in equivalent VMT (675*).

Impacts on Energy and Environment

In considering the energy impact of changes in transit service, it is necessary to consider not only the automotive energy savings of those trips new to transit which are former auto driver trips, but also the effect of the service change on transit energy consumption. This is particularly true with regard to bus service coverge and

Table 33
Impacts of Transit Service Expansion on Traffic Volumes
(675*)

Location	Annual VMT (millions)[1/]	Annual New Bus Miles (thousands)	Annual New Bus Passengers (thousands)	Average Trip Length (miles)	Annual New Bus Passenger Miles (thousands)	Annual Vehicle Miles if by Auto 2/ (thousands)	Annual Equivalent Vehicle Miles Reduced 3/ (thousands)	Equivalent Percent Reduction in VMT
Seattle, WA[4/]	7,153	2,028	2,913	3.5	10,196	8,496	4,440	0.06
Miami, FL[4/]	5,917	1,850	6,064	3.5	21,224	17,867	13,987	0.24
Portland, OR[4/]	4,299	4,878	7,393	2.5	18,483	15,402	5,646	0.13
San Diego, CA[4/]	6,929	2,158	3,933	3.0	11,799	9,833	5,517	0.08
Average for Larger Cities	6,075	2,729	5,076		15,425	12,899	7,397	0.13
Madison, WI[4/]	1,224	246	978	2.5	2,445	2,038	1,546	0.13
Eugene, OR[4/]	628	1,802	2,979	2.0	5,958	4,965	1,361	0.22
Raleigh, NC[4/]	1,156	279	214	2.0	428	357	-201	-0.02
Bakersfield, CA[4/]	709	329	529	2.5	1,323	1,102	444	0.06
Bay City, MI[5/]	367	329	255	1.5	383	319	-339	-0.09
Greenville, NC[5/]	96	134	107	1.5	161	134	-134	-0.14
Average for Smaller Cities	697	520	844		1,783	1,486	446	0.03

1/ Based on 1972 DOT National Transportation Study

2/ Assuming average auto occupancy = 1.2

3/ Assuming one bus-mile = two equivalent passenger-car miles

4/ Percentage increases in bus miles of service and ridership for these service expansions are provided in Table 31

5/ New transit system

frequency changes. Estimated gross and net fuel savings are given below from a study which modeled areawide bus service increases, using San Diego and Chicago as low density and high density urban area examples. Combined service coverage and frequency increases were expressed as a decrease in transit rider walk and wait time. The results for a 15 percent decrease are given here (511*).

15% Walk/Wait Time Decrease for:	Ridership Increase 2/	Savings in Weekday Energy Use 3/ Autos	Transit	Net
San Diego				
Circumferential service	15.1%	1,000	-900	100
Radial service	23.9	1,700	-1,400	300
All bus service	42.6	2,900	-2,200	700
Chicago 1/				
All Bus Service	12.7	16,400	-35,900	-19,000
Suburban Service Only	5.6	7,500	-7,200	300

1/ Assuming no change in rapid or commuter rail service.

2/ As a percentage of total areawide bus transit ridership. In Chicago some rail ridership increase was also estimated by virtue of improved bus feeder service.

3/ Gallons of gasoline or equivalent. Negative sign indicates additional consumption.

The results for the low density transit service city, San Diego, indicate a net energy savings. For improvement of coverage and frequency for all types of bus service the net annual fuel savings estimate is 179,000 gallons per year or less than one tenth of one percent of regional auto fuel consumption.g/ Note the greater ridership and fuel savings impact of a combined radial and circumferential bus service improvement program, as compared to the sum of independent programs, demonstrating the synergistic benefit of a systemwide approach. The results for the high density city, Chicago, indicate a net energy loss for increasing bus service coverage and frequency without the support of complementary actions.

Evaluation of the fuel consumption impacts of a bus service improvement program prior to Metrorail service initiation in the Washington, DC metropolitan area indicated a slightly higher than 50-50 probability that net fuel consumption had been increased. A 16 percent increase in bus miles of service and a 5 percent ridership gain resulted from the combined program of new lines, route modifications and frequency increases. The ridership response equates to a service elasticity of approximately 0.3, less than the norm. Despite the marginal results with respect to energy, the estimated pollutant emissions savings (1975 vehicle characteristics) were 6 tons of carbon

g/ Calculated by Handbook authors assuming annual transit operating and ridership data totals to be the equivalent of 300 and 290 weekdays per year, respectively.

monoxide and 260 kg. of hydrocarbons per day. This was equivalent to 15 percent of the then-applicable transit and carpooling Transportation Control Strategy requirement for CO emissions reduction. Similarly, new transit service in Orange County, California, with about 24,000 weekday riders, was estimated to have almost certainly cost in terms of net energy consumption, while small pollutant emission reductions were realized (148#). The Orange County service included dial-a-ride operation, which on average consumes about four times the energy used per passenger mile by national average conventional bus service (511*, 636).

Fuel savings estimates have also been computed for an actual case of major bus coverage and frequency improvement in San Diego, as well as for a similar program in Atlanta. However, in both instances synergistic benefits were obtained from implementation in conjunction with fare reductions, and the results are thus not directly comparable. The San Diego and Atlanta case studies are discussed under "Impacts on VMT, Energy and Environment" within the "Transit Fare Changes" digest.

The ten areawide transit service expansion programs presented in Table 33 involved some fare reductions, at least in constant dollar terms, but nothing as dramatic as the San Diego and Atlanta cases. The estimated energy impact of these ten programs is outlined below, in terms of averages for the four larger cities (Seattle, Miami, Portland, OR and San Diego) and the six smaller cities (Madison, Eugene, Raleigh, Bakersfield, Bay City and Greenville, NC). The data for San Diego are in the 1974-1975 period, subsequent to the 1972 fare decrease (673).

	Average - 4 Largest Cities	Average - 6 Smaller Cities
Average Population	1,212,000	136,000
Fuel Savings (Gals. Annually)[1/]		
Auto @ 15 mpg	857,000	99,000
Bus @ 5 mpg	-545,800	-104,000
Net Savings	311,200	-5,000
Percentage Urban Tansportation Fuel Savings	0.08%	Negl.

[1/] Negative sign indicates additional consumption.

None of the larger cities above are in the category of having transit service densities comparable, for instance, to Chicago. Up to a point, net energy savings appear most difficult to achieve through coverage and frequency improvements alone where transit service is very dense, and least difficult with suburban service (511*). On the other hand, suburban bus service productivity and service density may be the lowest to start with, such that the contribution to energy savings is not great. In small cities and outer suburbs, savings may be impossible to attain, as shown above for the six smaller cities.

Impacts on Costs

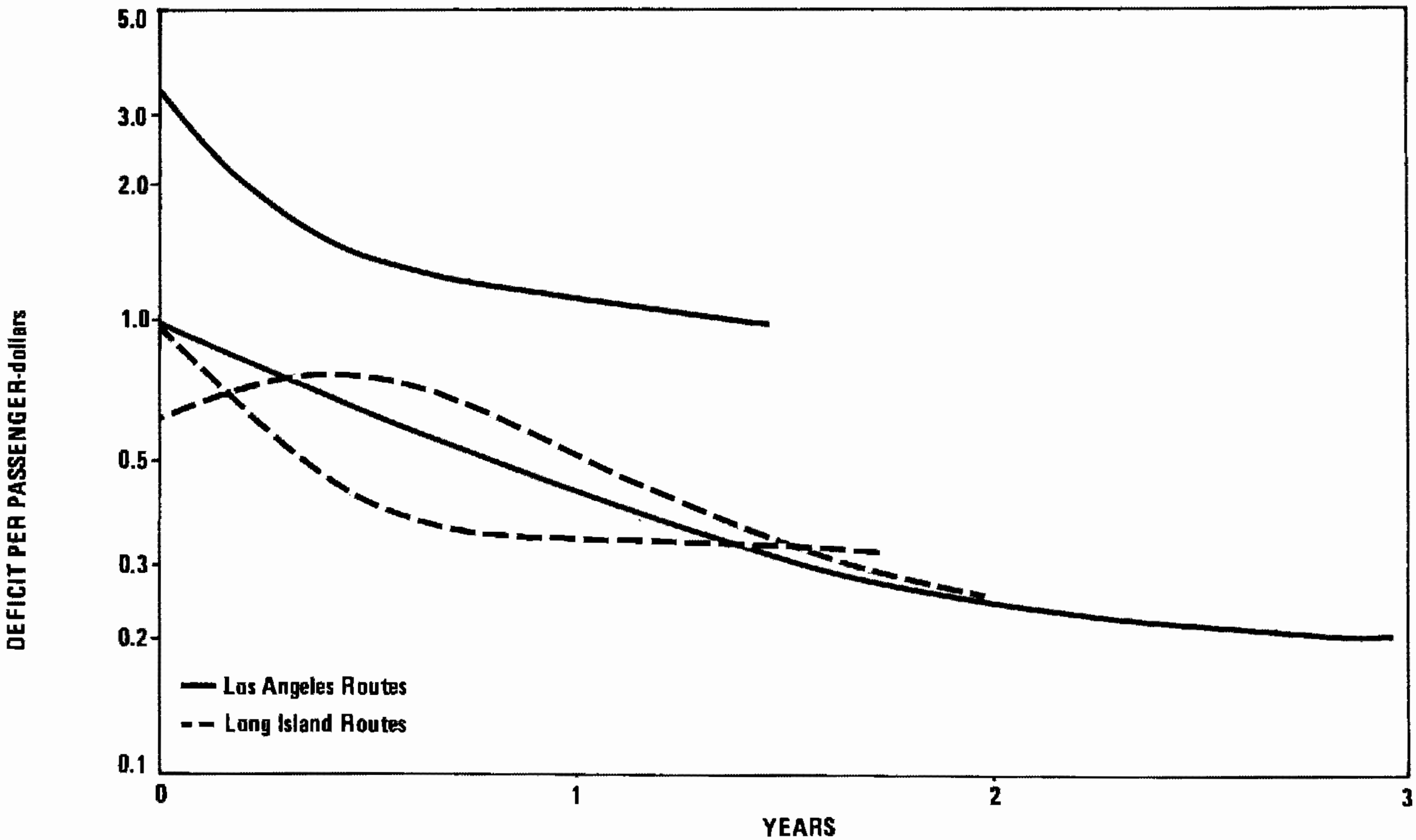
Full development of a new transit route normally takes 1 to 3 years (see "Traveler Response Time Lag," discussed next) so that a major cost element in extending service is sustaining operation while ridership builds up. The 3-year development of the Century Boulevard (Watts) crosstown in Los Angeles, a major route with 122 one-way bus trips a day, cost $750,000 in 1966-69 (145*). Near the other end of the scale, the 1-year development of Lawrence to Boston expressway service cost a net of $38,000 in 1963-64[h/] (377#). Development costs and the causative gradual growth of ridership on new routes suggest an implementation approach which targets the expected development pace, such that if the gap between actual progress and the plan widens beyond an acceptable amount, the project can be aborted (145*).

Virtually no mass transit systems today meet costs with farebox revenues, so that an acceptable financial outcome for new route development will normally be some continuing deficit that local government is willing to support. The feeder character of many crosstown lines suggests that their costs in particular need to be examined in relation to the system and not as independent entities (522+). Restructuring of a bus system may provide attractive service improvements at only the one-time cost, not insignifiant, of developing new schedules, manpower assignments, and public informational aids (13). Success may bring added costs, as in Iowa City, where the subsidy requirement increased when crowding required service expansion (177*). On the other hand, it is encouraging to note that 5 of 10 late 1970's route extensions in Albany and Rochester were profitable as computed on a marginal cost basis (82).

Traveler Response Time Lag

The limited information available on the progress of new route development beyond the first 12 months indicates that ridership growth tends to level out after 1 to 3 years. Expressed in deficit per passenger, Figure 16 illustrates the progress of four low income area routes for which at least 16 months of data were reported (145*). The following list gives the fourth-quarter ridership as a percentage increase over first-quarter ridership for several experimental bus routes (498*, 522+, 691#):

h/ The Eastern Massachusetts Street Railway Company operating cost basis used at that time was $0.50 per bus mile.



NOTE: VERTICAL AXIS IS LOGARITHMIC SCALE.

Figure 16
Route Development Patterns
(145*)

Long Island	
Multipurpose Route A	12%
Industrial Route B	144
Industrial Route C 1/	82
Industrial Route E 1/	144
Industrial Route F 1/	65
Memphis	
Industrial/residential radial	11%
Low-income suburbs radial	26
High-income suburbs radial	61
St. Louis	
7 radial routes to CBD	37%
Suburban crosstown	36

1/ First month excluded.

The continued growth of passengers per bus mile ratios for two new transit systems over periods exceeding three years (see "Response to New Transit Systems") indicates that the traveler response time lag for all-new systems may be even greater than it is for new routes of an established system.

Other Impacts

Benefit-cost studies, made of low income area bus route development, estimate benefits to be in excess of costs for multipurpose routes, and show mixed results for routes designed solely for connection with employment areas. Benefits considered included added income accruing to inner city residents and savings in time and cost to travelers. The split of the total benefit between the two benefit categories and the estimated benefit-cost ratios are listed in the following table (145*):

	Income Benefit Share	Traveler Benefit Share	Benefit/ Cost Ratio
Washington, DC 1/	1/3	2/3	1.7-2.5
Boston	9/10	1/10	0.7
Omaha	9/10	1/10	0.5+
Twin Cities 1/	1/3	2/3	0.6-2.5
Baltimore	4/5	1/5	0.8
Chicago 1/	1/3	2/3	4.0-8.0
Gary	9/10	1/10	1.2

1/ Multipurpose routes.

Surveys on five of these routes, limited in part to reverse-commute riders, showed that 50 percent of those surveyed were newly hired employees and that 64 percent resided in a low income area (145*).

Some of the social benefits of providing overall transit service can be inferred from the impacts of transit strikes, discussed earlier. A major comparative study of transit enhancement options concluded that the attainable benefits of diverting auto drivers to transit can be obtained at lower cost to society by the improvement of transit service levels than by elimination of transit fares (109+). Planning additional service requires choices to be made among the various types of bus routing and coverage options,frequency increases, and express service. The decisions made must include determination of whether it is peak hour, midday, evening, and/or weekend service that is to be modified. Providing a comprehensive package of improvements is apparently beneficial (277); certainly the largest reported percentage gain of new bus riders was in response to the reorganized routes, lower fares, new buses, and new schedule introduced simultaneously in Iowa City (177*).

Additional References

"A Review of Reports Relating to the Effect of Fare and Service Changes in Metropolitan Public Transportation Systems," by Dempster K. Holland (277) and "Increasing Transit Ridership: The Experience in Seven Cities," by the U.S. Department of Transportation, Urban Mass Transportation Administration, Office of Policy and Program Development (653), provide additional literature review and reference material concerning Bus Routing/Coverage. For further information on Bus Routing/ Coverage consult references:

2, 6, 10, 13, 21, 32, 35, 40, 47, 50#, 59, 82, 86, 90, 92, 93, 109+, 112, 120, 145*, 146, 148#, 156, 157, 177*, 178, 183, 185, 209, 229, 232, 234, 243, 244, 255, 259, 274, 275, 277, 280, 288, 319, 321, 325, 327, 339, 368, 377#, 384, 392, 394, 401#, 413, 414, 417, 434, 440*, 473, 479, 482*, 487, 498*, 509, 511*, 512, 522+, 525, 533#, 535, 546, 557, 565, 572, 575, 594, 600, 604, 608, 610, 624, 626, 629#, 631, 635, 636, 642+, 650, 654, 656, 658, 662, 673, 675*, 681, 684, 689, 691#, 692#, 693.

145. Crain, John. The Reverse Commute Experiment - A $7 Million Demonstration Program. Stanford Research Institute, Menlo Park, California; Project No. MSU-7598. Sponsored by the Urban Mass Transportation Administration, U.S. Department of Transportation. December 1970. 28 pages. NTIS PB-199-400. BUS ROUTING/COVERAGE,* TRANSIT SCHEDULING/FREQUENCY, EXPRESS TRANSIT. OBSERVED RESPONSE. TRAVEL CHOICE. ECONOMIC IMPACT.

The Urban Mass Transportation Administration and predecessor agencies initiated in 1966, and continued through 1969, a program of exploratory and service development grants intended to foster provision of missing but needed transit services between areas of high unemployment (mostly inner city) and suburban job sites. This study evaluated 14 such projects in St. Louis, Buffalo, Los Angeles, Long Island, Washington, DC, Baltimore, Boston, Omaha, Cleveland, Minneapolis-St. Paul, Kansas City, Chicago, Detroit, and Gary. Benefit-cost ratios (benefit divided by operating deficit) were developed for projects in 7 of the cities, considering benefits resulting from: (1) added income accruing to inner city residents as a result of connecting the inner city labor force with new job opportunities, and (2) savings in time and cost to travelers other than the workers receiving the added income.

About 59% of the grant expenditures were found to have resulted in, or likely to result in, permanent route development. Success was not measured by reduction of deficit to zero, but rather by deficit reduction to a point where some local agency placed the route into a permanent operating status. Some 36% of expenditures did not or were not likely to lead to permanent routes; for 5% the outcome was uncertain. Some of the failures were ascribed to poor conception, poor administration, or institutional constraints most prevalent among the large, early projects. Although 7% of all work trips made within metropolitan regions in 1960 were reverse-commute trips, it was concluded that the number of developable reverse-commute, conventional routes is limited, primarily because of the automobile-oriented organization of suburban work locations, shift times, and overtime requirements.

Multiuser routes that served not only poverty-area-to-employment travel but also other travel as well were the most successful: the Century Blvd. line through Watts in Los Angeles, which provided general crosstown service; those Long Island routes which also served shoppers and other user groups; the Maryland suburban lines in Washington, DC, which attracted suburbs-to-CBD commutation on the return trips; a similar arrangement in the Twin Cities; the Sunflower Arsenal line in Kansas City, which also provided Sunflower to Kansas City interurban service; and the O'Hare Express in Chicago, which provided general airport access. Some purely reverse commuter routes did succeed when the surburban job site served was large and work shifts were such that a single bus round trip could accomodate all arrivals and departures.

Benefit-cost ratios ranged from 6.0 (Chicago) to 0.5 (Omaha). The preponderance of travel over income benefits found in 3 of the 4 out of 7 projects with ratios greater than 1 was judged to reflect the ability to provide adequate service levels only when many user groups are served. The weighted average results of 7 on-board passenger surveys, restricted in part to reverse-commute riders, indicated that 50% of the riders were new hires, 64% resided in a poverty area, 65% were household heads, and 60% were members of minority groups. Home interviews with newly employed riders in 5 cities revealed that 67% were members of no-car families, and that 26% were poor or near poor, but that only 3% had been formally admitted to a welfare program. The percentage loss of individual riders per month varied between 4% in Baltimore and 11% in Omaha, compared to typical turnover rates for all blue collar employees of about 4% per month.

177. Dueker, K.J. and J. Stoner. "Examination of Improved Transit Service." Highway Research Record. Transportation Research Board, Washington, D.C. No. 419. 1972. Pages 27-36. BUS ROUTING/COVERAGE,* TRANSIT SCHEDULING/FREQUENCY, TRANSIT FARE CHANGES. OBSERVED RESPONSE. VOLUME.

On September 1, 1971, the municipal government of Iowa City assumed the ownership and operation of the city's bus transit system, simultaneously reducing the 25¢ base fare to 15¢ and increasing the number of routes from 7 to 10. The former operator had maintained a relatively constant service level throughout a period of metropolitan and automobile usage growth, while raising fares, and transit use had declined from 4% of all urban area trips in 1964 to 1% in 1970. The city's population grew by 40% between 1960 and 1970, to approach 50,000 residents, including 20,000 University of Iowa students. The central business district and the adjacent university campus and hospital complex attracted over 25% of all urbanized area trips, and thus provided a central activity focus inherently conducive to transit service.

Five of seven former line-haul bus routes contained long 1-way loops used to expand area coverage. Most new areas of the city were not served. Headways were 30 minutes on 4 routes and 20 minutes on the remaining 3. The prior routes were redesigned and through-routed to provided 5 cross-town route pairs. The new routings increased coverage by 20%, providing service within 3 blocks of most residential areas, and reduced average rider times. A 15¢ base fare was selected on the basis of past ridership responses to fare variations instituted in conjunction with public and university transit subsidies between 1967 and 1970. This experience indicated that a 25¢ to 15¢ fare decrease alone should produce a 57% ridership increase. The old 31 and 35 passenger buses, averaging 14 years in age, were replaced with new 45 passenger models. An all-day system-wide service headway of 30 minutes was established initially; however in January 1972, 5 buses were leased to alleviate capacity deficiencies and headways were reduced to 20 minutes in the peak periods. Service was provided between 6:30 AM and 6:30 PM, 6 days per week, as under private management.

Transit patronage rose from 85,540 in September 1971, the first month of operation, to 136,582 in February 1972. Ridership for the 6 months was up 165% over the same period for the prior year. Parking revenues dropped by 11% over the prior year. The additional service added in late January 1972 prompted a 10% increase in ridership by the end of February. In general, daily transit ridership grew from 2,000 trips before the service improvements to 6,000 trips with the new system. Saturday patronage also increased three fold because the lower fare was attractive to youths. The weekday proportion of all downtown oriented trips using transit increased from 3% to 11% with the new system. University scheduling and climatic conditions normally generated variations in monthly ridership ranging from August's 5.68% share of annual ridership to January's 11.22% share; however these variations became less pronounced as the improvements attracted increased patronage from choice riders, shoppers, and youths. The service required subsidy, and the necessary subsidy increased when crowding required service expansion.

A free campus-oriented shuttle transit service was instituted in the spring of 1972 with university sponsorship. The average daily ridership of 7,000 primarily comprised diverted walk trips; however, it was estimated that 500 automobiles were eliminated from the central campus.

440. New Castle Area Transit Authority. Mass Transportation in a Small City. Sponsored by the U.S. Department of Housing and Urban Development; Project No. PA-MTD-6. 1968. 40 pages. NTIS PB 185-218. BUS ROUTING/COVERAGE,* TRANSIT SCHEDULING/FREQUENCY, EXPRESS TRANSIT, POOL/TRANSIT FRINGE PARKING, TRANSIT FARE CHANGES. OBSERVED RESPONSE. TRAVEL CHOICE.

On September 1, 1965, the City of New Castle, Pennsylvania, initiated a 3 year mass transportation demonstration project designed to test the feasibility of using 19-passenger transit buses, rescheduling and rerouting services in response to user demand, and adjusting fares to influence the intensity of demand. The urban area involved covered 40 square miles, had a population of 65,200, a labor force of 23,000 (19,600 working in the immediate area) and an average worker income of $5,500 (1965). Fifteen compact buses were purchased, transit lines were rerouted at programmed intervals throughout a 27 month period on the basis of study findings, a test was made of lowering the transit fare in the off-peak, and commuter parking for bus patrons was provided. In addition to volume counts, on-board and neighborhood surveys were performed to obtain socioeconomic, travel, and opinion data.

Program results gave no evidence that the exclusive use of compact buses on specific routes either increased patronage or proved more attractive than standard buses to the riders. An average of 6.94 passengers per trip rode the 19-passenger vehicles, but 5.7% of the trips were over capacity, while 8.2% carried no passengers at all. A majority of the 7 specific route changes mentioned in the project report involved altering 2 or more preexisting radial routes by joining them either at the downtown terminal or with a segment of new route at their outer ends, forming either combination radial/crosstown routes or 2-way loop routes. These changes did not significantly increase revenues, but did provide through service that the riders found attractive, and in some cases afforded increased effective service frequency, or allowed a decrease in the number of buses necessary to service the route. The other routing experiments described were new routes or extensions. None of these attracted sufficient revenue to cover fully allocated operating expenses, but patronage on 1 extension to a dense suburb covered labor, fuel, and maintenance costs. The typical new route collected 30¢ in fares per average bus trip (1-way) in the first week, and 60¢ by the eleventh week, versus a $1.02 average per trip for the system. Service alterations were well publicized, and apparently the fairly frequent changes did not adversely affect ridership.

The off-peak fare reduction (10 AM-2 PM; February 5, 1968-March 1, 1968) caused a 15% increase in midday ridership but total ridership stayed about the same. Some 23.8% of total riders rode between 10 AM and 2 PM prior to and after completion of the test as compared to 26.8% during the test. The more advantageous distribution of passengers during the test imposed less of a peak load and led to a 26¢ per passenger operating cost as compared to 28¢ pre- and post-experiment.

In the neighborhood surveys, only 19% of those interviewed felt that express buses would be helpful, as no bus ride into the city took longer than 15 minutes. Only 2.7% (104 persons) of the work force of 5 major employers expressed an interest in a personalized "home-to-work" service. Actual experimentation with park and ride lots showed them to be unattractive, a result ascribed to the small city lack of congestion and lack of high parking costs in New Castle. The neighborhood surveys showed bus use (per capita) to be most prevalent in areas with large numbers of housewives, students, or industrial workers. On board surveys indicated the following reasons for traveling via bus; shopping (33.7%), work (43.4%), visiting (4.8%), school (5.3%), and other (12.8%).

482. Peat, Marwick, Mitchell and Company. Assessment of the Impacts of the AC Transit Strike Upon BART. Prepared for the Metropolitan Transportation Commission, Berkeley, California. 1975. 80 pages. NTIS PB 240-414. BUS ROUTING/COVERAGE.* OBSERVED RESPONSE. TRIP GENERATION, ACCESS MODE CHOICE, MODE CHOICE, ROUTE CHOICE.

A 62 day bus strike began July 1, 1974, in the Alameda-Contra Costa Transit District (AC Transit) of the San Francisco Bay area. At the time of the strike, the district had a population of 950,000 in Oakland and the other East Bay suburbs, covered 200 sq. miles of area, and had 200,000 bus trips made each day. Of these, 33% were transbay to San Francisco, 8% tranferred to the Bay Area Rapid Transit (BART), which did not begin transbay service until shortly after the end of the AC Transit strike, and 60% were internal. The majority of the AC Transit district population is beyond easy walking distance to BART, which services the district with 3 rapid rail lines and 18 of the 25 area BART stations. Of the 42,000 daily trips made on the 3 BART lines, 74% exited within the AC Transit district, and 25% of these transferred to local buses along with 5% to transbay buses.

Vehicle and passenger counts on bridges, from AC Transit patronage and revenue forms and at BART stations were analyzed to determine the relationship between BART and AC Transit usage as well as strike impacts on various groups of travelers. Shortly after the strike, in September, a feeder bus survey (430 interviews initiated, 86% completed) and a survey on AC Transit lines running parallel to BART in downtown Oakland (366 interviews initiated, 91% completed) were conducted.

During the strike, BART patronage increased by a net of same 2,600 daily trips (7%), while revenues decreased by 4% due to an 11% decrease in the average mileage fare collected. The lack of feeder bus service and transbay bus service during the strike cost BART some 9,200 daily passengers in lost ridership. Of those who had been feeder bus riders, 51% used an alternate access mode to BART, (37% auto driver or passenger, 51% walk, 12% other means), 14% used an alternate mode (84% auto) for the entire trip, and 35% suppressed (did not take) the trip. The net gain in overall BART ridership during the strike suggested that 10% of the 120,000 daily non-feeder, non-transbay bus riders had been diverted to BART. Of those trips normally made on bus routes roughly parelleling BART to downtown Oakland, 35% were suppressed. For those trips still taken, the modes used were BART (41%), auto passenger (33%), auto driver (11%), walk (7%), hitchhike (4%) and taxi (4%). The average trip cost for those who continued to travel rose from 40¢ to 85¢. Transbay bus riders had a 14% trip suppression rate, 26% drove automobiles by themselves, and 60% carpooled. Westbound vehicular traffic across the San Francisco-Oakland Bay Bridge increased 6.4% overall and 12.3% in the 3 hour AM peak period. AM peak auto occupancy rose from 1.44 to 1.75 and the period of AM congestion was extended from 30 minutes (non-strike) to 120 minutes (strike). Some traffic was diverted to the San Mateo-Hayward and Richmond-San Rafael Bridges, which showed 15.5% and 6.5% 24-hour traffic increases.

Some 46% to 59% of all non-work trips normally made on AC Transit buses were suppressed during the strike as were 9% to 21% of work trips. The elderly suppressed 55%-60% of all trips. The parallel bus route survey identified only 21% of the elderly as either owning a car or having a license to drive. There was a 50% trip suppression rate among the young as evidenced in the feeder route survey, and 20% of the youth attending summer school in Oakland reported extreme travel difficulties or could not attend at all. Normally the young and the elderly comprised 65% of all nonwork bus trips.

498. Pignataro, L. J., J. C. Falcocchio, and R. P. Roess. "Selected Bus Demonstration Projects." Transportation Engineering Journal. American Society of Civil Engineers, New York, New York. Volume 96, No. TE3, Procedure Paper 7454. August 1970. Pages 251-268. BUS ROUTING/COVERAGE,* EXPRESS TRANSIT, TRANSIT SCHEDULING/FREQUENCY, VAN-POOLS/BUSPOOLS. OBSERVED RESPONSE. TRAVEL CHOICE. SOCIOECONOMIC IMPACT.

Several of the mass transportation demonstration projects initiated pursuant to the Housing Act of 1961 were designed to explore the socioeconomic and financial implications of providing improved transit services in urban poverty areas. This paper reviews and compares 2 such projects, 1 on Long Island and the other in Los Angeles. (This paper also reviews express bus demonstrations not covered here.)

The Long Island demonstration involved initiation of 14 project routes, providing direct connections between low density residential poverty areas and concentrated industrial park employment areas in Nassau and Suffolk Counties. Of the 5 routes in operation long enough to yield usable results (June 1967-December 1968), 4 were rush hour only services geared entirely to serving journey-to-work travel and offering 3 to 7 one-way runs a day. The other was an all day operation, serving shopping and other activities in addition to employment with 17 runs a day. Fares commonly ranged between 25¢ and 50¢. Average daily ridership of each of the 4 rush hour only routes ranged from 26 to 166 one-way rides by the last month of the 18 month project. Comparable ridership was 256 a day for the all day route. An on-board ridership survey was conducted in May 1968. Working riders were asked if the bus service had provided "the means for me to get this job," and 71.7% answered affirmatively. The rush hour only services had virtually 100% work purpose ridership, while the all day route had 60% work trips, 28% shopping trips, and 12% other.

The Los Angeles area project involved several new bus routes in the South Central and East Los Angeles poverty areas. The primary route was a new crosstown line running from Los Angeles International Airport down Century Boulevard through the Watts area and out to Lynwood, an area of high job availability. Implemented on July 5, 1966, the route was operated throughout the day, 7 days a week, making 122 one-way bus trips a day. The fare was 25¢ plus 8¢ a zone. By May 1968, the route carried 3,000 riders per weekday, 1,700 per Saturday, and 700 per Sunday. About 50% of the riders were poverty area residents, and of these, 72% rode for work purposes, and another 6.6% used the line for seeking employment. A second route was opened in November 1967, running from the East Los Angeles area to the City of Commerce industrial region. Headways were 30 minutes, fares were 25¢, and 48 one-way runs were made each day. Ridership was only 160 passengers a day as late as December 1968. Of these, 67% used the bus for work and 16% for shopping. Three "community home-to-work" buspool type services were operated from the Watts area, providing transportation at a cost to the rider of $2.50 per week. Monthly ridership reached 4,735 in August 1968, with 12 buses in operation, before decreasing to 2,901 riders in the month of December 1968, after service cuts and large layoffs of unskilled workers.

The results indicated that special poverty area bus services cannot be expected to cover fully allocated costs, but that the routes tested did serve a vital community function. The major problem identified was the difficulty of serving dispersed industrial worker travel demand with fixed routes, and even buspools. The best used routes were those serving multiple types of activities, not just work purpose travel. The Tri-State Transportation Commission estimated that 4-5 passengers per trip could cover the marginal costs of midday operation (1968), while the improbable number of 90 riders per trip would be required to meet full costs of peak hour only operation, arguing for inclusion of off-peak services in route design.

511. Pratt, R.H. and P.S. Shapiro. The Potential For Transit As An Energy Saving Option. R.H. Pratt Associates, Inc. Prepared for Office of Energy Conservation and Environment, Federal Energy Administration; Contract No. C-04-50077-00. March 1976. 78 pages plus appendices. NTIS PB 263-087. BUS ROUTING/COVERAGE*, AUTO FACILITY PRICING, TRANSIT SCHEDULING/FREQUENCY, TRANSIT FARE CHANGES. FORECAST RESPONSE. MODE CHOICE, VOLUME. ENERGY.

Four representative cities (Albuquerque, San Diego, Baltimore, and Chicago) were selected for estimating the energy savings potential of adopting transit mode shift strategies in urbanized areas nationwide. The types of strategies considered were: 1) decreasing transit excess (walk and wait) times, 2) decreasing transit running times, 3) decreasing transit fares and 4) increasing auto use costs. Twenty-four actions were tested individually in the San Diego and Chicago contexts. From this group of actions, four combined scenarios were developed and tested in each representative city. The results were then expanded to provide a nationwide energy impact estimate.

The effects of the various actions on mode split were investigated using a set of equations describing low, medium and high sensitivity of transit ridership to system changes. For computing VMT reductions, prior travel mode for new transit users was based on empirical data. Transit energy use changes were estimated taking into account requirements for increased frequency based on base case and test case maximum load point volume distributions. Energy requirements for auto access to transit were not addressed, leading to possible overstatement of fuel savings. On the other hand, fuel savings that would result from increased ridesharing in response to auto disincentives were not included. Fuel consumption characteristics assumed were as of 1975.

The analyses of individual actions showed that there is a point beyond which negative energy savings will be incurred in providing a greater quantity of transit service (frequency and coverage) as an isolated strategy, with Chicago being at this point under present conditions. Combination of complementary transit enhancement and auto disincentive strategies into packages (scenarios) expands the range of energy conservation feasibility. The actions comprising the scenarios tested and the medium estimate results are summarized in the tables below. The effectiveness of these scenarios increased with greater density and transit availability. Scenario I, containing moderate transit improvements and auto disincentives, would result in estimated net annual fuel savings of 0.4%-0.8%. By further improving transit service and increasing parking cost in the CBD Scenario II obtains fuel savings of 0.8-1.6%. Scenario III maintains the sit improvements of Scenario II but significantly increases the auto disincentives, resulting in fue ings of 2.3%-4.0%. Scenario IV has no transit incentives but maintains the significant auto disin ives of Scenario III, resulting in fuel savings of 1.5%-2.4%.

Scenario	Transit Fare Decrease	Transit Run Time Decrease	Gasoline Cost Increase	P ng t Increase	Transit Excess Time Decrease	Bus Wait Time Decrease
I	10¢	5%	25%	—	5%	varies
II	20	10	25	CBD $1.00	15	according
III	20	10	100	CBD $2.00 ($0.70)	15	to
				CC $1.00 ($1.00)		passenger
IV	—	—	100	CBD $2.00 ($0.70)	—	loading
				CC $1.00 ($1.00)		requirements

(Figures in parentheses refer to increases applied to Albuquerque and San Diego.)

Scenario	Percent Reduction in Weekday VMT/Net Fuel								Percent Annual Nationwide Reduction	
	Albuquerque		San Diego		Baltimore		Chicago			
	VMT	Fuel	VMT	Fuel	VMT	Fuel	VMT	Fuel	VMT	Fuel
I	0.14	0.11	0.48	0.27	2.37	1.35	3.05	0.92	1.40	0.61
II	0.39	0.27	1.19	0.50	4.55	2.58	6.79	2.02	2.94	1.20
III	0.73	0.60	2.96	1.24	9.95	6.25	13.03	5.31	6.12	3.03
IV	0.16	0.16	0.94	0.40	5.02	3.34	9.53	4.53	3.53	1.89

Note that the fuel savings estimates are expressed as percent net reduction in urbanized area passenger transportation energy use. The transit vehicle fleet expansion required for Scenario I alone would be roughly 45%, equivalent to the bus fleet expansion accomplished during the course of World War II. Additional transit annual operating costs would be major, e.g., $5 million for San Diego in Scenario I and $63 million for Baltimore in Scenario III (medium estimates).

675. Wagner, Frederick A. and Keith Gilbert. Transportation System Management: An Assessment of Impacts. Alan M. Voorhees, Inc., McLean, Virginia. Prepared for Urban Mass Transportation Administration, Office of Policy and Program Development. Interim Report. Contract Number UMTA VA-06-0047. November, 1978. 195 pages. NTIS PB 294-986. BUS ROUTING/ COVERAGE, VARIABLE WORK HOURS, POOL/TRANSIT FRINGE PARKING, CARPOOLING ENCOURAGEMENT ACTIVITIES, AREA AUTO RESTRAINTS, TRANSIT SCHEDULING/ FREQUENCY, EXPRESS TRANSIT. OBSERVED RESPONSE. TRAVEL CHOICE, VOLUME.

This review covers the "Impact of Transit Route and Scheduling Improvements" chapter which examined the short-term results of comprehensive transit route and schedule improvements in 8 cities and the effects of the introduction of transit service into 4 cities previously unserved. Measures of transit system effectiveness in terms of service, ridership and productivity, and revenue and expense were presented for each system. Significant comprehensive service increases, in terms of bus-miles, occurred over 1-3 years and included the extension and addition of routes, route restructuring and increases in frequency and hours of service. In all 8 comprehensive improvement cases, the systems were mature with stable operation and made minor, if any, fare changes during the analysis period. The effects of inflation (declining fares in constant dollars), along with fare zone redistricting, multi-ride passes, special student or seniors fares and other exogenous factors were not segregated out in the analysis. The 4 new systems ranged from 3 peak buses and 134,000 annual bus miles serving a 24,000 population to 88 peak buses and 6,561,000 bus miles serving a 1,864,000 population.

The table below gives base year characteristics on an annual basis and subsequent changes for the 8 systems that underwent comprehensive improvements.

	Peak Buses	Bus-Miles (000)	Riders (000)	Pass./Mile (before/after)	% Change Peak Buses	% Change Bus-Miles	% Change Riders
Seattle	496	21,121	35,096	1.66/1.63	0.0%	+9.6%	+8.3%
Miami	298	14,794	55,631	3.76/3.71	+41.9	+12.5	+10.9
Portland	249	11,478	20,310	1.77/1.67	+54.2	+42.5	+36.4
San Diego	185	10,736	29,575	2.75/2.64	+35.7	+20.1	+13.3
Madison	104	3,234	10,992	3.40/3.44	+13.5	+7.6	+8.9
Eugene	35	1,082	1,098	1.01/1.41	+31.4	+166.5	+271.3
Raleigh	21	976	1,964	2.01/1.45	+66.7	+28.6	+10.9
Bakersfield	14	648	1,079	1.66/1.51	+50.0	+50.8	+49.0

Characteristics of the 4 new systems are contained in the preceding digest under the heading "Response to New Transit Systems." Three of the systems exhibited passengers/mile ratios of 0.8 to 1.1 after 1 year of operation, while the fourth recorded a ratio of 2.1 after 2 years. The authors concluded that unless new systems serving local travel achieve passengers/mile ratios of at least 0.6 to 0.8, pressure to revise routing or convert to a demand responsive mode will result.

Bakersfield, CA was highlighted as a case example of a comprehensive service improvement. Fourteen new buses were placed in service. Seven were used to expand service and seven replaced existing old, but well maintained and attractive buses. Service frequency was not increased, but greater route choice in some areas effectively increased frequency. Major route restructuring took place with new routes providing two-way service in areas previously served by one-way loops. Outlying shopping areas were made a focus of several routes, improving service to these points. Some routes were extended to areas previously unserved. New system maps and schedules were prepared and multi-ride fares instituted. Over the course of the first 6 months, the service elasticity was +0.78. By the end of the third year, it was +0.97.

Greenville, NC was highlighted as a case example of a new transit system. Three routes, two of which were large loops were initiated. One bus was assigned to each route, making one round trip each hour. All routes served the downtown, the principal outlying shopping center and the social service facility. Little transfering was required, although the loop routing required some trips to be indirect. Fares were 25¢, transfers were free and a reduced seniors fare was available. Schedules and maps were prepared and limited marketing was undertaken. In addition to weekday service, Saturday service was added in the fourth month. Aside from the first month when some promotional free trips were given, passengers/mile averaged 0.7 over the first 7 months. Over the next 4 months, passengers/mile averaged 0.9. (See the digest for more recent data for this system).

EXPRESS TRANSIT

Types of Express Transit

The provision of express transit service is an element of the overall transportation system management category "Actions to Improve Transit." Express transit services include:

1. Express buses operating on separate roadways reserved for bus or shared bus and carpool use, either within exclusive right-of-way or within the right-of-way of an adjacent freeway (140#, 397*).

2. Express buses using priority freeway lanes reserved for bus or bus and carpool use, including both with-flow and contra-flow schemes (68, 461#, 563#, 686).

3. Express buses operating in mixed flow traffic on freeways including express systems aided by exclusive bus ramps or bypass lanes for buses on congested ramps (101, 162, 292*, 401*, 403, 684, 708).

4. Express buses using priority arterial street lanes reserved for bus or bus and carpool traffic, including both with-flow and contra-flow lanes (101, 187+, 373, 406, 533*, 687#).

5. Express buses operating in mixed traffic on arterial streets (116, 408, 691*).

6. Express rail service, including skip-stop service and zoned express service (making stops at a series of outlying stations then operating via express mode to selected destinations).

Table 34 presents examples of express bus systems operated with and without priority facilities. The impacts of express service are influenced by operational characteristics of the service and also by complementary transportation facilities and services. Among these factors are:

1. The number and spacing of stops made during the express portion of the trip. The express portion can be without stops or can include one or more intermediate stops at major residential, employment and transfer locations.

2. The inclusion or exclusion of collector/distributor operation as part of the express route at one or both ends of the line.

3. The provision of feeder bus services to provide access for transit riders beyond walking distance of the express route.

4. The provision of fringe parking lots providing easy auto access to express service.

5. The improvement of transit service coverage or frequency in connection with new or expanded express routes.

Table 34
Selected Examples of Express Bus Applications

Express Buses On Separate Roadways	Washington - Shirley Highway Los Angeles - San Bernadino Freeway Pittsburgh - South PATway
Express Buses On Freeway Priority Lanes	Portland - Banfield Freeway Los Angeles - Santa Monica Freeway Miami - I-95
Express Buses In Mixed Traffic On Freeways	Seattle - I-5* Minneapolis - I-35W* Hartford - I-84 Milwaukee - I-94 Baltimore - I-83 Dallas - North Central Expressway Richmond - I-64
Express Buses On Arterial Priority Lanes	Miami - South Dixie Highway Miami - NW 7th Avenue Honolulu - Kalanianaole Highway Louisville - Third Street Ottawa - Ottawa River Parkway Washington - South Capitol Street
Express Buses In Mixed Traffic On Arterials	Cincinnati St. Louis Washington Calgary

* Aided by bus ramps and bus bypass lanes.

6. Institution of premium fares for express service and establishment of transfer policies affecting interchange with local buses.

7. The directionality of express service relative to peak commuter flow; service in the non-peak direction being implemented to facilitate transportation of low income area workers to suburban employment centers.

For impacts of actions often associated with express transit service, see the topic areas: "Pool/Bus Priority Facilities", "Transit Scheduling/Frequency", "Bus Routing/ Coverage", "Pool/Transit Fringe Parking" and "Collection/Distribution Transit."

Traveler Response Summary

Express buses operating on separate roadways in congested corridors carry 18,000 and 21,000 daily passengers in Los Angeles and Pittsburgh. In Washington, DC the Shirley Highway facility has carried 21,600 inbound passengers in the AM peak period. Pittsburgh bus ridership rose 17 percent in the corridor. In Washington and Los Angeles, service corridor bus ridership doubled and tripled while the work trip market share of transit rose from 27 and 12 percent to 41 and 24 percent, respectively. In-vehicle travel time savings for the three busways were 10 to 30 minutes.

Express buses using priority lanes on freeways have saved up to 5 minutes travel time and carry daily passenger volumes ranging from less than 1,000 to almost 4,000. These data exclude the New York City metropolis, where 75,000 daily passengers are carried on one set of contra-flow lanes alone. Increases of up to 200 percent in facility transit ridership have been obtained. Restructured transit service utilizing express buses in mixed freeway traffic aided by bus ramps or bypass lanes has produced corridor screenline peak period mode choice percentages of 19 and 12 percent transit in two major applications, carrying 11,000 daily riders in Seattle and 7,000 in Minneapolis. The daily corridor-wide ridership increases were 11 and 12 percent. Smaller scale express bus systems on freeways carry 200 to 600 AM peak period passengers, typically producing benefits such as stabilization of previously declining ridership, improved transit service and moderate attraction of former auto users.

Express buses on surface street priority lanes have carried 600 to 2100 daily riders while frequently affording users travel time savings over both local bus service and auto travel. Corridor transit use rose from 2 and 3 percent to 9 percent in two instances measured. Surface street express buses operating without priority have carried 300 to 3000 daily corridor riders. Reverse commute express bus services bringing urban residents to suburban employment centers have provided significant time savings and reliability improvements, and, when operated in concert with regular express service, can operate economically based on incremental cost allocation.

Under average appropriate conditions, increase of bus service through institution of express service and associated frequency and coverage improvements increases ridership one to two-thirds as much again as would be expected for frequency and coverage improvements alone. Express bus patronage increases are most pronounced in separate roadway applications. Other priority facilities do not appear to significantly influence the amount of ridership gain. Apparently it is the express service itself along with frequency and coverage improvements that is of primary importance to the user. Express services involving freeway travel, priority facilities and park/ride lots are successful at attracting proportionately more former auto users than express services not containing these elements. The peak period, peak direction nature of express service combined with long travel distances and low seat turnover cause express buses to operate at higher cost/revenue ratios than conventional local buses, but counterbalancing system effects may exist. Some systems charge a premium fare for express service, apparently without detriment to patronage.

Response to Priority Roadway Service

Express buses operating along congested corridors on exclusive right-of-way reserved for buses or buses and carpools have reduced in-vehicle travel time by 10 to 20 minutes in Los Angeles and Washington area corridors, providing 15 to 35 percent reductions of in-vehicle bus travel time. Pittsburgh's 4 mile long "South PATway" busway and tunnel has provided 15 to 30 minute savings over prior bus travel times. On an average weekday in Pittsburgh, 650 PATway bus trips carried 21,300 passengers in May, 1980. Light rail vehicles, which share the tunnel and other portions of the PATway with buses, carried an additional 21,600 passengers on 600 trips. During the initial 2½ years of operation, bus patronage has risen 17 percent and ridership per bus trip has increased 7.2 percent. The impacts of the increased express service on light rail ridership and auto traffic were not specified.[a]

Prior to the opening of the 11-mile San Bernadino busway near Los Angeles in December 1973, local buses in the freeway corridor carried 3800 passengers and express buses carried an additional 1200 passengers during the 6-9 AM and 3-6 PM combined peak period. Nine months after the busway opened (and 2½ months after express service was increased threefold and a park/ride terminal provided), express bus patronage had increased 150 percent to 3000 peak period trips while local bus patronage decreased 5 percent to 3600 peak period trips. Express service and patronage continued to expand, reaching a plateau in 1975. The transit market share among commuters in the eastern sector of the service area reached 24 percent in three years compared to 12 percent before project inception. Peak ridership has remained at about 11,000 in the 1975 to 1978 period despite fluctuations occasioned by three major fare increases, a transit strike and the introduction of carpools to the roadway. A mere 250 to 300 bus riders switched to carpooling after carpools were permitted on the busway. Daily express bus ridership in April 1978 was 18,000 passenger trips (139, 140#).

In March 1979, 540 inbound express buses on the 11-mile Shirley Highway busway near Washington, DC carried 21,600 passengers during the 6:00-9:30 AM time period, up from 450 buses and 18,000 passengers in 1977 (538, 673). This is approximately the same volume of riders that the express bus systems on the South PATway and the San Bernadino Freeway carry in both directions throughout the day. When the first section of the busway opened in 1969, 98 inbound AM peak period (6:30-9:00 AM) bus trips carried 4200 passengers. By the end of 1974, the number of express bus trips had increased to 357 and the volume of inbound passengers to 16,100; increases of 265 percent and 280 percent respectively. Bus patronage on parallel arterials decreased by only 1400 trips, indicating that most of the ridership growth was not due to diversion from alternative bus routes.

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[a] Information obtained from Port Authority of Allegheny County.

An estimated 700 to 800 former Shirley Highway express bus users chose the carpool mode after carpools gained access to the exclusive lanes. Nevertheless, net bus ridership and market share continued to increase throughout project development. AM peak period inbound bus ridership across the entire study corridor screenline (4 miles across) rose from 14,800 in 1970 to 24,900 in 1974 after carpool introduction, a 68 percent increase. Among work trips in the corridor that could reasonably use the inner-suburban bus service, the proportion made by bus rose from 27 percent to 41 percent during the same time period (397*).

Response to Priority Lane Service on Freeways

Newly established or expanded express bus systems operating on exclusive bus or bus and carpool freeway lanes have saved users up to 5 line haul minutes over mixed traffic vehicles and have carried up to 3800 daily passengers between suburban residential areas and urban employment locations. Listed below are operating and patronage data for three such systems; the Banfield Flyer on Portland's Banfield Freeway, the Orange Streaker on Miami's I-95 and express service on Los Angeles' Santa Monica Freeway. All three projects have utilized with-flow lanes with carpool use of the lanes permitted. Although use of exclusive lanes on the Santa Monica freeway has since been terminated, much of the expanded express bus operation was retained (68, 461*, 686).

	Length of Priority Lane	Daily Bus Trips	Daily Ridership	Patronage Increase
Banfield Fwy. Portland, OR	3.3 miles	20	650 1/	43% 2/
Santa Monica Fwy. Los Angeles, CA	13 miles	135 3/ 75 4/	3,800 3/ 2,300 4/	224% --
I-95 Miami, FL	7.5 miles	53	1,700	187% 5/

1/ A more recent estimate of daily ridership is 960, based on 33 bus trips (675).

2/ Increase over that expected without priority lanes and new express service.

3/ All routes.

4/ New routes only.

5/ Derived by Handbook authors from corridor modal split data, assuming constant total trips.

Although it is difficult to separate out the impacts attributable to express bus service from those attributable to priority lanes or increased frequency and coverage, results suggest that the express service itself and increased frequency and coverage have greater relative impact on ridership than does use of priority lanes. In Los Angeles, on the one pre-existing route that remained substantially unaltered, ridership increased 6 percent at the start of the priority lanes project and decreased 8 percent when the exclusive lanes were terminated. In contrast, taken together, all routes that continued to operate after the freeway returned to mixed-mode operation gained an initial ridership increase of 155 percent and suffered a final decrease of only 17 percent. An overall service reduction of 8 percent accompanied the lane termination. Similarly, in Boston, where a with-flow priority lane was implemented without changes in bus service, patronage increased by only 5 percent. In Miami, daily patronage on express buses in mixed traffic on I-95 reached 1100 in seven months of operation. The advent of priority lanes and minor service increases resulted in the 1700 figure, a 50 percent increase (68, 563#, 686).

Four of the five new express routes in Los Angeles that included a residential passenger collection element in the route continued to operate successfully during and after operation of the priority lane. All three new routes that operated primarily between suburban park/ride lots and the downtown were terminated during or after the project due to inadequate patronage caused by poor park/ride lot location. In contrast, a large park/ride lot was instrumental in the success of the express service in Miami. Routes serving downtown areas were judged more successful than routes serving outlying employment locations. The two separate Banfield Flyer routes also operated successfully from park/ride lots (68, 461#, 563#). Further information on park/ride lot usage is contained in the "Pool/Transit Fringe Parking" topical area.

In contrast to express service on with-flow freeway lanes, the major contra-flow bus lane applications have involved largely pre-existing express bus operations, and are thus not addressed here. The outstanding example is the I-495 facility on the New Jersey approach to New York City, which carries 75,000 bus passengers daily (675). Information on this type of facility is provided in the "Pool/Bus Priority Facilities" digest under the heading "Response to Contra-Flow Freeway Priority Lanes".

Response to Predominantly Mixed Traffic Service on Freeways

Express bus systems operating in mixed traffic on freeways, aided by exclusive ramps and offering frequent service and extensive coverage, have served to carry over 3,000 passengers in a single peak period. Patronage levels during peak periods exceed those carried by express buses operating on priority freeway lanes in several cities and compare favorably with bus systems using separate roadways. The table below compares peak period ridership on express buses in mixed traffic on Seattle's I-5 (The "Blue Streak" express) and Minneapolis' I-35W with ridership on express buses on the San Bernadino busway (140#, 401*, 684).

	Bus volume	Patronage	Year
Seattle - I-5[1/]	--	6,400	1971
Minneapolis - I-35W[2/]	225	6,100	1974
San Bernadino Busway [2/]	300	10,000	1978

1/ 4 hour combined AM-PM peak period; bi-directional

2/ 5½ hour combined AM-PM peak period; peak direction only

Daily patronage impacts on express and local buses in the affected corridors are given below for Seattle and Minneapolis (401*, 684):

		Before Ridership	After Ridership	Change in Ridership	Change in Bus Trips
Seattle -	Blue Streak routes	17,269[1/]	10,790[2/] 10,203[3/]	+21.6%	--
	Other routes	10,010	9,192	-8.2	--
	All routes	27,279	30,185	+10.7	+12.4%
Minneapolis -	Express buses	2,164	7,047	+225.6	+235.8
	Local buses	22,264	20,431	-8.2	-6.8
	All buses	24,428	27,478	+12.5	+31.8

1/ Future Blue Streak routes.

2/ Express buses.

3/ Local buses remaining on parallel arterials.

In Seattle, the effect was greatest on bus travel to the CBD. The provision of express service increased CBD patronage in the corridor by more than one-third, from 7,500 to over 10,000 passengers per day.

Improved express service had a measurable effect on modal split in both the I-5 and I-35W corridors, as illustrated in the table below for the AM peak period at mid-way screenlines. I-35W corridor transit usage to the Minneapolis CBD increased from a modal split of 33 percent to 37 percent. Increased transit mode share underscores the attractiveness of express bus service vis-a-vis auto travel (401*, 684).

Mode Shares of Total Corridor Travel at Screenline

Travel Mode	Seattle I-5		Minneapolis I-35W	
	Before	After	Before	After
Auto driver	70%	67%	64%	63%
Auto passenger	20	21	19	18
Transit	10	12	17	19

Several exogenous factors in both Seattle and Minneapolis influenced the impact of the express bus systems. Both cities provided exclusive bus ramps or ramp bypass lanes on the freeways so that express buses not only saved up to 15 to 20 minutes over local buses but also saved up to 5 minutes over freeway auto traffic on the line haul segment of the trip. The provision of improved express service was accompanied by coverage of new areas with transit service and increases in frequency in other locations. These actions no doubt attracted riders irrespective of the type of service. The patronage gains in Seattle occurred despite a severe local economic recession which caused total areawide travel to decrease 3.8 percent and areawide transit travel to decline 10 percent. The project in Minneapolis included the metering of I-35W, which improved travel conditions on the freeway for both buses and autos, matching or bettering conditions two years previous when traffic was less. Metering reduced AM peak hour inbound freeway travel times by 26 percent, from 29.4 to 21.9 minutes, and reduced travel time variance by 84 percent (401*, 684).

Smaller scale express bus systems operating on freeways have had a negligible impact on corridor-wide travel, but have attained successful patronage levels and diverted a significant proportion of their ridership from auto use. AM peak period inbound ridership and modal shift data for several small express system bus lines in cities of various sizes are presented below (101, 292*, 403, 708).

Location	Inbound AM Peak Bus trips	Inbound AM Peak Patronage	Former Auto Users	Year
Hartford, CT	12	300	76% 1/	1972
Milwaukee, WI	4	180	38 2/	1975
Baltimore, MD	7	200	44 1/	1967
Dallas, TX	22	600	--	early 1970's
Dallas, TX	27	405	50	early 1970's
Richmond, VA	10	300	--	1973

1/ Of those who had previously made trip.

2/ Includes new trips within first 5 months of service.

All but the second Dallas entry serve park/ride lots and all have downtown distribution elements. The buses in Milwaukee, Baltimore and the second Dallas project circulate through residential areas before entering the freeway. No corridor-wide travel data were presented, however, the Hartford and Baltimore projects were said to enhance bus ridership and operated in the year indicated without subsidy. The Milwaukee project apparently stemmed a transit patronage decline in the affected service area while operating at a deficit (292*, 403, 708).

Response to Priority Lane Service on Surface Streets

Express buses using bus lanes on surface streets have attracted substantial increases in ridership in some but not all applications. Daily ridership on express buses using contra-flow lanes in Miami (South Dixie Highway), Honolulu and Louisville and a with-flow lane in Miami (NW 7th Ave.) is given below (101, 116, 533*, 687#):

Location	Daily Patronage	Bus trips
Miami, FL (NW 7th Ave.)	1500	53
Miami, FL (South Dixie Hwy.)	2100	61
Honolulu, HI	800 1/	40
Louisville, KY	600	32

1/ Reached 1500 at the height of the 1974 energy shortage.

With express operation, a six-fold increase in bus service on Miami's South Dixie Highway (U.S. 1) led to an approximately five-fold increase in ridership. The percent of corridor trips observed to use transit rose from 2 percent to 9 percent in the U.S. I corridor and from 3 percent to 9 percent in the NW 7th Avenue corridor. Corridor-wide patronage in Louisville rose 47 percent with an 80 percent increase in bus service over pre-project conditions, after initial operational problems were corrected and one route discontinued. Approximately half of the corridor transit trips in Louisville were made on express buses and half were made on local buses. The 800 passengers per day ridership level in Honolulu was said to be substantially higher than prior corridor patronage (101, 116, 533*, 687#).

Significant travel time savings were realized by express buses when compared to local bus service in the three applications that made the comparison. In Miami and Honolulu, the exclusive lanes also permitted time savings over auto travel for the line haul segment of the trip, as illustrated in the table below (101, 187+, 373, 533*, 687#):

Location	Express Bus Time Savings	
	Time savings over auto 1/	Time savings over local bus
Miami (NW 7th Ave.)	+1 to 2 minutes	--
Miami (South Dixie Hwy.)	+11 minutes	+15 to 20 minutes
Honolulu	+3 to 12 minutes	+20 to 25 minutes
Louisville	(-4 to -10 minutes)	+5 to 15 minutes

1/ Line haul segment of trip only. Parentheses indicate slower speeds via bus.

In Louisville, express-bus/local-bus/auto travel time differentials were essentially identical during both AM and PM operation, despite the availability of exclusive lane use only during the AM period. This would indicate that the nature of express service operation was more instrumental in obtaining time savings than was the granting of priority to buses (187+).

Response to Predominantly Mixed Traffic Service on Surface Streets

Express bus systems operating without priority on arterial streets have attained patronage levels which compare favorably with express buses using arterial bus lanes and small express bus systems operating on freeways. Daily patronage on several such systems is listed below (101, 116, 408, 691*):

Location	Bus Volume	Bus Volume Increase 1/	Daily Patronage	Patronage Increase 1/
Cincinnati, OH	52	50%	1,100	81%
St. Louis, MO	78	--	2,300	14% 2/
Washington, DC	40	--	1,300	--
Calgary, Alberta	--	--	6,300	--

1/ Compared to levels prior to institution of extensive express service.

2/ Estimated by Handbook authors based on prior mode data.

Caution must be exercised in comparing project results from St. Louis, Washington and Calgary with other express bus systems. Whereas all other express bus services covered in this digest have served a single corridor, the Calgary project involved two main corridors and the St. Louis and Washington express buses operated in three distinct corridors. Data on a route by route basis indicate a daily corridor express bus ridership of 400 to 1400 in St. Louis and 300 to 550 in Washington. The Washington routes include only all-new service, not express route service expansions also implemented (116, 408, 691*).

Washington express buses relied heavily on park/ride lots for ridership attraction and over four-fifths of all riders arrived at the bus via auto. Aside from one route in Cincinnati, the other four systems operated conventional collector/distributor functions before operating via express mode to the CBD and thus relied on passengers walking to the bus stop. The Calgary express service concept differed from most in that it did not operate without bus stops during the express segment, but limited stops to about 3 per mile (101, 116, 408, 691*).

Express bus systems on surface streets without benefit of priority have diverted substantial portions of their ridership from local buses, as illustrated below. They have also attracted a fair number of former auto users. Calgary's limited express concept led to a particularly large diversion from other buses by permitting a wider range of destinations for riders (101, 116, 408, 691*).

Location	Diversion from other buses	Diversion from autos
Calgary, Alta.	71%	25%[1/]
Washington, DC	44	56[1/] [2/]
St. Louis, MO	60	28
Cincinnati, OH	--	40

1/ Of those who previously made trip.

2/ Auto plus other modes.

Response to Reverse Commute Service

Both Baltimore, MD and Washington, DC have experimented with reverse commute express services linking low income urban residential areas with suburban employment sites. Such service contradicts two primary features of normal express service; it runs counter to peak passenger flows and it is targeted for captive as opposed to choice riders. In addition, reverse commuters do not usually contend with high parking costs or excessive congestion, two factors influencing transit use. Although the express systems have carried moderate passenger volumes as illustrated in the table which follows, their purpose and benefits have been defined more in social service terms than in traditional transit terms of mode shift, cost/revenue or volume of passengers (408)[b/].

b/ Information on Baltimore reverse commute service obtained from City of Baltimore.

Express Reverse Commute Location	Daily Bus Trips	Daily Patronage
Baltimore, MD	16	375
Washington, DC	20	325

The most significant benefit to users appeared to be in the travel time savings afforded. Competing local service tended to involve much longer in-vehicle times, circuitous routing and one or more transfers, and often was late or incompatible with work start/finish times. The resulting total travel and waiting time savings accruing to express riders were frequently in excess of 30 minutes and occasionally more than an hour each way. Combined with low fares in Baltimore and reduced transfer costs in Washington, the quality of service provided apparently resulted in substantial benefits, particularly to the large proportion of female head-of-household riders for whom both time and money were at a premium. A typical comparison of express bus service versus the local bus alternative in Baltimore is presented below:

	Express Bus	Local Bus
In vehicle time	33 minutes	48 minutes
Transfer time	0	7
Total	33 minutes	55 minutes[1/]

[1/] On day of survey, local bus was 17 minutes late, 12 minutes after the shift start time.

As expected, local bus service, rather than the automobile, was the primary alternative mode for reverse commute express bus users. The table below indicates what recourse travelers would take if express service was discontinued (408):[c/]

	Baltimore	Washington
Drive auto	2%	4%
Carpool	over 10%	15
Local bus	over 80%	54
Quit Job	--	19
Undecided	--	8

[c/] City of Balimore, op. cit.

Express Service with Frequency and Coverage Changes

In the majority of cases where express bus service has been implemented, it has been in addition to pre-existing local service. In such cases, there is a meaningful percentage increase in service (bus trips) provided in the corridor. This increase provides the new option to choose between local and express service, and may also provide greater service coverage and/or higher individual route frequencies than existed before. Because of wide variations in ridership response to increased service coverage and to frequency changes, as reported in the topical digests "Bus Routing/ Coverage" and "Transit Scheduling/Frequency," it is difficult to isolate the effect of express bus operation per se when examining the reported patronage changes. However, the total ridership response to deploying additional bus trips in conjunction with starting express service can be compared with the ridership response to using additional bus trips solely for increasing coverage or frequency.[d/]

In general, each 1 percent frequency and coverage increase has led to a ridership increase of distinctly less than 1 percent. The increase is usually around 0.4 to 0.6 percent for frequency changes and 0.6 percent to 0.9 percent for coverage changes. These findings equate to service elasticities of +0.4 to +0.6 for frequency changes and +0.6 to +0.9 for coverage changes.[e/] The implementation of new and expanded express bus services has resulted in patronage increases that are on the average half again as much as would be expected from frequency and coverage changes alone.

Table 35 lists service elasticities for express bus projects based on the number of bus trips provided before and after. The ridership responses reflect the effects of increased frequency and coverage along with the effects of express service per se (101, 397*, 401*, 461#, 533*, 565#, 684)[f/]. The elasticities cited in Table 35 are in the upper range of what might be expected from frequency or coverage changes not involving express service, in that the average express corridor or total facility service elasticity is +0.8 to +1.0. The lower of these two averages, +0.8, excludes the separate roadway operations.

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d/ The device employed here for comparison is the measure "service elasticity". This measure indicates the percentage change in ridership observed or expected in response to a 1 percent change in service. An elasticity of +0.9, for example, indicates that a 1 percent service increase has caused or is expected to cause a 0.9 percent gain in ridership. See Appendix A for a discussion of elasticity measures. Note that in using service elasticity, no direct measure is provided of response to increased speed or reduced travel time. To the extent that the service elasticity for making service changes in the form of express bus operation is greater than the service elasticity for frequency and coverage changes, the positive effect of time savings and other express service characteristics is implied.

e/ See the topical digests "Transit Scheduling/Frequency" and "Bus Routing/Coverage" for additional discussion.

f/ Includes information obtained from Port Authority of Allegheny County.

Table 35
Service Elasticities for Express Bus Projects
(101, 397*, 401*, 461#, 533*, 563#, 684)

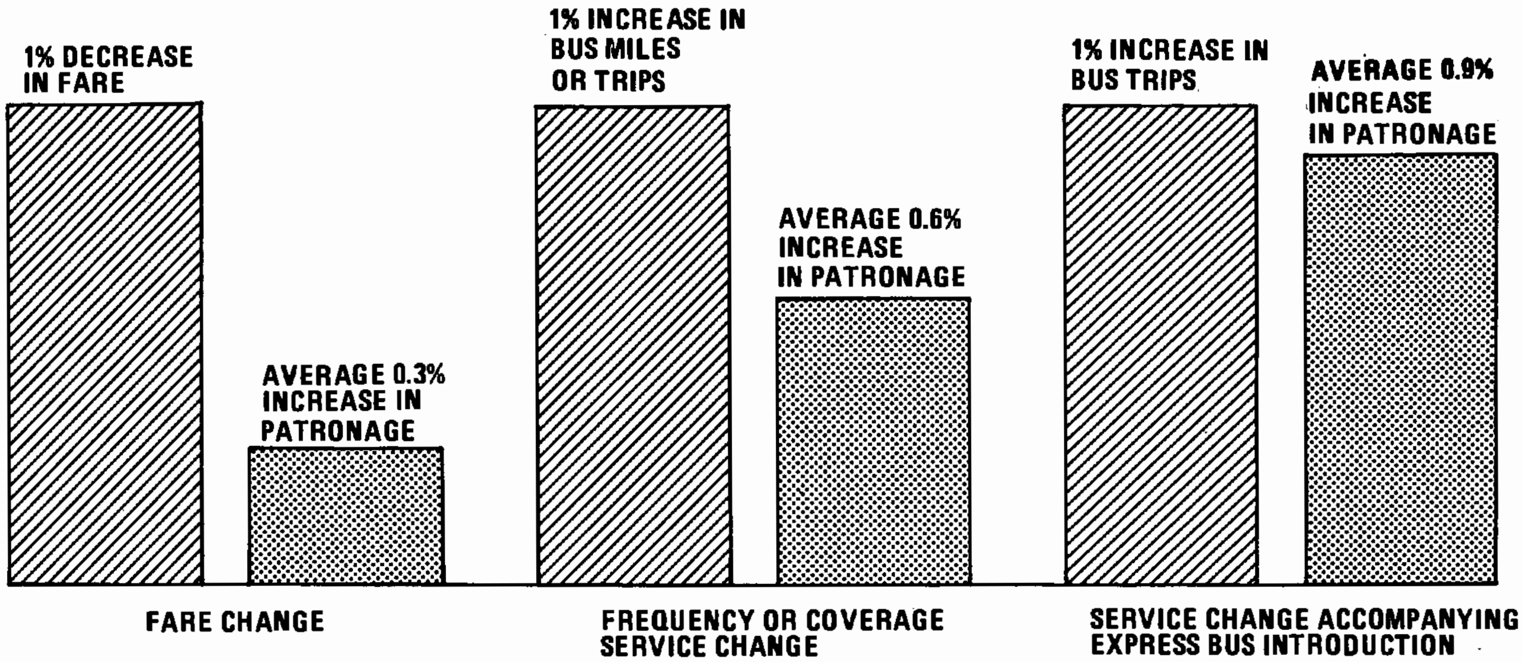
Location	Service Elasticity 1/	Priority Treatment
Cincinnati, OH	+1.45	None
Dallas, TX	+.68	None
Seattle, WA	+.86	Exclusive ramp
Minneapolis, MN	+.43 2/	Ramp bypass lane
Miami, FL	+.92 3/	Contra-flow arterial
Louisville, KY	+.66	Contra-flow arterial
Portland, OR	+.70	With-flow freeway
Santa Monica, CA	+.89 3/ 4/	With-flow freeway
Washington, DC	+1.28	Separate Roadway
Pittsburgh, PA	+2.06 3/	Separate Roadway

1/ All service elasticities calculated by the Handbook authors (see footnote "d" in text). Service elasticity in this table relates passenger volume change to the change in number of bus trips serving the market population either in the corridor as a whole or on the specific facility examined. The elasticities given pertain to total corridor data except where foornote "3" applies.

2/ Service elasticity of +0.97 for express trips only, including effect of passenger diversion.

3/ Degree of diversion from local routes unspecified.

4/ Service elasticity of +0.59 for pre-existing routes only, i.e., routes that had established ridership patterns.



NOTE: See Figure 15 in the "Bus Routing/Coverage" digest for an illustrative example of the variation which can occur within any one of these categories.

Figure 17
Patronage Increases Attributable To Transit System Changes

Aside from the separate roadway experience, the presence and type of priority treatment for buses apparently does not influence the service elasticities to any discernable extent, although the number of cases involved are too few to draw definitive conclusions. Figure 17 summarizes and compares average ridership response to changes in fares, changes in frequency or coverage, and service changes accompanying express service introduction. In terms of gross averages, and always assuming travel patterns supportive of service changes, ridership is shown to be progressively more sensitive to frequency/coverage service changes (+0.6 average elasticity) and express service related changes (+0.9 average elasticity) as compared to fare changes (-0.3 average elasticity). (For a discussion of what constitutes travel patterns supportive of express service, see the "Implications of Travel Patterns" section of this digest.)

Express Service with Special Fares

Some express bus services have charged premium fares for the increased quality of service afforded, apparently without detriment to successful operation. The type of rider attracted to express service is more apt to be a choice rider with a higher income than the average bus rider and is apparently willing to pay a higher fare for the improved service that express buses offer. Express bus systems that have charged premium fares included applications in St. Louis (10¢ over 25¢ base fare), Richmond (15¢ over 35¢ local fare) and Minneapolis (5¢ premium, average local fare of 28¢). Express buses operating within New York City have fares three times as high as local buses (162, 401*, 408, 691*).

Underlying Traveler Response Mechanisms

Compared to local transit, express buses afford travel time savings and improved comfort and reliability by avoiding numerous stops and starts and variations in passenger loading. Any differences in ease of access or time spent waiting for the bus are not inherent in the express service concept. Express service user costs (fares) are usually the same or nominally more than for local transit. Compared to auto travel, express buses offer user cost savings along with the improved convenience/comfort associated with the avoidance of driving and parking in congested areas, with little or no sacrifice in line haul travel time and reliability. Where severe congestion exists, express buses aided by priority facilities can provide former auto users with line haul travel time and reliability improvements. The former auto user must accept the walk or auto access requirements and wait times associated with transit travel. Factors with potential to induce local bus and auto users to shift to express buses are illustrated in Figure 18.

Comparison among different projects of reasons given for using express bus service is difficult because of differences in wording among passenger surveys. It is clear, however, that convenience[g/] and reliability, followed by time savings, consistently elicited more responses than did cost savings (68, 292*, 397*, 401*, 408, 461#, 533*, 708). Because multiple responses were permitted, both former auto users and former bus users would cite convenience/comfort. Usually only one of the two groups would mention time, and the same for cost. Survey limitations not withstanding, convenience/comfort may well be a prime factor in attracting cost-conscious former local bus users and time-conscious former auto users.

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g/ Although not defined, "convenience" apparently refers to "favorable to one's comfort" and reflects the attributes associated with non-stop travel.

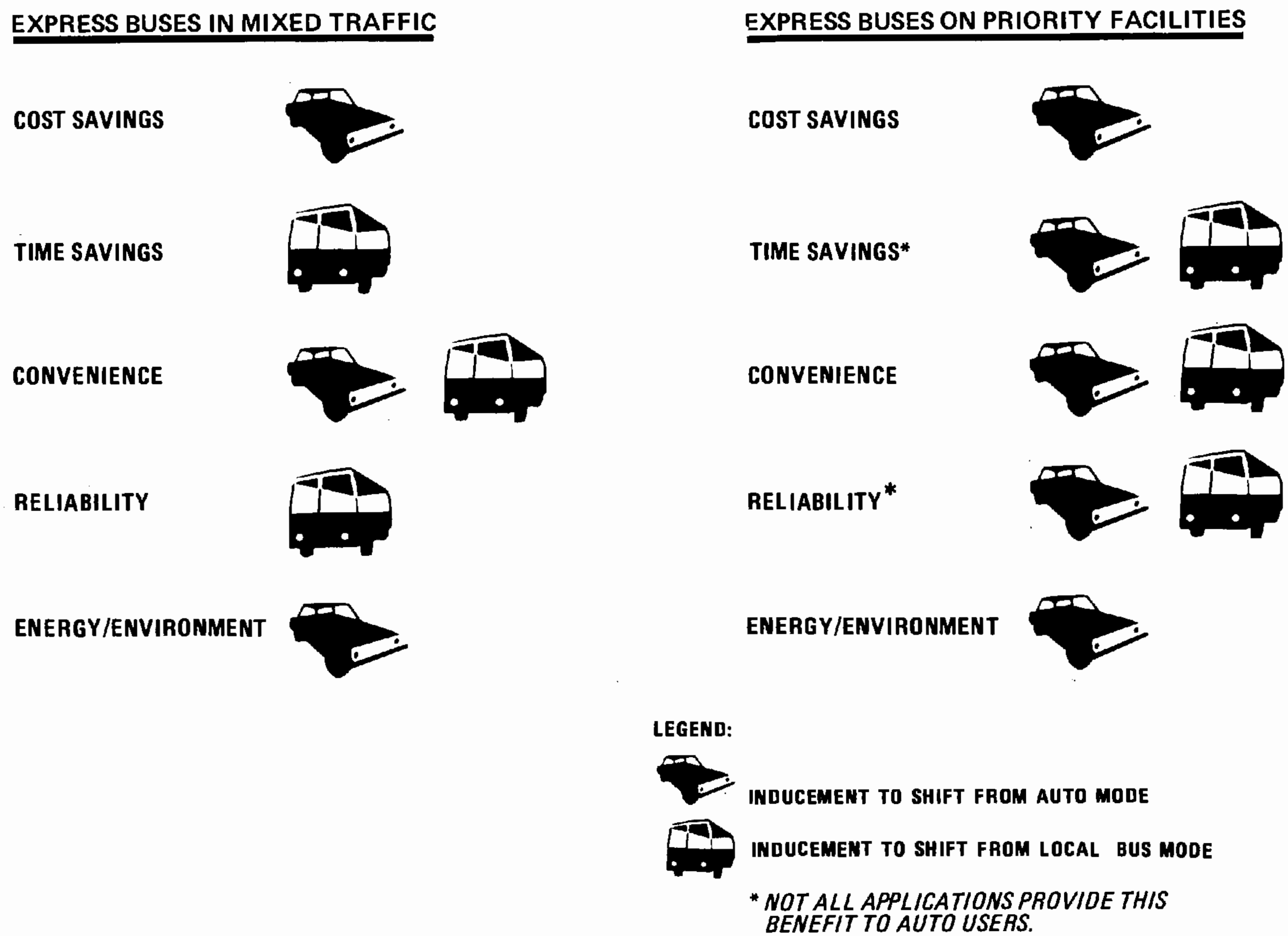

Figure 18
Inducements for Mode Shift to Express Bus

Particularly instructive is a survey administered to express bus riders on I-35W in Minneapolis. Responses were segmented among former auto commuters on arterials, former auto commuters on I-35W and former local bus riders, uncovering differing reasons among the three groups for initially riding the express bus (401*):

Reason for switching to express bus 1/	Former Commute Mode: arterial auto	I-35W auto	local bus
Car unavailable	29%	40%	0%
Handy/convenient	21	30	41
Saves time/fast	13	11	43
Cost	0	5	2
No distinct reason	17	16	25

1/ An additional 8 responses were listed; multiple responses were permitted.

The quantitative effect on traveler response of the line haul travel time reductions associated with express bus operation is unclear. Aside from the operations on separate roadways in comparison with other express services, there does not seem to be a strong relationship between line haul time savings and attractiveness of the service. As discussed earlier, the frequency and coverage improvements afforded by many new express services will rank with time improvements in importance to the user. It may also be that in the case of small actual time savings, the perceived travel time savings are greater, analogous to the perceptions of carpool lane users identified in Honolulu, discussed in the "Pool/Bus Priority Facilities" digest. Travel decisions may be made on the basis of misconstruing non-stop travel as significantly faster travel. Lack of investigation into this possibility precludes definitive conclusions at this point.

Implications of Travel Patterns

To operate more successfully than local buses, express buses need long person trip lengths with significant travel demand at both ends of the trip. In order to attract enough riders with a unique origin and destination, express buses must generally operate between the CBD and a dense outer residential district or satellite city (101, 140#, 162, 563#), or rely on park/ride lots (292*, 406, 533*, 563#, 684, 687#) or extensive feeder networks (533*, 563#) to provide sufficient demand at the residential end of the trip. Reverse commute express services have attempted to capitalize on the shift of many large industries from central cities to suburban sites and compensate for the predominantly CBD orientation of express service.

An informative study of the suburban residential and urban workplace densities required to support express bus service has been conducted using travel demand models and comparing express buses serving park/ride lots with express buses acting in a residential collector capacity before beginning express operation. Factors considered in the analysis were downtown attractions, residential density, distance traveled, frequency of service, cost, travel time and type of service (collector versus park/ride).

Assuming 12 minute service frequency, a 15 mile one-way distance, 35 mph line haul speed and reasonable cost assumptions the following results were obtained (721):

Required Residential Densities (dwelling units/acre) to Support Express Service

Type of Service	Approximate Urbanized Area Size		
	Atlanta, GA	Hartford, CT	Charlotte, NC
Collector	16	25	prohibitive
Park/ride	3	4	6

Although no empirical confirmation of the results is available, the relative density requirements estimated for the two types of service and different sized areas are instructive. In St. Louis actual experience was used in an attempt to correlate the number of passengers (one-way trips) attracted to express buses per dwelling unit to the ease of bus stop access from nearby residences and the degree of competing transit service. Dwelling units within 4 blocks were counted. The influence of access and competition on express bus trip generation is summarized below. Routes serving areas with large suburban employment centers tended toward the lower end of the scale (691*).

Ease of Access	Transit Competition	St. Louis Express Bus Passengers/100 Dwelling Units
good	none	11.0-17.6
good	local feeder	5.6-10.2
good	radial local	5.6-7.9
good	radial express	5.0-7.5
poor	none	2.1-5.5
poor	local feeder	3.4-3.6
poor	radial local or express	2.7-3.9

The potentially disastrous results of instituting express service in areas where the demand for travel is not primarily between two distinct locations is illustrated by a subsequently terminated experimental route in Louisville. The CBD oriented express route originated at a suburban industrial plant and little demand for downtown destined travel materialized. In addition, many of the previous local bus riders were students whose destinations were along the portion of the express route where no stops were made (187⁺). Most transit operators seek to diminish the latter type of problem by possibly curtailing, but not eliminating, local service and by providing a small number of intermediate stops if sufficient demand exists. The lesser patronage generated by express service originating in areas with major suburban employment, noted in St. Louis as well as Louisville, is very likely a reflection of the fact that where extensive local employment opportunities are available there is normally a lesser CBD orientation of work trip travel demand.

Sources of New Ridership

Express bus systems attract a significant proportion of riders who are former automobile users. As would be expected, express buses oriented to park/ride lots attract proportionately more former auto users than do express buses which serve as local collectors before the express portion of the trip. Express buses on priority facilities attract proportionately more former auto users than do non-priority buses.

Freeway express buses attract more former auto users than do arterial express buses. Surveys of local and express bus riders in Seattle and Minneapolis revealed the following prior mode choices for riders who had previously made the trip (401*, 684*):

	Prior Mode		
	Auto driver	Auto passenger	Transit
Seattle			
all express routes	19%	6%	75%
park/ride express routes	54	11	35
local routes	7	5	88
Minneapolis			
express routes	38	10	52
local routes	34	17	49

Table 36 presents prior mode statistics for several express bus operations along with the operating characteristics of each project. Prior or alternate mode anomolies related to specific patterns of express operation were noted in the sections of this digest, "Response to Predominantly Mixed Traffic on Surface Streets" and "Response to Reverse Commute Service". Figure 19 depicts the relative degree to which different express bus systems attract prior auto users (116, 140*, 292, 397*, 401*, 403, 406, 408, 461#, 533*, 563#, 684, 687#, 691*).

Mode of Access

Because most express buses operate in conjunction with park/ride lots, have a suburban orientation, and offer significant appeal to former auto users, it is logical that they obtain a greater share of their ridership via the auto access mode than do local buses. Two of the studies encountered made this direct comparison. Routes that were converted to express operation in Seattle had 6 percent of their passengers arrive by auto (driver or passenger) before conversion and 14 percent arrive by auto after conversion. Routes serving the primary park/ride facility had 82 percent of their riders arrive via auto (684). Seventeen percent of non-busway transit riders in Washington's Shirley Highway corridor used an auto to reach the bus compared to 33 percent of Shirley Highway express bus riders (397*).

Another issue not addressed in the assessment of most express bus operations was whether transit riders who had previously walked to a local bus switched to park/ride when express bus service began. Where data is available, it appears that on the order of 15 to 20 percent of park/ride patrons previously walked to transit (192*, 292*, 408). The "Pool/Transit Fringe Parking" topical digest examines this question in more detail.

Modes of access for several express bus operations are summarized in Table 37. The mode of access varies widely according to the route structure, the lack or presence of park/ride facilities, and other local conditions. It is worthy of note that both the auto and walk modes of access each vary all the way from about 5 to almost 90 percent of the total among the different express bus systems (116, 292*, 397*, 406, 408, 533*, 563#, 684, 691*).

Table 36
Prior Mode of Express Bus Users
(116, 140#, 292, 397*, 401*, 406, 408, 461*, 533*, 563#, 684, 687, 691*)

Prior Mode	Shirley Highway Washington, DC	San Bernadino Freeway Los Angeles, CA	I-95 Miami, FL	Banfield Freeway Portland, OR	Santa Monica Freeway Los Angeles, CA
Auto driver	41%	58%	50%	44%	39%
Auto passenger	12	16	9		8
Bus	38	10	16	47	36
Other/trip not made	9	16	25	9	17
Project	Separate Roadway	Separate Roadway	With-flow Lane	With-flow Lane	With-flow Lane
Characteristics	Freeway	Freeway	Freeway	Freeway	Freeway
	Moderate Park/ride	Major Park/ride	Major Park/ride	Limited Park/ride	Limited Park/ride

Prior Mode	I-5 Seattle, WA	I-35W Minneapolis, MN	I-84 Hartford, CT	I-83 Baltimore, MD	NW 7th Avenue Miami, FL
Auto driver	16%	30%	57%	24%	49%
Auto passenger	5	8	15	10	15
Bus	64	41	23	42	22
Other/trip not made	15	21	5	24	14
Project	Bus Ramps	Bus Ramps	No Priority	No Priority	With-flow Lane
Characteristics	Freeway	Freeway	Freeway	Freeway	Arterial
	Limited Park/ride	Limited Park/ride	Major Park/ride	Moderate Park/ride	Major Park/ride

Prior Mode	S. Dixie Hwy. Miami, FL	South Capitol Street Washington, DC	Two Routes Calgary, Alta.	Several Routes St. Louis, MO	Several Routes Washington, DC
Auto driver	69%	14%	19%	16%	38%
Auto passenger	8	8	6	12	
Bus	17	62	71	60	30
Other/trip not made	6	16	4	12	32
Project	Contra-flow Lane	With-flow Lane	No priority	No Priority	No Priority
Characteristics	Arterial	Arterial	Arterial	Arterial	Arterial
	Major Park/ride	Limited Park/ride	Limited Park/ride	Limited Park/ride	Major Park/ride

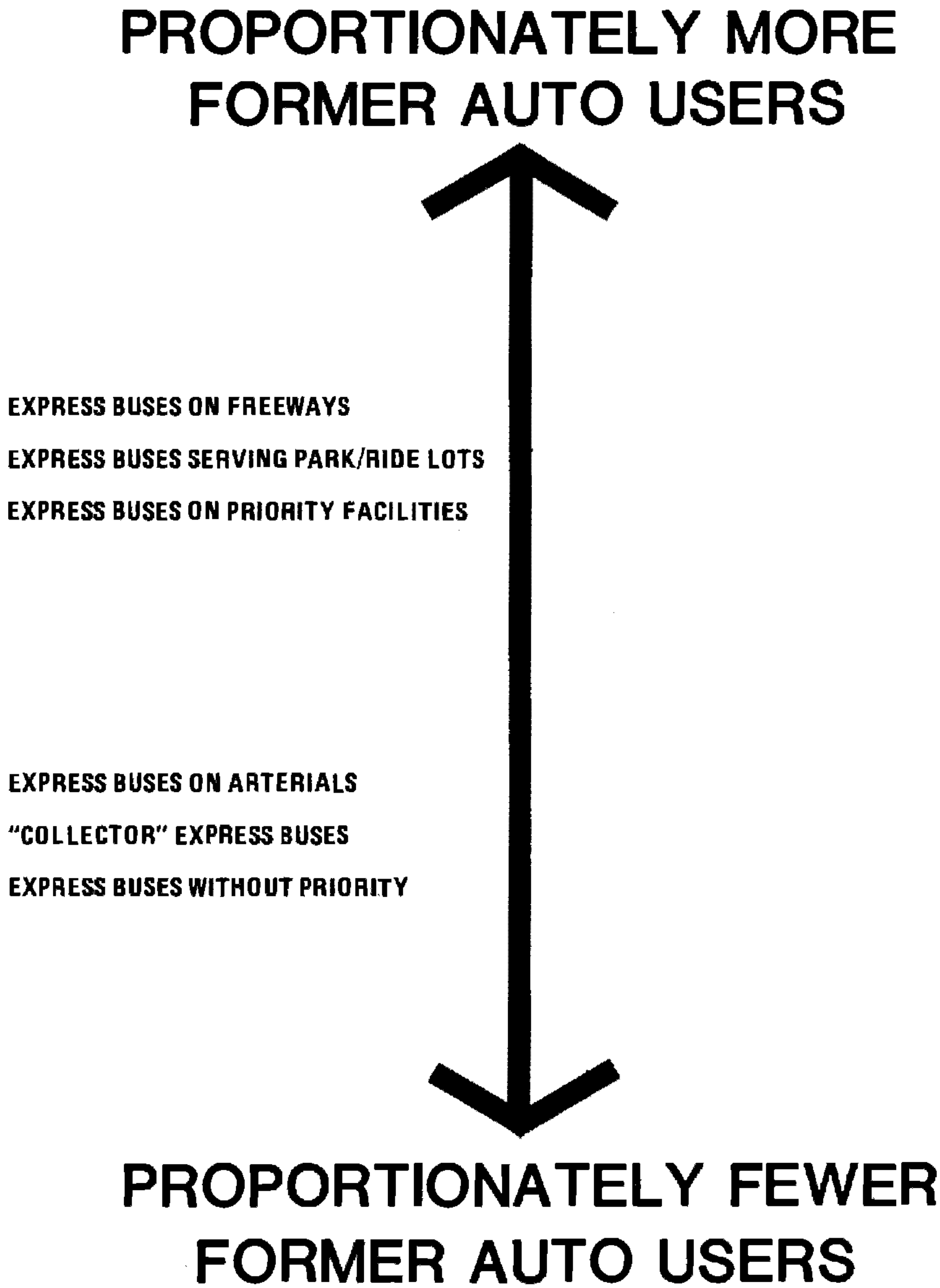

Figure 19
Observed Prior Mode of Express Bus Users

Table 37
Access Mode of Express Bus Users
(116, 292*, 397*, 406, 408, 533*, 563#, 684)

Access Mode	Shirley Highway Washington, DC	I-5 Seattle, WA	Santa Monica Freeway Los Angeles, CA	I-83 Baltimore, MD	I-84 Hartford, CT
Walk	67%	82%	58%	39%	5%
Bus	—	3	27	0	0
Auto driver			8	33	69
Auto passenger	33	14	7	28	26
Park/ride level	moderate	limited	limited	moderate	major

Access Mode	S. Dixie Hwy. Miami, FL	Several Routes Washington, DC	Two Routes Calgary, Alta.	Several Routes St. Louis, MO	South Capitol Street Washington, DC
Walk	37%	13%	84%	88%	26%
Bus	2	0	12	4	32
Auto driver	45	52	2		36
Auto passenger	16	35	2	8	6
Park/ride level	major	major	limited	limited	limited

Impacts on Temporal Ridership Patterns

Because successful express bus operation requires a high volume of people with the same basic origin and destination, express bus systems tend toward peak-period, peak-direction travel between home and work. Many express bus routes only operate during peak hours for want of off-peak demand. Work trips frequently account for over 90 percent of all trips made by express buses, with levels as high as 99 percent reported. In Seattle, a comparison between express and local transit users in the inbound direction throughout the day revealed that work trips accounted for 72 percent of the express trips and 65 percent of the local trips. In so far as increased express service will attract peak period former auto commuters to the bus system, it is logical that system ridership will become more peaked, although no empirical data were reported to either support or refute this contention (116, 292*, 397*, 401*, 533*, 684, 708).

Impacts on Traffic Volumes

In instances where express bus operation has been implemented in conjunction with priority facilities, substantial increases in facility person volumes have occurred with relatively minor increases in vehicular volumes. Both I-35W in Minneapolis and I-5 in Seattle encountered increased patronage while experiencing no growth in auto traffic, despite predominantly mixed-traffic operation of express buses. Metering on I-35W and a severe recession in Seattle no doubt played major roles in influencing traffic patterns (401*, 684). Changes in vehicle and person flows for several express bus systems are summarized under the heading "Impacts on Traffic Volumes" in the "Pool/Bus Priority Facilities" digest.

Impacts on VMT, Energy and Environment

The Shirley Highway express bus service in Washington and the San Bernadino Busway service in Los Angeles are estimated to have resulted in savings of fuel and reductions in carbon monoxide and hydrocarbon emissions as follows:

	Weekday Savings/Reductions 1/			Annual Fuel Savings 2/
	Fuel	CO	HC	
Shirley Busway	3,100 gal.	3.5 tons	50 kg.	775,000 gal.
San Bernadino Busway	3,500	3.5	240	875,000

1/ Calculated on the basis of 1975 vehicle characteristics.

2/ Weekday to annual conversion calculated by Handbook authors assuming 250 equivalent weekdays of express bus service.

These estimates do not include the beneficial effect of subsequent opening of both facilities to carpools. They take into account previous mode of travel and use of auto for system access, but not second order impacts such as possible traffic congestion reductions and household use of autos formerly employed for commuting (148*). The carbon monoxide reductions for the San Bernadino Busway service represent the net effect of an estimated 4.4 ton reduction along the inner corridor, including downtown Los Angeles, and an 0.9 ton increase along the outer corridor, including the busway terminal.

Extrapolated VMT reduction estimates for the Shirley and San Bernadino Busway and I-35W Minneapolis express bus services, along with planning estimates for Seattle, Denver, and two hypothetical cities, have been used to produce a range of estimates for the VMT reduction potential and associated characteristics of comprehensive, areawide express bus operation. A summary is given below, constructed to represent the potential in a city of 1,000,000 population (675):

	Low Impact	Mean of 7 Cases	High Impact
Daily express bus trips	150	450	950
Number of buses required	63	188	396
Weekday auto VMT reduction	26,923	80,769	170,515
Weekday express bus VMT	3,000	9,000	11,085
Equivalent weekday VMT reduction	20,923	62,769	418,345
Percent reduction in:			
Work trip VMT to and from CBD	1.93%	5.93%	14.1%
Regional work trip VMT	0.29	0.89	2.11
Total annual VMT	0.10	0.31	0.74
Net annual cost per two-way commuter diverted from auto	$522 to $786 (all cases - 1978)		
Net cost per VMT reduced	17.6¢ to 26.3¢ (all cases - 1978)		

Table 15 in the "Impacts on VMT, Energy and Environment" section of the "Pool/Bus Priority Facilities" digest gives large prototypical urban area fuel and emissions reduction estimates for hypothesized areawide express bus programs in combination with priority treatments. The estimated annual fuel savings are in the 1,600,000 to 2,900,000 gallon range (171). All such estimates are for short term effects, and do not reflect possible long term impacts related to such phenomena as land use density changes. In both the Shirley Busway and San Bernadino Busway examples, over half those recently moving into the corridor indicated that the availability of bus service had a definite (37+ percent) or slight (19+ percent) influence on their choice of location. These survey findings are judged not sufficient for assessing development density impacts (148*).

Impacts on Costs/Revenues

The financial attractiveness of express bus service vis-a-vis local service is unclear. Although cost/revenue ratios of 1.0 or less than 1.0 have been reported in several applications (292*, 397*, 403), most notably the Shirley Highway project in its early 1970's demonstration phase, other systems have reported express service operating ratios significantly greater than 1.0. Cost/revenue relationships for the routes in question were based on fully allocated costs (101, 218, 401*, 429, 563#, 687#, 708).

Cost/revenue ratios were compared for express and local buses in Minneapolis, Seattle and New York with the following results (401*, 429, 684):

	Cost/Revenue Ratio
Minneapolis	
Express routes	2.47
Local routes	1.54
Seattle	
Express routes	1.33
Control routes	1.27
Local routes remaining parallel to express routes	.99
New York	
Express routes	1.70
Local routes	1.37

The higher express service cost/revenue ratio in New York occurred despite an express fare three times the local fare. Minneapolis charges a 5¢ premium on express service while Seattle has no premium charge for express service. The higher cost/revenue ratio of express service is attributed to low turnover of seats on express buses and the peak-oriented, short duration of express service in combination with the minimum hour payment provisions contained in most transit labor agreements (429). Reverse commute express buses, when operated in conjunction with regular express service, have been marginally profitable on an incremental cost basis (434).

No express bus studies have been encountered which address overall system economics in terms of vehicle or manpower usage, although a few projects mentioned probable savings in fleet utilization and overtime pay due to the better reliability associated with express bus operation (461#). In the breakdown of cost/revenue ratios given above, it is interesting to note an apparent counterbalancing effect in the case of Seattle. The new express routes show an operating ratio higher than unaffected control routes. However, the restructured local routes designated to remain parallel to the express routes show a significantly lower cost/revenue ratio, presumably because of being relieved of long, low-turnover trips.

Traveler Response Time Lag

New express bus service takes the form of either service overlayed on existing routes giving increased combined local and express frequency, or service to new areas giving increased coverage. Lagged response to increased frequency and coverage is addressed in the topical digests "Transit Scheduling/Frequency" and "Bus Routing/Coverage". The pattern of ridership growth over time for express buses does not differ markedly from that observed for improvements to regular service. The following list gives the number of months before express transit ridership stabilized for several express bus projects (140#, 292*, 401*, 403, 408, 563# 691*):

Location	Steady Ridership Acheived
St. Louis, MO	6 months
San Bernadino, CA	18 months
Santa Monica, CA	3 months
Minneapolis, MN	15 months
Washington, DC	3 months
Hartford, CT	3 months
Milwaukee, WI	steady ridership loss

The San Bernadino express service stopped attracting additional riders once the terminal park/ride facility was filled to capacity. The Shirley Highway service achieved continual growth over the initial five years as additional bus runs were scheduled, followed by more modest ridership increases (140*, 397*, 673).

A different kind of traveler response time lag was noted for a reverse commute express service in Washington, DC, serving two suburban firms which had recently relocated from downtown. Ridership started at its high point and declined 10 to 20% over a period of a year. The cause was probably a process of employees adjusting to other means of travel such as carpooling, and also some changing of residence locations to be nearer the worksite (434).

Additional References

For additional information on Express Transit consult references:

2, 6, 11, 32, 40, 41, 67, 68, 72, 88#, 101, 111, 116, 131, 139, 140#, 145#, 148*, 159, 162, 171, 192#, 215, 216, 218, 281, 292*, 373, 377#, 387, 394, 397*, 401*, 403, 406, 408, 416, 429, 433, 434, 440#, 461#, 498#, 506, 519, 524, 526, 533*, 563#, 572, 589, 593+, 605#, 611, 671, 675, 681, 684, 686, 687#, 691*, 696, 698, 700, 705, 708, 721.

148. Curry, James P. Case Studies of Transit Energy and Air Pollution Impacts. De Leuw, Cather & Company. Prepared for the Office of Energy, Minerals and Industry, Office of Research and Development, U.S. Environmental Protection Agency; Contract No. 68-01-2475. May, 1976. 198 Pages. NTIS PB 253-211. EXPRESS TRANSIT*, NEW TRANSIT FACILITIES/EQUIPMENT, POOL/BUS PRIORITY FACILITIES, POOL/TRANSIT FRINGE PARKING, TRANSIT SCHEDULING/FREQUENCY, BUS ROUTING/COVERAGE, TRANSIT FARE CHANGES. OBSERVED RESPONSE. TRAVEL CHOICE, VOLUME. ENERGY, ENVIRONMENT.

This study made maximum use of actual case studies and existing data in estimating the air quality and energy impacts of 1) public transit service and fare changes, 2) establishment of busway express transit service, and 3) establishment of corridor rail rapid transit service. This review covers the first two categories, and presents only the estimates made on the basis of 1975 vehicle characteristics. Factors taken into account included auto and transit energy consumption and pollutant emissions characteristics, the impact of auto cold starts on emissions, ridership response to new transit services including system load factors, previous mode of travel of new service users, and use of auto for transit system access. Not included in the computation were second-order effects and indirect energy use including use of autos formerly employed for commuting for other household trips, energy required for construction, and possible reductions in traffic congestion due to diversion to transit. Some data had to be approximated, and certain uncertainties were handled as random variables with associated probability functions. Results were expressed as ranges and maximum likelihood values.

In Washington, DC in 1974 a 16% increase in bus miles resulted in a 5% increase in ridership. The impact was a likely net fuel consumption increase of 250 gallons/day, balanced by emissions reductions for carbon monoxide (CO) of 6 tons/day and for hydrocarbons (HC) of 260 kg/day. Possible fuel consumption effects ranged from a net increase of 4,000 gallons/day to a savings of 2,000 gallons/day. Implementation of bus-only lanes on the Shirley Highway resulted in a 40% peak period mode share in that corridor toward downtown Washington. A gross auto fuel savings of 7,000 gallons per day was reduced significantly by the increased bus miles and the use of the automobile for about 33% of all bus access. The likely net value of fuel savings was 3,100 gallons/day with a range from 1,300 to 4,800 gallons/day. The CO reductions were 3.5 tons/day with HC reductions of 50 kg/day. Of those moving into the corridor within the past five years, 37% indicated that the availability of busway service had a definite influence on their location decision and 19% indicated that it had a slight influence.

Ridership on buses using the San Bernardino busway resulted in a 30% mode share in the corridor during peak periods. Surveys indicated that 79% were diverted from auto driving. Notably, 72% accessed the busway system by auto. The expected fuel savings was 4,300 gallons/day with a range from 2,200 to 6,300 gallons/day. However, of autos left at home, 39% were used during the day. Assuming each auto left at home and used during the day consumed an average of 1 gallon, the expected fuel savings would be reduced to 2,500 gallons/day. The potential savings from reduced congestion would reach a maximum of 7,800 gallons/day if volumes actually dropped by the number of autos removed from the highway by the introduction of bus service. Reductions in emissions were estimated to be 3.5 tons of CO and 240 kg of HC daily. In a pre-busway survey, 39% of those recently moving into the corridor indicated that the availability of bus service had a definite influence in their choice of residence, and 19% indicated that it had a slight influence.

In 1976, the Metropolitan Atlanta Transit Authority reduced fares from 40 cents to 15 cents and increased bus miles approximately 16%, resulting in a 28% increase in bus ridership. The likely fuel savings was 9,300 gallons/day, or approximately 0.5% of the regional daily fuel consumption for all passenger transportation. Probable fuel savings ranged from 4,300 to 13,100 gallons/day. Estimated reductions in air pollutants were 13 tons/day of CO and 670 kg/day of HC. Probable fuel savings ranged from 4,300 to 13,100 gallons/day. In San Diego, a 1972 fare reduction of 39% and a 29% increase in bus miles resulted in a 60% increase in ridership, with a likely fuel savings of 5,000 gallons/day. Probable fuel savings ranged from 2,000 to 8,000 gallons/day. The associated emission reductions were 7.5 tons/day of CO and 400 kg/day of HC. An investigation was also made of a further 63% increase in bus miles of service which had been planned but not implemented. Implementation would have resulted in an expected ridership increase of 26% and a likely 240 gallons/day savings above that which had been achieved already. However, the range of probable values for further fuel consumption change ranged from a net increase of 4,000 gallons/day to a savings of 4,000 gallons/day, with a significant probability of a net loss. The likely CO reductions would have amounted to 5.4 tons/day and HC reductions, 240 kg/day.

292. Jain, Rajendra P. and Stanley A. Mokrzewski. "An Express Bus Service in Connecticut Works Without Sophisticated Control." Traffic Engineering. Institute of Transportation Engineers, Arlington, Virginia. Volume 44, Number 4. January 1974. Pages 60-65. EXPRESS TRANSIT*, POOL/TRANSIT FRINGE PARKING. OBSERVED RESPONSE. MODE CHOICE, ACCESS MODE CHOICE, VOLUME

Express service was initiated in January 1972 between West Hartford and Hartford (1975 population of 140,000), linking the downtown with a 250-space park/ride lot in a shopping center adjacent to I-84. The service operates on 10 minute headways during peak periods only and the seven mile trip on I-84 is made in 13-18 minutes.

Weekly ridership counts were taken and two passenger surveys were conducted to ascertain prior mode use, access mode to the service and commuting attitudes. Both surveys were conducted within three months of project implementation, therefore long term effects may differ.

Weekly ridership grew from 500 during the first week to 1500 during the 40th week of operation. Ridership of 1400 was neccesary to break even. The park/ride lot, initially 20% filled, was filled to 80% of capacity by the 40th week. The prior mode and mode of access for express riders are given below:

Prior mode		Access mode	
auto driver	56.0%	auto driver	69%
auto passenger	13.2	auto passenger	26
carpool	3.1	walk	5
auto and bus	7.0	bus	0
bus	15.4		
hitchhike	0.9		
did not make trip	4.4		

Buses operate without priority on the freeway and apparently without any feeder bus service to the park/ride lot or collection/distribution portion of the express route.

Over half of the respondents surveyed on the buses indicated that they saved time and money by using the express service, however, the most important factor cited for bus use was a dislike for driving in congested traffic. High cost of parking ranked second. Trips between home and work account for 99% of the trips made by express bus. The success of the service spawned four more express routes in Hartford and one in New Haven.

397. McQueen, James T., David M. Levinsohn, Robert Waksman, and Gerald K. Miller. The Evaluation of the Shirley Highway Express-Bus-On-Freeway Demonstration Project. Final Report. National Bureau of Standards, Technical Analysis Division. Prepared for Urban Mass Transportation Administration, U.S. Department of Transportation; Project No. DOT-UT-306. August 1975. 154 pages. NTIS PB-247-637. EXPRESS TRANSIT*, POOL/BUS PRIORITY FACILITIES, POOL/TRANSIT FRINGE PARKING. OBSERVED RESPONSE. MODE CHOICE, AUTO OCCUPANCY, ROUTE CHOICE. ENERGY, ENVIRONMENT.

The Shirley Highway Express-Bus-on-Freeway Demonstration Project consisted of: 1) an 11 mile, 2 lane reversible busway in the median of I-95 (Shirley Highway) from Washington, DC, and the Pentagon employment area into the Northern Virginia suburbs, 2) new and extended bus routes utilizing Shirley Highway, with 138 route miles and 299 AM peak period bus trip departures in 1974 versus 60 route miles and 156 bus departures in 1971, and 3) fringe parking facilities. The project was tied in with massive reconstruction of Shirley Highway, and with opening of the busway to 4-or-more-occupant carpools once construction work south of the Pentagon was complete. The chronology was as follows: Sept 1969, first 5 miles of busway opened, 12-18 minutes saved inbound in the AM; Sept. 1970, more busway opened; April 1971, full length (part temporary) opened, demonstration project initiated; June 1971, 8 new bus routes started; Feb. 1973, last of 90 new buses in service; Dec. 1973, carpools admitted south of Pentagon; Dec. 1974, demonstration project completed. Bus reliability was improved from 33% "on time" arrival at their first DC stop (i.e., within 6 minutes of the scheduled time) to 92% "on time" arrival. In 1974, measured inbound in the morning, the busway afforded typical savings during the maximum traffic flow of 19 minutes to buses and carpools.

Vehicle, auto occupancy, and bus passenger counts were taken in the corridor thrice yearly, 1970-74, across a 4 mile screenline centered on Shirley Highway and including 7 other arterials. Local and through traffic, and public and private bus operators, were all included. Mail-back surveys covering attitudes and trip/tripmaker characteristics were taken in Oct. 1971 and Oct.-Nov. 1974 of busway and non-busway auto drivers, auto passengers and bus passengers. The October screenline count results for the corridor were as follows (6:30-9:00 AM, inbound):

Year	Condition	Autos	Autos Persons	Occupancy	Bus Persons	Percent Transit
1970	Partial Busway	40,000	55,700	1.39	14,800	21%
1971	New Bus Routes	36,000	48,000	1.33	17,600	27
1972	More Bus Service	37,100	48,300	1.30	20,000	29
1973	More Bus Service	40,400	53,300	1.32	21,900	29
1974	Carpools Allowed	38,600	56,100	1.45	24,900	31

Daily AM peak period patronage on Shirley Highway express buses rose from 4,200 to 16,100 between June 1969 and November 1974, with no drop when carpools were admitted to the bus lanes. Within the travel market which could potentially use project bus services, the proportion of trips on buses increased from 27% to 41%. Auto occupancy on Shirley Highway itself (as opposed to the corridor information given above) gradually rose from 1.35 to 1.61 upon opening of the bus lanes to carpools. Carpool admittance to the busway coincided with the 1973-74 gasoline shortage, but the number of carpools continued to grow from 698 in March 1974 (AM peak inbound on the busway) to 1,050 in November 1974, well after the shortage had eased. Of busway bus riders in 1974, 19% had no car or did not drive, compared to 30% for other bus riders in the corridor. Among the "choice" busway bus riders, 57% started using their present bus because of a residence or workplace location change, 19% made the trip previously as a solo auto driver, 11% were in carpools, 8% used a different bus, and 5% reported other travel means. The top 4 reasons for carpooling among busway carpoolers in 1974 were commuting cost savings, express lane availability, carpool parking privileges, and the convenient work location of other carpoolers. Some 85%-90% reported having special carpool parking privileges at work. Among carpoolers using the busway, 28% were prior bus riders, and of the carpoolers specifically attracted by busway availability, 32% previously rode the bus.

401. Metropolitan Council of the Twin Cities. I-35W Urban Corridor Demonstration Project. Final Report. Prepared for Urban Mass Transportation Administration, U.S. Department of Transportation; Project No. DOT-FH-11-7953. August 1975. 445 pages. NTIS PB-247-663. EXPRESS TRANSIT*, POOL/BUS PRIORITY FACILITIES, BUS ROUTING/COVERAGE, TRAFFIC OPERATIONS IMPROVEMENTS, POOL/TRANSIT FRINGE PARKING. OBSERVED RESPONSE. MODE CHOICE, AUTO OCCUPANCY. ENVIRONMENT.

A demonstration project involving the operation of an expanded express bus system on 16 miles of metered urban freeway was initiated in October 1972 on I-35W between downtown Minneapolis and its southern suburbs. The project covered 3 phases: 1) Fall 1972, when limited express bus service existed in the corridor; 2) December 1972 to April 1974, when full express bus service operated using regular mixed traffic facilities; and 3) April 1974 to December 1974 when the operation included comprehensive ramp metering, a real-time surveillance, command, and control system, and priority access to the freeway for express buses. Express bus service was increased from 11 express routes with 36 morning and 31 afternoon trips in phase 1, to 18 express routes with 118 morning and 107 afternoon trips in Phase 3.

The data collection for each phase was in the fall of the year, and covered a study corridor about 5 miles wide. Included were vehicle volume and occupancy counts, travel time and delay runs, ramp queue length and signal length observations, auto-user and transit-user post-card origin-destination surveys, and telephone attitudinal surveys. Gasoline shortages and price increases occurred between Phase 2 and Phase 3 data collection, but 15%-30% traffic increases on metropolitan freeways overall between December 1972 and December 1974 indicated that impact on the project was probably minimal.

Mean travel times on the freeway rose between Phase 1 and Phase 2 along with vehicular volumes, but dropped upon Phase 3 introduction of the metering system. Travel time variance did the same, but with marked Phase 3 improvement over Phase 1. Non-priority vehicle delays at metered ramps ranged from 0.1 to 2.5 minutes during the peak period, but these delays averaged less than the time savings on the freeway. No significant speed changes were observed on parallel arterials. The priority access, designed to avoid meter queues, worked best at exclusive ramps. Dual ramps and widened ramps had bus access problems when queues extended onto surface streets. Implementation of express bus service in the corridor produced scheduled travel time savings over local service ranging from 25% to 50% between outlying areas and the CBD. In the corridor, screenline averages near the CBD for peak period vehicular volumes (6:30-9:00 AM inbound plus 3:30-6:30 PM outbound), corresponding auto occupancies, and daily transit patronage changed as follows:

Phase	Peak Period Volumes and Auto Occupancies: I-35W		Arterials		Total		Daily Transit Patronage: Express	Local	Total
1	23,700	1.32	12,800	1.33	36,500	1.32	2,100	22,300	24,400
2	24,200	1.30	14,000	1.33	38,200	1.31	5,400	20,800	26,200
3	24,100	1.28	13,200	1.31	37,300	1.30	7,100	20,400	27,500

In the corridor, from Phase 1 to Phase 3, AM peak period inbound transit modal split to the Minneapolis CBD increased from 33% (28% local bus and 5% express) to 39% (24% local bus and 15% express). The corresponding auto driver modal split decreased from 48% (23% arterial and 25% I-35W) to 43% (21% arterial and 22% I-35W). The most important factors affecting the travel mode decision as reported by I-35W bus riders were total travel time, frequency of service, and closeness of bus stops to home and work, with cost having lesser importance. Eighty percent of express bus users reported they had a car available to them. Availability of transit was cited to be important in the locational selection of a home by 83% of the local transit users and 67% of express transit users.

533. Rose, Harry S. and David H. Hinds. "South Dixie Highway Contraflow Bus and Car-Pool Lane Demonstration Project." Transportation Research Record. Transportation Research Board, Washington, DC. Number 606. 1976. Pages 18-22. EXPRESS TRANSIT, POOL/BUS PRIORITY FACILITIES, BUS ROUTING/COVERAGE. OBSERVED RESPONSE. ACCESS MODE CHOICE, AUTO OCCUPANCY, VOLUME.

This report covers the first 9 months of operation (July 1974-April 1975) of express buses operating on a 5.5 mile arterial contra-flow bus lane on Miami's South Dixie Highway (U.S. 1). In addition to the bus lane, a parallel with-flow carpool lane was established. The local transit authority developed 5 new bus routes and expanded one existing one, increasing the number of peak-period bus trips in the corridor from 10 to 61. Several shopping center lots were designated as park/ride lots and a 200 space lot, at which all express buses stopped, was specially constructed for the project. Feeder buses linked the express service to outlying residential areas. The highway section involved contained 15 signalized intersections and numerous curb cuts. The operation of the priority lanes has subsequently been altered such that both buses and carpools now use the with-flow lane.

Morning bus riders were surveyed via handback questionnaires. Of the 960 surveys distributed, 77% were returned. Daily ridership counts were conducted throughout the project on all bus trips. In addition, carpoolers, general lane users, and local businesses were surveyed as to project impacts.

Transit ridership in the corridor increased 5-fold, from 400 to 2,100 trips/day, as compared to a 6-fold increase in the number of bus trips. Express buses using the priority lane saved 15-20 minutes over prior local bus service and traveled to the CBD 11 minutes faster than autos in the general lanes. The combination of express service and carpools on priority lanes enabled the highway to carry 2,400 more persons/day in 350 fewer vehicles. Despite the time saving accruing from use of the bus lane, 77% of new transit riders cited convenience as a reason for using the bus as compared to 47% citing speed, indicating that the nature of the express service may have been somewhat more important to the users than the exclusive lane. Low cost was mentioned as a reason by 49% of new riders. Prior travel mode of express bus riders was:

Single occupant auto	-	65%	Bicycle	-	3%
Carpool	-	12	Other	-	3
Bus	-	17			

Mode of access to the bus was:

Walk	-	36.5%	Bus	-	1.5%
Auto driver	-	45.0	Bicycle	-	0.7
Auto passenger	-	15.8	Other	-	0.5

The specially constructed park/ride lot was filled to its 200-car capacity nearly every day and was the boarding location of 16.3% of the inbound riders, some driving over 10 miles to reach it. Express bus riders were younger and had much higher incomes than the system average. Work trips comprised 94% of trips taken on the express buses.

691. W.C. Gilman and Co., Inc. The Radial Express and Suburban Crosstown Bus Rider. Sponsored by U.S. Department of Housing and Urban Development, Project No. INT-MTD-8. 1966. 232 pages. EXPRESS TRANSIT*, TRANSIT MARKETING/BROKERAGE, BUS ROUTING/COVERAGE. OBSERVED RESPONSE. MODE CHOICE, ACCESS MODE CHOICE, VOLUME.

Between May 1964 and May 1965, 7 express bus routes linking St. Louis, MO with its suburbs were operated as a demonstration project. The routes varied between 11.5 and 26.0 miles in length and between 29% and 47% of the total route mileage was operated in a local mode. The express portion of the routes operated on arterial streets with the exception of 1 route that operated for 15 miles on a freeway and 2 routes that operated for 4.5 miles on limited access highway. No priority facilities or park/ride lots were employed in the demonstration. All routes made 3-4 stops along the express portion. All buses were airconditioned and a premium of 10¢ above the regional 25¢ fare was charged. Six of the routes ran 6 peak-period, peak-direction trips while the seventh operated 3 peak-period peak-direction trips. Marketing/promotional activites included news stories, advertising and house-to-house distribution of schedules and complimentary tickets. After the demonstration, 1 route was eliminated, 1 modified slightly and the remaining 5 operated unchanged. There was minimal competition from local buses.

Data was collected from 8,000 home interviews in the market areas, 1,200 on-board interviews and quarterly boarding/alighting counts. Express patronage in thousands of revenue-passengers and percent of service area transit trips carried by express buses are listed below by route for the four quarters of the one year demonstration project:

	Express Patronage (000)					% Transit
Route	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Total	Via Express
1	27.1	30.9	31.6	33.7	123.3	66.7%
2	19.6	23.6	25.4	28.0	96.6	24.5
3	19.3	23.2	24.5	28.0	95.0	32.2
4	20.3	21.4	21.9	23.1	86.7	26.2
5	5.8	8.4	8.7	9.2	32.1	30.8
6	8.8	13.8	13.4	15.3	51.3	41.4
7	8.1	12.1	12.9	12.5	45.6	81.8
Total	109.0	133.5	138.4	149.7	530.6	42.6

The two routes with the highest patronage were those with the highest proportion of local mode operation. Route 5 was the only route to travel extensively on freeways and operated only half as many runs as the other routes. Route 7 had the lowest proportion of local mode operation. Listed below are the range and average of prior mode and access mode of express bus riders. There was no difference in these measures relating to freeway operation or proportion of route operating in local mode.

Prior Mode			Access Mode		
auto driver	15.8%	(9.2-21.1)	walk	87.6%	(73.7-94.8)
auto passenger	12.3	(2.5-37.7)	auto	7.6	(3.4-16.9)
transit	60.1	(26.4-79.2)	bus	4.4	(1.2- 9.5)
other	11.8	(4.5-24.2)	other	.2	(0- 1.2)

No change in mode split in the service areas was reported. The auto/transit split during the project was 89%/7%. Overall the express services attracted 1000 new riders and improved service for 1650 retained riders. The authors related ease of express route access and competition from other bus services to trips attracted as tabulated below. The existence of large suburban employment centers near express routes resulted in attraction rates at the lower end of the scale.

Access	Transit Competition	Trips/100 dwelling units
good	none	11.0-17.6
good	local feeder	5.6-10.2
good	radial local	5.6-7.9
good	radial express	5.0-7.5
poor	none	2.1-5.5
poor	local feeder	3.5-3.6
poor	radial local or express	2.7-3.9

relationship equates to a fare elasticity[a/] of -0.40[b/], illustrated in Figure 20.

Evidence continues to accumulate that the Curtin Rule adequately describes average patronage loss from fare increases affecting typical, predominantly line haul, urban bus operations (149, 188, 346[+], 454*, 542[+], 634). Variations from the mean are of significant interest, however, and will be further discussed. The average shrinkage ratio for 281 fare increases in 114 U.S. cities between 1950 and 1967 was -0.33, same as the Curtin Rule, but only 12 percent were between -0.31 and -0.35 and the range was from -0.004 to -0.97 (188).

Comparison of mean surface transit fare elasticities for different countries emphasizes the consistency of average response, as shown in the following tabulation (71):

	Fare Elasticity	Number of Values	Standard Deviation
U.S. (fare reductions and increases)	-0.41	35	±0.05
U.S. (fare increases only)	-0.28	16	±0.03
Great Britain	-0.30	79	±0.02
West Germany	-0.34	13	±0.04
Other Countries	-0.32	5	±0.10

Figure 20 illustrates the foreign values given above in comparison with the -0.4 arc elasticity equivalent of the Curtin Rule. When rail transit fare change response results are included in the computation of an average fare elasticity, the mean elasticity is lowered. An overall average fare elasticity of -0.28 has been derived from 67 primarily U.S. and English bus and rail cases. Apparently neither the magnitude of the initial fare nor the percentage increase has any discernable effect on the fare elasticity (384).

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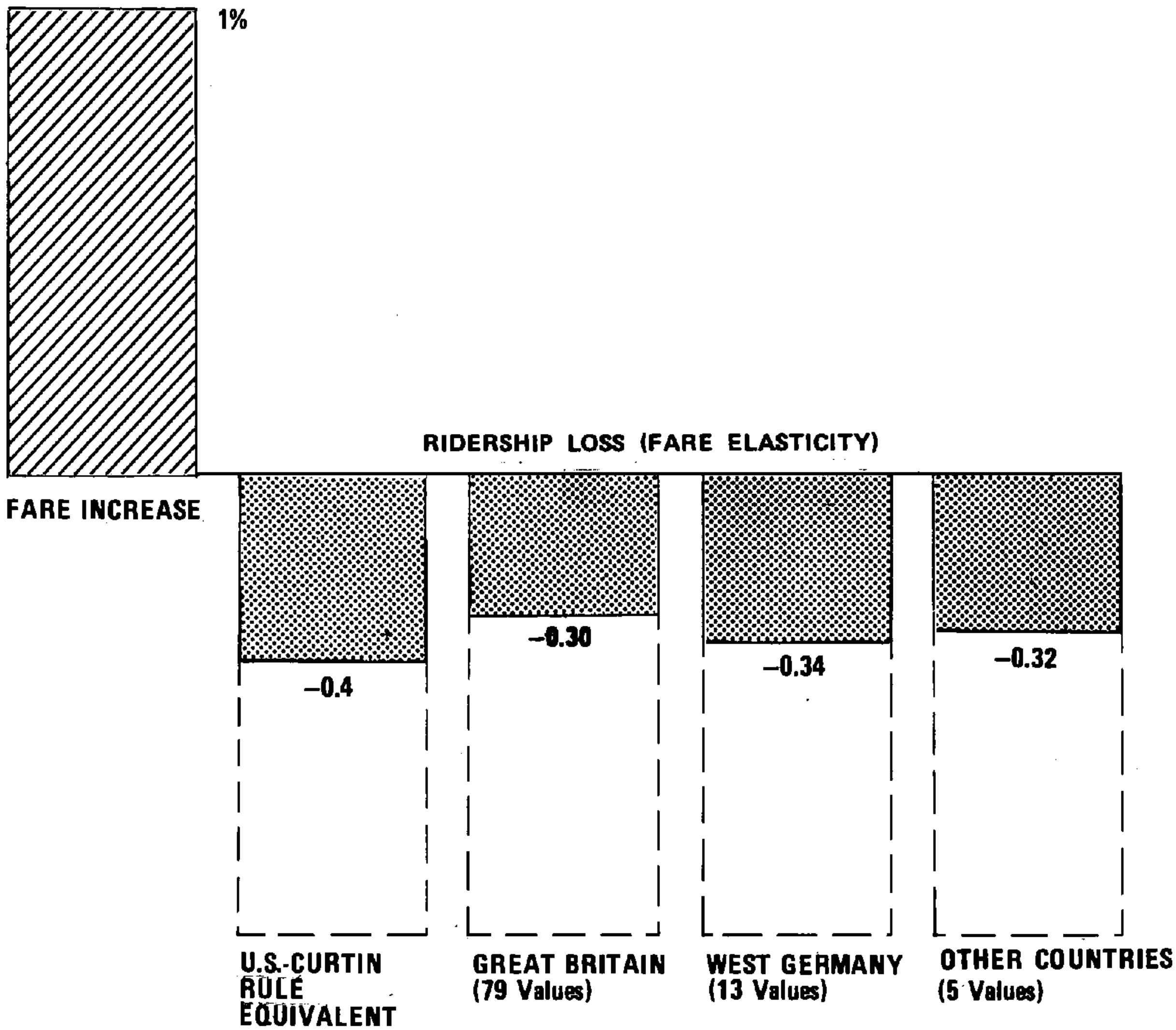
a/ The measure "fare elasticity" indicates the percentage change in ridership observed or expected in response to a 1 percent change in fare. An elasticity of -0.40, for example, indicates that a 1 percent fare increase has caused or is expected to cause a 0.40 percent loss in ridership. The negative sign indicates that the effect operates in the opposite direction from the cause. When the fare goes up, patronage goes down, and vice versa. See the "Concept of Elasticity" section of Chapter 1 and Appendix A for definition and discussion of elasticity measures. Except as noted, all elasticities given in this Handbook are midpoint or logarithmic arc elasticities, or closely comparable point elasticities.

b/ The Handbook authors computed that for prior fares between 10 cents and 45 cents, the revenue loss as estimated by the Curtin Rule would equate to a midpoint arc elasticity value of between -0.39 and -0.41.



NOTE: VALUES FROM SOME FARE DECREASES ARE INCLUDED IN THE FOREIGN DATA, BUT FARE INCREASES PREDOMINATE.

Figure 20
Mean Bus Fare Elasticity Values

Response to Fare Reductions

Disagreement exists as to whether or not the traveler response observed with respect to fare increases will hold in reverse for fare decreases (71, 174, 188, 277). However, available data gives little evidence to support the hypothesis that patronage losses due to fare increases cannot be regained.

Fare elasticities for demonstration projects where the effect of reduced fares may have been confounded by that of improved service range all the way from -0.16 to -1.56 (71). The following list of fare reduction elasticity results include only situations where service remained constant or where the fare elasticities were estimated after allowing for the effect of service changes (71, 229, 322, 430*):

Atlanta (1972)	-0.15 to -0.20
Cincinnati (1973)	-0.38
San Diego (1972-1975)	-0.51
St. Louis (1973)	-0.20

In Kansas City, a fare reduction from 50¢ to 40¢ failed to stem an annual ridership decline of 6 percent per year (188). However, excepting the extremes, the available observations indicate that a 1 percent fare reduction will cause a 0.15 to 0.50 percent increase in transit ridership. They are consistent with the fare elasticities illustrated for fare increases in Figure 20.

Further support for the conclusion that the ridership response and associated elasticities for fare decreases do not differ significantly from those for fare increases is provided by a recent study which selected for comparison only observations from cities of similar size. The results were as follows (384):

Type of Fare Change	Mean Fare Elasticity	Number of Cases	Standard Deviation
Fare increases	-0.34	14	±0.11
Fare decreases	-0.37	9	±0.11

Traveler response to inflation effects has only been examined in Great Britain. In London it was found that over time a 1 percent increase in retail prices and earnings was associated with an increase in transit receipts of about 0.35 percent, equivalent to a fairly typical fare elasticity of -0.35. This and a similar analysis in Sunderland concluded that elasticity with respect to real fares decreasing due to inflation is the same as with respect to a fare increase (71). This very limited evidence tends to support the view that small fare increases scale with inflation should have no long term effect on ridership.

Response to Free Transit

Free fare experiments and permanent programs have produced no significant evidence that traveler response to fare elimination is dramatically different from the corresponding response to fare reduction. The mean fare elasticity for 12 free-fare programs, including off-peak only and intra-central business district applications, is -0.38. However, the same study that developed that average concludes that with the exception of intra-CBD applications, free fare elasticities are generally lower than reduced-fare program elasticities (384).

Implemented area-wide free-fare programs have been applied only in the off-peak period in large cities, and are discussed in the next section, "Response to Off-Peak Fares." A research study of free transit service implications estimated that total elimination of fares in the Boston area would increase ridership by about 28 percent, or 32 percent when the feedback effect of necessary increases in service frequency were included (109+).

Reported observed results in smaller cities include the following (231, 322, 542+, 678):

City	Action	Findings
Auburn, NY	One month elimination of 25¢ fare	Monthly patronage increased from 18,000 to 88,000
Wilkes-Barre, PA	Imposition of 15¢ flat fare after 3 months free transit following flood	Ridership decreased 17%
Commerce, CA	Free transit	7 to 8% of population uses transit daily (double the average for comparable size towns)
Salem, OR	Elimination of 30¢ fare for downtown commuters (with registration requirement)	Commuter ridership increased 43%
Amherst, MA	Expansion of free university bus service into surrounding community	Attracted 4,000 daily riders (40% prior auto drivers)

Portland, OR and Seattle, WA have instituted fare-free service for trips taken entirely within the central business district on regular bus service. Both programs involved elimination of dime-fare downtown shuttles. In Portland, a nine-fold ridership increase was roughly estimated for intra-CBD trips after an average fare of 22.5¢ was abolished and major service improvements were made (122). In Seattle, surveys showed that free intra-CBD transit resulted in a three-fold increase after eight months over the intra-CBD ridership previously carried on all buses (123*). Surveys in both cities evidenced a small favorable impact on paid transit usage.

Response to Off-Peak Fares

Since uniform fare changes typically affect off-peak more than peak riding, it follows that changes leading to off-peak fares lower than peak fares should further enhance off-peak transit use relative to peak use. Available experience is listed in Table 38. Note that the Madison, Denver and Trenton cases involve off-peak free transit. Denver and Trenton reported 87 percent and 45 to 50 percent off-peak ridership increases with 24 percent and 8 percent peak ridership reductions, respectively[c/] (129, 188, 239, 377#, 440#, 592*). Analysis of the Denver and Trenton demonstration results indicates that low fare elasticities were obtained in these particular experiments; -0.29 and -0.19 respectively (384).

Changes in peak to daily ridership ratios can be extracted from Table 38 as follows:

	Before Ratio	After Ratio	Percent Decrease
Louisville	0.45	0.33	27%
Denver	0.50 (assumed)	0.30	40
Trenton	0.68 (estimated)	0.55	19

This magnitude of reduction in the daily peaking of ridership represents a significant leveling of transit demand in response to differential peak/off-peak fares. Off-peak versus peak effects of fares kept uniform throughout the day are covered in the section, "Temporal Response to Fare Changes."

Senior Citizen and Paratransit Fare Changes

Reduced fare programs for senior citizens have not engendered major transit usage increases by the elderly. In 16 of 90 such programs studied in the United States, the reduced fare had little or no effect on the number of elderly passengers. Table 39 gives fare elasticities and other information for those programs which did produce and also quantified a change in senior citizen ridership (188). The average senior citizen fare elasticity indicated is -0.21, adjusting to reflect the 18 percent of all cases with zero elasticity.

Reduced fares for the elderly effective only in the off-peak typically produce a shift of elderly riders from the peak to off-peak period. In Pittsburgh a 45 percent off-peak fare reduction for the elderly increased off-peak senior citizen riding by an estimated 51 percent, and decreased peak riding by 19 percent. In Milwaukee, 14 percent of elderly passengers switched from peak to off-peak riding, and in Los Angeles about 10 percent shifted (188, 536*).

The very limited experience to date with paratransit system fares and fare changes does not allow generalization with respect to fare elasticity but does suggest that the service characteristics are more important than the fare. Fare changes have provided the following fare elasticity observations (188, 390):

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c/ Prior to the off peak free-fare demonstration, Denver already had a lower off-peak fare (25¢) than peak fare (35¢ the previous year, 50¢ the previous month). Trenton likewise had a lower off peak fare (15¢) than peak fare (30¢).

Table 38
Off-Peak Fare Reduction Experience
(188, 239, 377#, 440#, 592*)

City	Fare Changes	Ridership Impact	Off-Peak:Peak Ridership Ratio [1/]
Austin, TX	Off-peak: 30¢ to 15¢ Peak: 30¢ retained (with service improvements)	30% increase overall (entire day)	51:49 with off-peak differential
Louisville, KY	Off-peak: 50¢ to 25¢ Peak: 50¢ retained	7% overall (adult ridership) or 25% relative to historical trend	55:45 before fare differential 67:33 with off-peak differential
Lowell, MA	Off-peak: 25¢ to 10¢ Peak: 25¢ retained	No discernable increase overall	24:76 [2/] before fare differential 27:73 with midday differential
Madison, WI	Free off-peak Service for one week	93% increase overall	(not reported)
Denver, CO	Off-Peak: 25¢ to free Peak: 35¢ to 50¢ (just prior to free fare demonstration)	34% increase overall 87% off-peak increase 24% peak decrease	50:50 without free fare (assumed) 70:30 with off-peak free fare
Trenton, NJ	Off-Peak: 15¢ to free Peak: 30¢ retained	10-15% increase overall 45-50% off-peak increase 8% peak decrease	32:68 without free fare (estimated) 45:55 with off-peak free fare

1/ Peak period definition may vary from city to city.

2/ Midday (10:00 AM-2:00 PM) : Rest of Day

Table 39
Selected Senior Citizen Fare Reduction Results
(188)

Location	Fare (Regular/ Senior Citizen)	Hours	Increase in Elderly Riders	Effect on Revenue (Annual)	Log Arc Elasticity[1/]
Albuquerque, NM	30/20¢	All Hours	23%	NA	-0.51
Baltimore, MD	30/15	Off-peak Hours	8	$600,000 loss	-0.11
Euclid, OH	25/15	All Hours	7	NA	-0.13
Los Angeles, CA	22.5/15	Off-peak Hours	24	$130,000 loss	-0.53
Madison, WI	25/15	All Hours	20	NA	-0.36
Milwaukee, WI	50/25	Off-peak Hours	9	$750,000 loss	-0.12
Montebello, CA	25/15	All Hours	less than 1%	$10,000 loss	-0.02
Pittsburgh, PA	34/19 (avg.)	Off-peak Hours	21	$630,000 loss	-0.33
Providence, RI	35/20	All Hours	2	NA	-0.04
South Bend, IN	30/15	Off-peak Hours	20	NA	-0.36
Torrance, CA	35/20	All Hours	30	$ 6,000 loss	-0.21
Washington, DC	40/25	Off-peak Hours	26	$250,000 loss	-0.49

1/ Elasticities calculated by Handbook authors.

Note: Cases with no ridership change reported are excluded (18% of all cases)

Location	Service Type	Fare Elasticity
Ann Arbor, MI	Dial-a-ride vans	-0.44
Benton Harbor-St. Joseph, MI	Dial-a-ride vans	-0.09
Levittown, NY	Shared-ride taxis	-0.81
Midland, MI	Dial-a-ride vans	-0.37
Danville, IL (full-fare riders)	Shared-ride taxis	-0.54
Bay Ridges, Ontario	Dial-a-ride	0.00

Widely varying responses to taxi fare increases are noted. However, an inelastic relationship between ridership and taxi fares is believed to exist, which is to say that the change in ridership should be less than the relative change in fare (212).

Response to Fare System Restructuring

Fare decreases in the U.S. have tended to include fare system restructuring, typically conversion from zone to flat fares and/or elimination of transfer charges. This type of restructuring speeds up fare payment, makes the fare easy to remember and favors longer trips. The effect on ridership has generally been masked, however, by the impact of the overall fare reductions. Findings concerning the impact of exact fare systems on ridership are also inconclusive (15#, 122, 683+, 692*).

Rationalization of previously uncoordinated fares in Stockholm, Sweden, into a zone system with a monthly universal pass (1973 cost, approximately U.S. $12.15) led to use of the pass for 70 percent of all passenger trips. Patronage rose 5 percent, primarily reflecting increased lunch time and weekend travel (322). Pass systems in the U.S. are less well used but are growing in popularity in connection with fare prepayment. (See "Response to Area-Wide Fare Prepayment" and "Response to Employer-Based Fare Prepayment" within the digest "Transit Marketing/Brokerage.")

Barrier-free fare collection schemes, widely used in Europe, have induced an average of over 50 percent of all passengers to use multiple journey payments and may have speeded service by as much as 10 percent. These schemes work on a self-service honor system reinforced by roving inspectors. The reported percentage of passengers defrauding the system averages 0.5% (470).

Temporal Response to Fare Changes

Even without differential peak/off-peak fares, fare changes affect the distribution of transit riding over the hours of the day and the days of the week. Fare increases typically affect off-peak transit patronage more adversely than rush hour riding, and fare decreases similarly cause larger percentage ridership increases in the off-peak than in the peak.

The sensitivity of off-peak ridership to fare changes averages about twice that of peak ridership.

Reported off-peak versus peak period patronage changes resulting from lowered fares and associated service improvements, or fare increases, include (277, 346+, 352+, 454*):

	Peak	Midday	Evening
New York (1966, subway patronage)	2-5%	8%	15%
New York (1975, subway patronage)	4	6	7
		Off-Peak	
St. Louis (effect of off-peak senior citizen fare included	8-10	24-26%	
Denver (1971, 5 bus routes, effect of off-peak senior citizen fare included)	10	25	

The fare change in each of these cases was uniform except for the senior citizen fares noted. Similar impacts have been observed in Great Britain, as reflected in the following fare elasticities (71, 428):

	Peak	Off-Peak
Stevenage	-0.27	-0.87
London	-0.20	-0.40

The provision of free intra-CBD transit in Portland and Seattle resulted in substantially increased transit usage during the midday period, especially during the conventional lunch hour. Weekend transit use typically responds more to fare changes than weekday riding, although exceptions have been reported for St. Louis and Sunday riding in New York (277, 346+, 454*). For the Atlanta fare reduction, the reported ridership increase over trend line patronage was 28 percent on weekdays, 41 percent on Saturdays, and 79 percent on Sundays (50*).

Most mode choice models calibrated on cross-sectional survey data show work purpose trips to be less sensitive to fare changes than non-work trips (109+, 188, 604). A cross-sectional analysis of data from 30 British towns identified fare elasticities of -0.19 for work trips and -0.49 for non-work trips (428). These findings correlate with the observed greater impact on off-peak riding.

Modal Response to Fare Changes

Rail rapid transit ridership appears to be about twice as resistant to fare increases as local bus patronage, as indicated overall by the following fare elasticity comparisons (346+, 384, 454*).

	Fare Elasticity		Transit Fare		Ridership Loss	
	Bus	Subway	Before/ After	Percent Increase	Bus	Subway
New York (1966)	-0.36	-0.08	15¢/20¢	33%	9.9%	2.4%
New York (1975)	-0.32	-0.14	35¢/50¢	43%	10.7%	5.0%
New York (six cases, 1948–77)	-0.32	-0.16		N.A.		
London (1966-76) 1/	-0.33	-0.16		N.A.		
Paris	-0.20	-0.12		N.A.		

1/ Time-series model results.

Available findings with respect to commuter rail ridership are sparse and less consistent, but probably are indicative of a similar pattern. The following fare elasticities have been calculated for observed commuter rail fare decreases and increases (260, 377#, 384):

	Commuter Rail	Bus
Boston	-0.09 1/	N.A.
Boston (off peak)	-0.31	-0.65
Australia	-0.18	N.A.

1/ Arc elasticity computed by the Handbook authors

Higher commuter railroad fare elasticities have been estimated using various modeling techniques, but the values obtained stand in conflict with demonstration results which give evidence of a low rider sensitivity to commuter rail fares (377#, 574#). (See "Frequency Changes with Fare Changes" in the topical digest "Transit Scheduling/ Frequency" for additional information concerning commuter rail fare changes.)

In contrast to rail fare elasticities, scattered evidence indicates that patronage on bus feeder services to rapid transit is significantly more sensitive to fare increases than regular bus patronage (346+, 454*, 509). Fare response information with respect to express bus service is extremely limited and inconclusive. A St. Louis fare reduction study found that within an overall -0.20 fare elasticity calculated for a 1973 fare reduction, express bus routes exhibited a higher elasticity of -0.36 as compared to -0.19 for local bus routes (430*).d/ On the other hand, comparisons in the Virginia

d/ Log arc elasticities computed by the Handbook authors from the reported fare change and ridership response summaries.

suburbs of Washington indicate fare elasticites of -0.27 and -0.53 for priority freeway lane express service as compared to -0.74 for mixed local and express service on an arterial street (384).

Area Type Response to Fare Changes

Small cities typically exhibit higher fare elasticities than larger urban areas though contrary findings have been reached (174, 188, 634). Shrinkage ratio averages computed for almost 500 individual fare changes in differing city size categories tend to support the hypothesis that ridership sensitivity to fare changes increases with decreasing city size. As shown below, the case is stronger with respect to the more recent data (384):

Population of Principal City	Average Shrinkage Ratio 1947-52	1960-61	1961-67
More than 500,000	-0.34	-0.28	-0.22
100,000-500,000	-0.36	-0.33	-0.32
Less than 100,000	-0.33	-0.36	-0.43
All cases	-0.35	-0.32	-0.35

Limited evidence also indicates suburban bus ridership to be more sensitive than center city bus ridership as shown by the following fare increase observations (277):

	Suburban Bus Fare Elasticity	Center City Bus Fare Elasticity
York, Pennsylvania (1948)	-0.65	-0.46
Springfield, Massachusetts (1949)	-0.34	-0.29

Other reported differential responses to fare changes include variance of fare elasticity with respect to service quality and trip length. In small Iowa cities fare elasticity was found to be inversely proportional to the quality of transit service provided. In London studies, and in U.S.A. free-fare programs as well, trips short enough for walk to be an alternative mode (less than 1 mile) were found to be more sensitive to fare changes than intermediate distance trips. The relationship with respect to long trips (over 3 miles) is less clear (384). The various types of observed differential responses to fare changes are summarized graphically in Figure 21.

Fare Changes with Service Changes

Fare decreases in combination with service improvements obviously lead to greater ridership increases than would result from fare changes alone. Three months after a 32 percent fare reduction and a 6 to 9 percent service increase in Los Angeles, patronage was up 17 percent (692*). Eight months after fare reductions and service improvements in Atlanta, ridership was 30 percent above what it would otherwise have been given the previous downward patronage trend.

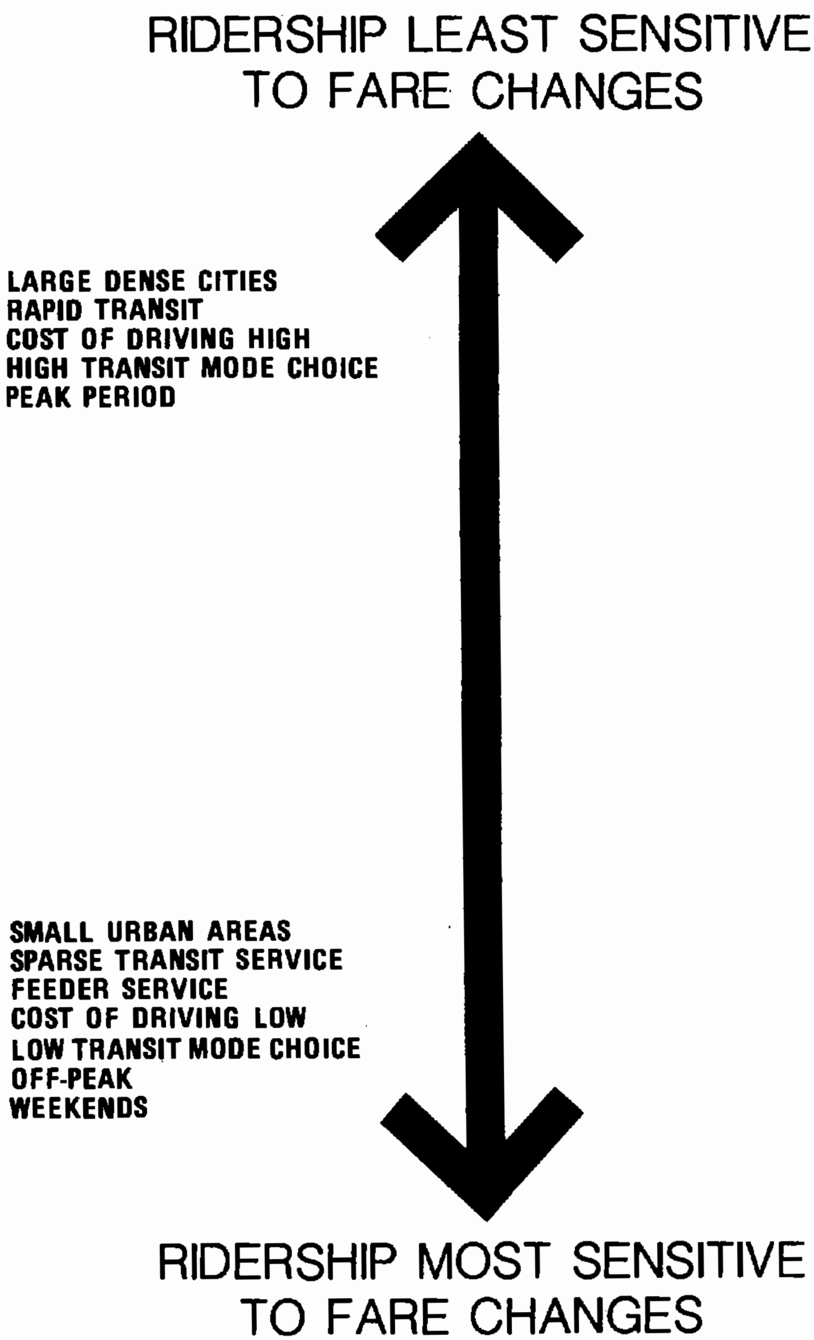


Figure 21
Observed Differential Responses to Fare Changes

Fifty-two percent of new riders in Atlanta said they shifted to bus because of the low fare (50*). Application of mathematical models to quantify causality indicated that roughly two thirds of the increase is attributable to the fare reduction. However, these findings do not necessarily show that fare reductions are more effective than service improvements in increasing ridership. On the contrary, the patronage gain obtained in Atlanta for each one percent of fare reduction (fare elasticity) is estimated to be only one half to two thirds the patronage gain achieved with each one percent of increase in service as measured by bus miles operated (service elasticity) (322).

The following comparisons between observed fare and service elasticities have been reported (188, 229, 322, 428):

	Fare Elasticity	Service Elasticity	Service Measure Used
Atlanta	-0.15 to -0.20	+0.30	bus miles
San Diego			
all routes	-0.51	+0.85	bus miles
established routes	-0.67	+0.65	bus miles
17 U.S. Transit operators	-0.48	+0.76	bus miles/capita
12 British bus operators	-0.31	+0.62	bus miles
30 British towns			
work trips	-0.19	+0.58	bus miles/capita
non-work trips	-0.49	+0.76	bus miles/capita

Excepting "established routes" in San Diego, these observations all indicate that ridership is one-third to two-thirds as responsive to a fare change as it is to an equivalent percentage change in service.

Underlying Traveler Response Mechanisms

The concept of transit captivity (discussed under "Demographic Considerations" in Chapter I) is useful in explaining certain observed traveler responses. The existence of a body of transit riders who must make certain necessary trips and who cannot readily switch to auto use helps explain why the response to fare changes is not larger in terms of rides lost or gained. It also provides one possible explanation of why fare increases affect suburban transit and express bus ridership more than central city ridership given that the proportion of the low income residents and hence the prevalence of transit captives is normally higher in the inner city.

However, transit captivity alone cannot explain several of the phenomena reported, including the observations that response to fare changes is greater in small cities than in large ones, and lesser for rapid transit than for bus transit. Variance in the competitive position of transit vis-a-vis auto travel seems to provide a more consistent explanation of differences in fare elasticities. Where transit service is fast or at least frequent and auto parking charges are high, transit mode choice is also high and fare changes cause the least impact. This occurs, for example, in the larger metropolitan areas, in central cities, and on rapid transit in particular. Where transit service availability is marginal and auto use is easy and inexpensive, transit mode choice is low and fare changes have greater relative patronage impact. These situations occur particularly in small cities, in suburban areas, on feeder service, and during off peak periods.

Differentation between non-discretionary and discretionary travel helps explain other phenomena, particularly the greater sensitivity to fares of off-peak travel. Work trips, which are largely mandatory, predominate in the peak. Non-work trips, which predominate in the off-peak, are more flexible. Travelers may more easily change non-work trip timing or destination to accommodate auto availability or may elect to forego travel altogether.

Sources of New Ridership

In assessing the impact of the ridership increases attainable from fare reduction or elimination, it is incorrect to assume that new riders are comprised entirely of auto driver trips or even auto driver plus auto passenger trips. Transit ridership gains or losses relfect changes in trip frequency, destination choice and mode choice.

Changes in trip frequency and destination choice show up as "trips not made previously" in rider surveys made after transit fare reductions. Changes in mode choice appear in "after" surveys as trips made previously via a non-transit modes. The list below indicates the source of new riders gained in response to fare reductions or eliminations, often made in combination with service improvements (50*, 123*, 592*, 692*, 699):

	Prior Trip Mode				
	Auto Driver	Auto Passenger	Walk	Other	Trip Not Made Previously
Atlanta					
Fare reduction and service improvement[1]	42%	22%	4%	10%	22%
Los Angeles					
Fare reduction and service improvement	59	21	—	10	10
	Auto				
Trenton					
Fare off-peak fare	16%		23	16	45
Denver					
Free off-peak fare	46		--	22	32
Seattle					
Free CBD fare	12		47	3	38

[1] Weekday new trips. Does not include additional trips by old riders, which comprise 9 percent of the patronage increase.

In Salem, OR, 48 percent of all riders using the free commuter service previously drove alone (678). A sample of prior transit riders in New York City exhibited the following allocation among new modes for the trip to work after a fare increase caused them to shift modes (454*):

Auto driver	41%
Auto passenger	18
Bus (from subway)	14
Walk	16
Other	11

Aside from the Trenton experience, these data suggest that the auto driver mode is the alternate choice of about a third to a half of the riders who shift to and from transit in response to fare changes. Seattle, being a special application, cannot be compared with the other cases.

Since transit ridership is normally a relatively small proportion of areawide urban travel, the impact of fare reductions on auto traffic is also frequently small. Traffic volume reductions have proved too small to measure in reported attempts to identify vehicular traffic changes following fare changes (692*). A Boston-based evaluation of free transit concluded that it is difficult to divert auto drivers to transit by lowering fares and that most diversions would involve work purpose trips. The study estimated that free fares would increase peak hour transit riding by 20 percent and decrease peak hour auto travel by 6 to 9 percent in Boston proper, where the number of peak hour auto and transit travelers are almost equal (109+).

Socioeconomic Group Responses

Where significant socio-economic differences have been identified, it has been noted that new bus riders attracted by overall fare decreases tend to be younger and to have higher incomes and higher car ownership than previous bus riders (50*, 71, 592*, 692*). The effects of sex and race on traveler response are inconclusive (174, 337, 454*) and are probably overshadowed by income and employment effects. A somewhat greater degree of work trip mode shifting in response to the 1975 New York City fare increase was found among those heads of households over 35 years old, or with income over $15,000, or with 13 or more years of education, or owning one or more autos (454*). The Denver and Trenton off peak free fare demonstrations have produced the following fare elasticities stratified by income and age group (384):

Household Income	Denver/Trenton Fare Elasticity[1/]	Age Category	Denver/Trenton Fare Elasticity[1/]
Under $5,000	-0.18	1 to 16 years	-0.32
$5,000 to $9,999	-0.17	17 to 24	-0.27
10,000 to 14,999	-0.33	25 to 44	-0.18
15,000 to 24,999	-0.18	45 to 64	-0.15
25,000 or more	-0.37	65 or more	-0.14

1/ Mean value of Denver and Trenton off-peak fare elasticities

These results show a tendency toward higher sensitivity with increasing income and definitely support the hypothesis that younger age groups respond more to fare changes, or at least to fare reductions. The Denver and Trenton demonstrations also show smaller changes in transit use among transit captives and in lower auto ownership groups, as tabulated below (384):

Denver		Trenton	
Rider Category	Fare Elasticity	Autos Owned	Fare Elasticity
Captive	-0.25	0	-0.11
		1	-0.22
Choice	-0.31	2	-0.21
		3	-0.30

These and related findings concerning response to fare changes within specific socio-economic groups are generally consistent with the view that fare changes have the greatest effect on use of transit by choice riders, who have other transportation options, and the least effect on transit use by captive riders. One reported exception is in the case of the 1966 New York City subway fare increase, reported to have affected subway ridership most in low income areas (346+). In this case the decision by captive riders to forego certain trips apparently overshadowed any systemwide diversion from transit to auto by choice riders. Another exception is provided by a study of consumer preferences in New York State which concluded that elderly people and autoless people are more sensitive to fare changes than young people and people with autos (174). However, anticipated response has been shown to be sometimes different than the actual response of transit users (454*). The response in such surveys may reflect more the perceived budgetary or life style impact of the fare change than the likely effect on travel mode or pattern.

Impacts on VMT, Energy and Environment

Where transit ridership is low, 5 percent or less of all work trips, the energy impact of modest fare changes is miniscule. For example, studies which modeled traveler response using Fort Worth and San Diego travel patterns concluded that fare system restructuring and fare increases or decreases of 10 percent or less would all have regional auto fuel usage impacts on the order of three hundredths of one percent or less (511#, 590#). Theoretical study of a 50 percent fare reduction or employer subsidy in cities of varying sizes produced the following gross fuel savings and pollutant emissions reduction results for work purpose trips (590#):

	Weekday Areawide Percentage Change[1/]					
	Transit Rides	Auto VMT	Auto Fuel	Auto Emissions HC	Auto Emissions CO	Auto Emissions NOx
Denver	+5.4%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
Fort Worth	+5.7	-0.1	-0.1	-0.1	-0.1	-0.1
San Francisco	+5.3	-0.8	-0.7	-0.7	-0.6	-0.8

1/ Work purpose travel only; negative sign indicates savings/reductions.

The expected impact is relatively greater in cities with heavily developed transit networks, however, it is in these same cities that vehicle loading requirements will necessitate increased frequencies and significantly more transit fuel usage to handle increased patronage. Modeling of a 50 percent overall bus and rail fare reduction in a Chicago context indicated that while a 2.7 percent weekday automotive fuel savings might be achievable, the net fuel savings after accounting for transit fuel would be 0.7 percent. This estimated net savings equates to 18,900 gallons of gasoline per weekday or 5,000,000 gallons annually (511#).

Fare decreases in conjunction with transit service increases have a synergistic effect on fuel savings to the extent that while both divert a measure of travel from auto to transit, service increases tend to produce an excess of capacity that can absorb additional riders attracted by reduced fares (or auto use disincentives). Transit productivity losses can thus be minimized or productivity can even be enhanced. Nevertheless, fare reductions remain an expensive way to conserve energy, if that is the only objective (511#).

Actual combined fare reductions and service increases in San Diego and Atlanta produced the ridership gains, estimated net energy savings and emissions reductions given in the table below (148#). The fuel savings are on the order of one half of one percent of regional automotive fuel consumption.

	Percentage Change in			Weekday Reduction in 1/			
	Fare	Service	Ridership	Fuel (Gals.)	CO (Tons)	HC (Kg.)	Annual Fuel Savings 2/
San Diego	-39%	+29%	+60%	5,000	7.5	400	1,400,000
Atlanta	-60	+16	+28 3/	9,300	13	670	2,700,000

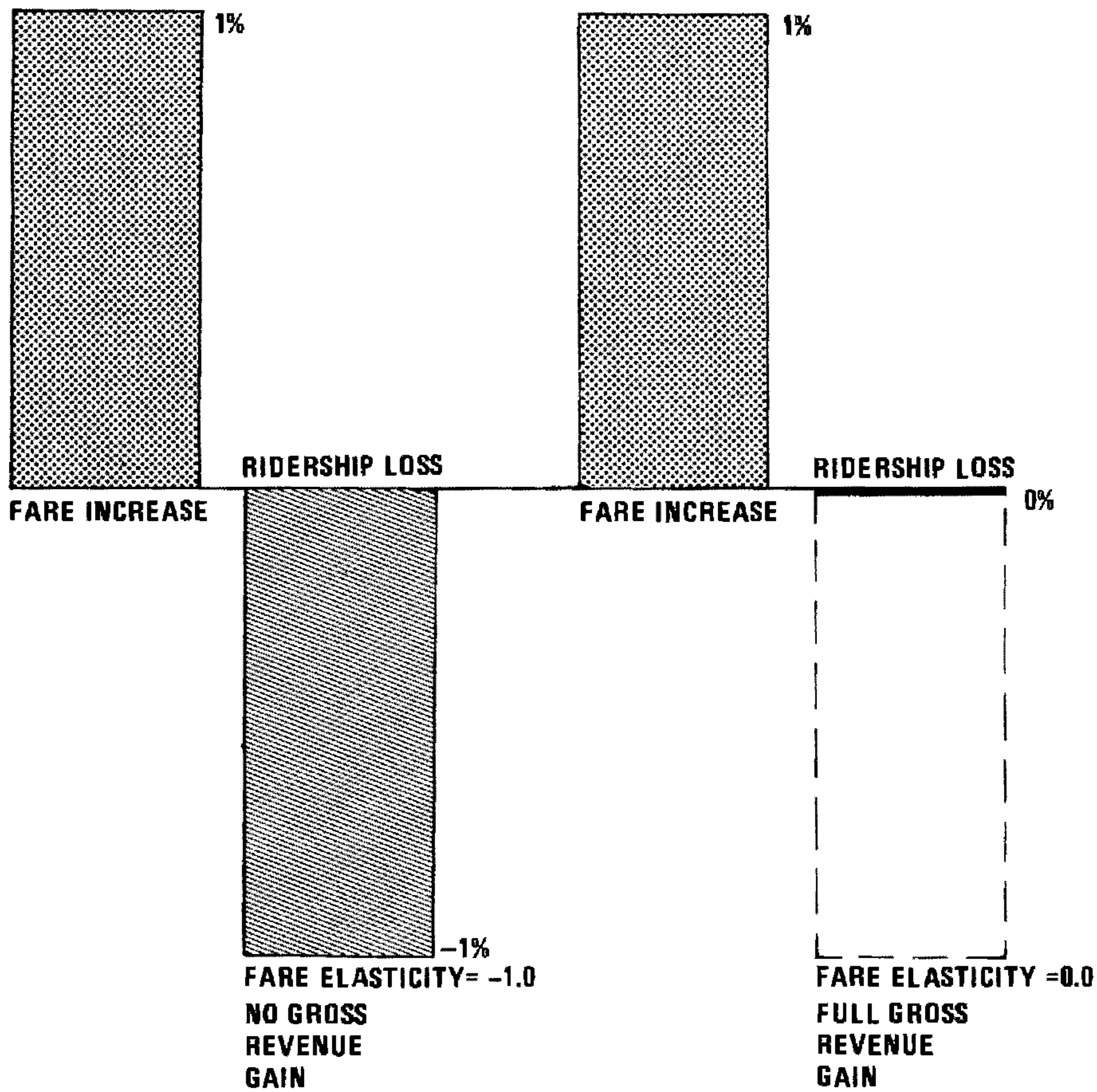
1/ Calculated on the basis of 1975 vehicle characteristics. Bus service measured in bus miles.

2/ Calculated by Handbook authors assuming annual fuel conservation data totals to be the equivalent of 290 weekdays.

3/ Relative to expected ridership given previous trends.

Impacts on Revenues

The hypothetical examples in Figure 22 illustrate that should the fare elasticity be -1.0, a fare increase (or decrease) will cause a ridership loss (or gain) such that there is no change in gross revenue. At a fare elasticity of 0.0, a fare change will not affect ridership, leading to a corresponding gross revenue gain (or loss). These relationships are valid only for arc elasticity or point elasticity calculations and do not hold for shrinkage ratios. Since fare elasticities almost invariably lie between -1.0 and 0.0, an increase in transit fares can be expected to result in some ridership loss, but to still provide increased farebox revenue. Similarly, fare reductions will attract transit trips but also lead to an increased net cost of providing transit service.



(Hypothetical arc elasticity example)

Figure 22
Basic Fare Elasticity/Revenue Relationships

Fare restructuring may provide exceptions or at least come close. Rationalization of fares and use of a monthly universal pass in Stockholm, Sweden, led to both a 5 percent patronage increase and, after an initial decline, an increase in revenues above the original level (322). A study involving several transit systems in New York State concluded that no scheme for lowering off peak fares and raising peak fares could induce increases in both ridership and revenue but that in some instances, a substantial increase in one of the two measures could be realized with only minor losses in the other (698).

Two separate studies investigated the fare level above which declining absolute revenue would occur given further fare increases. This level was estimated to be 45 to 70 cents (1965 dollars) under varying local bus service conditions in the Chicago north suburbs, and 80 cents (1972 dollars) in accordance with an estimating curve pertaining to local bus service in Wilkes-Barre, Pennsylvania. The Wilkes-Barre equation was found to fit the Curtin Rule in the range of normal experience (509, 542+).

Impacts on Costs

Overall, while areawide transit fare reductions increase ridership and produce attendant benefits, they do so at farily high net cost to the provider of transit service (322). The cost is particularly high if the reduction in user costs to those who already rode transit is not considered among the benefits. The national net operating cost of providing fare-free transit was estimated in 1968 to be $2.0 billion annually (109+). Free off peak transit service in Denver cost the system $3.7 million annually in lost revenues, and operating expenses were expected to increase by over $300,000 annually. The Trenton off peak free fare project was estimated to lose $340,000 in revenue annually (129, 592*).

Free intra-CBD service, on the other hand, has proven to be a high visibility, low cost program attractive to business interests. In both Seattle and Portland, less than 1 percent of the transit authority's operating budget is used to subsidize the service (122, 123*).

Selectively reduced fares do provide certain transit operating efficiencies in terms of manpower, equipment, and fuel utilization per passenger carried. When fares were reduced in Los Angeles, for example, the passengers per bus mile increased from 2.62 to 2.75 for the principal operator despite increases in total bus mileage (692*). The achievement of enhanced transit usage must be approached through supplying transit service characteristics seen as desirable by specific markets. This may involve differing degrees of subsidy, and a suitable balance should be sought between fare reductions and service improvements, each of which have net operating costs associated with them (188, 277).

Additional References

"Patronage Impacts of Changes in Transit Fares and Services," by Mayworm, Lago and McEnroe (384), "The Effect of Fares on Bus Patronage" by P.H. Bly (71), and "Public

Transportation Fare Policy," by Dygert, Holec and Hill (188),[e/] provide additional literature and case study review material concerning Transit Fare Changes. For further information on Transit Fare Changes consult references:

10, 15#, 21, 30, 34, 39, 43, 50*, 52, 65, 71, 81, 84, 90, 107, 109+, 119, 122, 123*, 129, 134, 138#, 148#, 149, 150, 152, 156, 166, 174, 177#, 178, 180, 187+, 188, 206, 212, 228, 229, 231, 239, 245, 257, 260, 266, 276, 277, 281, 283#, 318, 319, 321, 322, 323, 324, 325, 330, 334, 337, 346+, 352+, 362, 363, 371, 377#, 378#, 384, 389, 390, 391, 411, 415, 424, 426, 428, 430*, 435, 440#, 449, 453, 454*, 456, 470, 500, 511#, 512, 515, 516, 522+, 536*, 542+, 545, 548, 566, 570, 573, 574#, 590#, 592*, 599, 604, 610, 614, 623, 628#, 634, 635, 650, 653, 654, 656, 668, 676, 678, 683+, 690, 692*, 694, 697, 698, 699, 706.

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e/ The reader must be alert to major definitional differences among this Handbook and the principal references with respect to elasticity, as shown in the following table:

Handbook	Mayworm, et al (384)	Bly (71)	Dygert, et al (188)
shrinkage ratio	shrinkage factor	shrinkage ratio	arc elasticity*
fare elasticity* (or log or linear arc elasticity)	arc elasticity* (log or midpoint)	fares elasticity* (or arc, or linear arc elasticity)	"Kemp...definition of arc elasticity"
point elasticity*	point elasticity*	point elasticity*	point elasticity*

The forms principally used in the respective publications are indicated by an asterisk. Note that the discussions of arc elasticity properties in Dygert, et al pertain only to what are termed shrinkage ratios/factors or growth ratios elsewhere.

50. Bates, J.W. "Effect of Fare Reduction on Transit Ridership in the Atlanta Region: Summary of Transit Passenger Data." Transportation Research Record. Transportation Research Board, Washington, D.C. No. 499. 1974. Pages 1-11. TRANSIT FARE CHANGES,* TRANSIT SCHEDULING/FREQUENCY, BUS ROUTING/COVERAGE. OBSERVED RESPONSE. TRIP GENERATION, MODE CHOICE, ACCESS MODE CHOICE.

On March 1, 1972 the Metropolitan Atlanta Rapid Transit Authority reduced the base bus transit fare from 40¢ to 15¢, and eliminated the 5¢ transfer charge. Between February and November 1972 service improvements increased annual bus miles traveled from 19 million to 22 million through extensions of 13 lines, revisions to 14 lines and the initiation of 5 lines. In 1970, the annual transit ridership in the Atlanta area was 83.30 trips per capita.

The results of a hand-out/mail-back survey conducted in October 1970 were analyzed along with the results of an on-board passenger survey conducted November 11 through November 21, 1972. The 3,738 usable 1972 interviews were obtained from clustered samplings covering 6 time period and 4 route market segment strata selected by income of residential area served and the nature of the service improvements. Expansion factors specific to each stratum were applied to replicate the entire transit ridership. The sample was approximately 1% of total ridership and excluded persons who had moved since the fare change.

The November 1972 survey indicated an overall ridership increase since March 1 of 30.2% as compared to a 100% base of continuing old riders. This breaks down to an increase of 28.0% on weekdays, 41% on Saturdays and 78.8% on Sundays. Of the total increase, 91% consisted of new riders as contrasted to additional, new trips by old riders: 100% of the weekday increase was attributable to new rider trips, as was 52.2% of the Saturday increase, whereas 63.5% of the Sunday increase was due to increased trip making by existing transit riders. Fifty-four percent of the new riders indicated they had shifted to the bus mode because of the fare reduction, 2.9% indicated they had changed because of service improvements, and 42.7% indicated "other" reasons. However, 80.1% of the new riders indicated that they would ride transit at a 25¢ fare and 46.3% indicated that they would ride transit at the original 40¢ fare.

Among the weekday new riders, 41.8% previously made their trip by driving an auto, 21.9% riding in an auto, 10.3% traveling in some other vehicle, and 4.5% walking, while 21.5% were making trips not made prior to the fare change and service increases. Some 21,642 automobiles were estimated to have been removed from the roadways on weekdays; 3,753 in the PM peak hour. Interestingly, the new rider group was younger, wealthier and had greater access to an automobile than did the old rider group. New riders drove to the transit stop more frequently (3.2% vs. 1.6%), had made fewer transfers when interviewed (16.1% vs. 20.8%), and were more often traveling for purposes other than work (48.1% vs. 37.7%). Nearly 3/4 of both new and old riders (73.8% vs. 70.9%) walked to the bus they rode, and almost equal proportions (5.0% vs. 6.0%) were driven to the bus.

123. Colman, Steven B. Case Studies in Reduced Fare Transit: Seattle's Magic Carpet. De Leuw, Cather and Company. Sponsored by Urban Mass Transportation Administration, U.S. Department of Transportation; Contract No. DOT-TSC-1409. San Francisco, California. April, 1979. 41 pages. TRANSIT FARE CHANGES*. OBSERVED RESPONSE. VOLUME, MODE CHOICE, TEMPORAL DISTRIBUTION. ECONOMIC IMPACTS, REVENUES/DEFICITS, AIR QUALTIY.

Beginning in September, 1973, a 105 block area encompassing the primary tourist, retail, and office centers of Seattle's CBD was designated as a free-fare zone, called the Magic Carpet. All intra-zone trips carried by METRO, the local transit authority, are free for all hours of the day. Fares for trips between the Magic Carpet and external locations are collected at the external end of the trip either during boarding or departure. In 1974, Magic Carpet was expanded to include the International District, an ethnic enclave on the south side of the CBD. In January of 1978, a 35-block urban renewal district on the north side called Denny Regrade was added to the fareless zone. Magic Carpet service replaced the "Dime Shuttle," a 10¢ downtown circulator service which traversed the CBD and carried 58% of all intra-CBD bus trips. METRO, serving a metropolitan population of 1.4 million, carries 168,000 fare paying trips per day, 4% of all trips made in the region. Thirty-five percent (35%) of peak hour trips to the CBD are carried by METRO. An estimated 70,000 persons are employed in the downtown. Reasons for instituting the Magic Carpet included: (1) encouragement to redevelop Pioneer Square, an historic section of town; (2) improving METRO's image with a high visibility, low cost program; (3) speeding passenger loading and unloading along the few major streets in the downtown; and (4) its popularity with the business community. Regional METRO service partonage is experiencing significant growth with a 13% increase between 1977 and 1978.

Data for the analysis were obtained from two passenger surveys, one performed during July, 1973, before the inception of the Magic Carpet and the other performed in May, 1974, eight months after implementation. The surveys identified ridership levels, trip purposes, and in the 1974 survey, prior travel behavior. An additional trip purpose survey in 1977 eliminated some ambiguities contained in the 1974 survey.

The 1973 survey revealed that 4,100 intra-CBD trips per day were carried by the Dime Shuttle and other METRO buses. The institution of the Magic Carpet resulted in 12,250 intra-CBD trips per day on METRO buses, a 200% increase. METRO officials estimate that 1978 Magic Carpet patronage is in the order of 13,500 to 16,000 trips per day (approximately 8% of total system ridership), though no data are available to support this conclusion. Approximately 65% of the Magic Carpet trips are taken between 11 AM and 2 PM, 49% during the normal 12 PM to 1 PM lunch hour. Five percent (5%) of the Magic Carpet trips are destined for home, 39% for work, 1% for school, 15% for entertainment, 16% for personal business, and 24% for shopping. Of the 12,250 trips per day taken in 1974, 25% would not have been made prior to the implementation of the Magic Carpet, 31% would have been made by walking, 19% by the Dime Shuttle, 15% by other buses, 8% by auto, 1% by taxi, and 1% by other means. A survey of 642 downtown employees determined that 7% of the downtown work force (4,900 persons) use bus service outside of the Magic Carpet more often than before because of the free CBD service, representing perhaps a 1,000 to 2,000 daily transit trip increase.

The Magic Carpet service cost $425,000 including revenue foregone to operate in 1978, approximately $200,000 more than the Dime Shuttle and slightly less than 1% of METRO's total operating budget. Of the $200,000 difference, METRO paid $24,000, the City of Seattle paid $166,000, and a private developer of Denny Regrade paid $10,000. An estimated 900 vehicle trips per day (2% of all intra-CBD traffic) have been eliminated from the street system due to modal shift to Magic Carpet. Most of these trips were made during the midday. An additional 25 bus hours of service are provided during the noon and PM peaks to handle the increased loads, mostly by routing already existing bus lines through the Magic Carpet. The overall effect on bus travel times attributable to Magic Carpet service is unknown. It is estimated that the free fare program accounts for $2.5 million to $5 million in annual retail sales in the downtown, approximately 1% of total annual retail sales. Effects on VMT, fuel consumption, and pollutant emissions are minor. METRO officials estimate that the carbon dioxide standard is exceeded four fewer days per year because of the Magic Carpet, though this has not been confirmed.

430. Mundle, Subhash, W.E. Weidemann, and S.R. Roesch. "Transit Price Elasticities in St. Louis." Compendium of Technical Papers, Institute of Transportation Engineers 48th Annual Meeting. 1978. Pages 42-46. TRANSIT FARE CHANGES*. OBSERVED RESPONSE. VOLUME.

In 1978, the Bi-State Development Agency serving the St. Louis metropolitan area undertook a study of alternatives to the existing fare structure. In so doing, the study team conducted a route-by-route investigation of the ridership impact of a 1973 fare decrease. The base transit fare had been reduced in November, 1973, from 45¢ to 25¢. Changes were also made in the elderly and monthly pass fares, while the fare zone configuration, zone charges, and transfer charges remained unchanged. No indication is given as to any marketing campaign which may have accompanied the fare change.

In October, 1973, a ridership survey was conducted which established route-by-route patronage figures for the before condition. In May, 1974, counts of the number of elderly, student, transfer, and pass riders on each route were conducted, and origin-destination patterns by fare zone were identified by means of a systemwide origin-destination survey. Passengers paying base and zone fares were estimated as the difference between total ridership and the number of elderly, student, transfer, and pass riders on each route. The percentage of elderly, student, and pass riders on each route was assumed to be the same before and after the fare change. Because non-registering fareboxes were in use at the time of the 1973 and 1974 ridership surveys, it was necessary to estimate the average fare for each route based on the information collected in the 1974 survey and to use this to derive the ridership on each route. Sixty-five routes, representing more than one-half of the routes in the system, were chosen for analysis. These routes, both local and express routes in both Missouri and Illinois, were selected because there was no change in their service levels for a significant amount of time before or after the fare change.

Of the 65 routes analyzed, only 1 exhibited elastic behavior (elasticity of or in excess of -1.0). The estimates of arc elasticity for individual routes ranged from 0.0 (with a 39.66% reduction in average fare) to -1.39 (with a 31.26% reduction in average fare). The overall elasticity was -0.20, a figure somewhat lower than experience in other cities. The results of the analysis are summarized below:

	Service Type	No. of Routes Analyzed	Percent Change in Ridership	Percent Change in Fare	Arc Elasticity[1/]
Missouri	local routes	29	15.3%	-54.8%	-0.18
	express routes	22	17.1	-38.7	-0.32
	subtotal	51	15.4	-53.3	-0.19
Illinois	local routes	10	18.2	-45.0	-0.28
	express routes	4	35.8	-35.7	-0.69
	subtotal	14	19.2	-44.9	-0.29
Bi-State Service Area Total	local routes	39	15.7	-53.8	-0.19
	express routes	26	18.8	-38.3	-0.36
	Total	65	15.9	-52.3	-0.20

1/ Arc elasticities calculated by the Handbook authors.

Express service ridership, typically considered less sensitive to fare changes than local service ridership, was found to be more sensitive in this analysis. However, ridership in both service categories was found to be inelastic with respect to the fare change. The elastic response on express routes in Illinois (-0.69) was not believed to be a reliable finding due to the small sample size. The greater sensitivity found on routes in Illinois in general is explained on the basis of the greater service coverage in Missouri, and the correspondingly substantial portion of the market captured in Missouri before the fare change.

454. Obinani, Felix C. "Analysis of User Response to the 1975 New York City Transit Fare Increase." Transportation Research Record. Transportation Research Board, Washington, D.C. No. 625. 1977. Pages 12-14. TRANSIT FARE CHANGES*. OBSERVED RESPONSE. MODE CHOICE.

On September 1, 1975, fares on the buses and subways of the New York City Transit Authority System were increased by 43% from 35¢ to 50¢. This report addresses the impact of this fare increase on the travel patterns of transit users and compares actual changes in travel characteristics with the changes anticipated by a sample of riders before the fare increase was announced.

In June, 1975, heads of households in New York City were surveyed to identify their existing travel patterns and their predicted travel patterns if transit fares were raised from 35¢ to 50¢. In December, 1975, three months after the fare increase, 307 respondents to the June survey were interviewed again to ascertain actual changes in their travel habits. An additional 205 primary wage earners who were identified through telephone sampling as having changed modes after the fare increase were interviewed to enlarge the sample of those making mode shifts.

Initial expectations were that respondents to the June survey would overestimate the changes they would make, either because of misconceptions about the true costs and difficulties associated with the use of alternative modes, or in an angry reaction, particularly on the part of near captive riders, to the prospect of a fare increase. This expectation was borne out by survey results which showed that although 20% of the respondents predicted that they would make changes in their journey to work travel, only 14.6% actually did. The following table records the distribution of alternate work trip modes for those who predicted they would change and for those who actually did.

Alternate Mode	Predicted	Actual
carpool	12%	18%
drive alone	34	41
walk	23	16
bus (from subway)	14	14
taxi, bicycle, other	17	11

Forty-seven percent (47%) of the June respondents predicted that members of their households would use transit less during off-peak periods if fares were raised, 25% stating that they would discontinue use and 22% stating they would curtail usage. In actuality, 38% used transit less, only 4% discontinuing use and 34% reducing the number of transit trips they took. Of those using transit less, 60% indicated that they were making fewer total trips while 49% stated they had shifted some off-peak trip making from transit to auto.

Although aggregate actual changes are not grossly different from predicted values, individual predictions were frequently different from actual responses. Riders over 35, riders with incomes over $15,000, non-white riders, riders with higher educations and riders owning cars shifted modes somewhat more than their counterparts. Of the 86 respondents who had indicated that the subway was their primary mode to work, 16.3% stated they changed their work trip, although 6% made the change on the portion of their trip not made by subway. A frequently reported change among the 6% was use of an auto or walking in lieu of bus for subway access. Twelve and one half percent (12.5%) of the 32 respondents who used bus as the primary mode to work indicated that they made a change in their work trip. Systemwide ridership counts for the October-December, 1975, period yielded the following percent decreases over the corresponding period in 1974:

Mode	Weekday	Weekend	Total
Bus	11.3%	9.5%	10.7%
Subway	4.8	6.1	5.0

Differences between the survey and ridership count results probably result from restriction of the survey sample to household heads living in New York City and other factors related to survey design and limitations.

536. Roszner, E. S. and L. A. Hoel. Impact on Transit Ridership and Revenue of Reduced Fares for the Elderly. Transportation Research Institute, Carnegie-Mellon University. Sponsored by the Urban Mass Transportation Administration, U.S. Department of Transporation; Project No. URT-5(69)-71-2. Pittsburgh, Pennsylvania. July 1971. 43 pages. NTIS PB 204-432. TRANSIT FARE CHANGES*. OBSERVED RESPONSE. VOLUME, TEMPORAL DISTRIBUTION.

On February 1, 1970, the Port Authority of Allegheny County offered a 15¢ off-peak fare reduction to all Pittsburgh area transit patrons ages 65 years or older, lowering the average single ride fare from 34¢ to 19¢. By December 1970, 78,960 of the County's 175,900 senior citizens (45%) had registered for the required identification card. In 1970, the number of annual transit rides per capita in the Port Authority service area was 65.48 (approximately 11 round trips per month) for persons of all age groups.

Ridership behavior of senior citizens holding identification cards was sampled through 1,476 telephone interviews in July 1970, a 2.4% sample. Since comparison was made between the transit trip rates reported for 1970 (with the reduced fare program) and the trip rate recalled by these same individuals for 1969 (without the program), it was necessary to account for external impacts on trip making behavior. Trip attrition due to retirement or illness and transit trip increases due to reduction in car ownership were identified as equating to a net reduction per individual of 0.45 peak hour round trips and 0.11 off peak round trips per month. Expected 1970 transit trip rates were derived by applying these reductions to the reported 1969 rates.

The expected 1970 trip rate without fare reduction, for participating senior citizens, was 5.73 round trips per month. The actual rate was 6.95. The expected off peak travel rate was 3.29 round trips per month. The actual rate was 4.98. The 1.69 additional off peak trips were comprised of 0.56 round trips diverted from the peak period, 0.94 newly generated round trips, and 0.19 round trips diverted from automobile. Of the newly generated trips, 61.5% were shopping trips, 26.2% were social trips, and 6.8% were medical trips. The expected rate for peak period travel, without off peak fare reduction, was 2.44 round trips per month. The actual rate was 1.97, reflecting the 0.56 round trip diversion to the off peak period, and inadvertent addition of 0.09 new trips meant to have been taken offpeak but which slipped into the evening peak.

Pittsburgh residents constitute 67% of the program participants and account for 77% of the trip making activity. Within Pittsburgh the total of senior citizen transit trips with the fare plan was 16.4% greater than the number of trips expected without the plan and in the rest of Allegheny County the total was 33.3% greater. This finding was interpreted to indicate that residents of lower service areas are the most responsive to transit fare changes. New riders who began using transit solely because of the fare program constituted 1.50% of the senior citizen riders residing in Pittsburgh and 2.82% of the riders residing in surrounding areas. The overall 21.3% increase in transit trip making indicates that the elderly exhibit a strong sensitivity to downward transit fare changes, especially considering that the 45% average fare reduction does not apply during the weekday rush hours. Nevertheless, the average passholder in making use of the fare plan causes the Port Authority a 66.5¢ monthly loss in revenue (87.6¢ for Pittsburgh residents and 27.4¢ for residents of the remainder of the County). This translates into an estimated $628,900 annual revenue loss.

592. Swan, Sherril and Robert Knight. Denver Off-Peak Free Fare Public Transit Experiment. DeLeuw, Cather and Company. Sponsored by Urban Mass Transportation Administration, U.S. Department of Transportation; Contract No. DOT-TSC-1409. May 1979. 59 pages. NTIS PB 298-783. TRANSIT FARE CHANGES*, OBSERVED RESPONSE. TEMPORAL DISTRIBUTION, VOLUME, MODE CHOICE. REVENUES/DEFICITS, AIR QUALITY.

Beginning February 1, 1978, the Denver Rapid Transit District (RTD), serving a metropolitan population of 1.6 million, offered free rides during off-peak hours (all hours except 7-9 AM and 4-6 PM). Regular peak hour fares ($.50-$1.25) remained in effect. The project was initiated in response to growing citizen concern about air quality and fuel conservation in the Denver region. Initially, the project was designed to operate for only one month and was accompanied by a marketing campaign designating February as "Transit Awareness Month." Toward the end of February, UMTA and RTD agreed to extend the off-peak free fare program through February, 1979. On May 1, 1978, the morning peak period was changed to 6-8 AM to better reflect identified commuting patterns. It is estimated that RTD carried 3 to 4% of total regional person trips and 30% of CBD work trips prior to the institution of off-peak free fares in an area where auto ownership is high and driving conditions are favorable.

Because the program was formulated and implemented within a two-week period, little thought went into the planning and design of an evaluation procedure. As a consequence, some of the program's effects had to be estimated as opposed to measured directly, thereby reducing the reliability of the results. Data were obtained from RTD operations management reports, regular systemwide ridership counts, and two on-board surveys (February and July). In order to guage the impact on ridership response, modal diversions, revenues, and operating costs due solely to the off-peak free fare program, adjustments were made concerning the following external factors: (1) in 1977-78, revenue miles of service were increased by 14.6%; (2) transit ridership was increasing before the free fare went into effect; (3) a new ridership counting method was initiated in January, 1978; and (4) fares were substantially restructured in January, 1978, raising the peak fare from 35¢ to 50¢ while keeping the off-peak fare at 25¢ and offering monthly passes. These adjustments resulted in a conservative estimate of ridership due to the free fare program. The authors estimate that stable operation did not occur until after the redesignation of the morning peak hour in May.

The increase in total one-way weekday person trips due solely to the off-peak free fare programs was estimated to be 34% (41,000 trips). These new trips were all taken during off-peak hours. This represented an increase in total daily trips from 122,000 trips if free fares were not available, to 163,000 trips, the estimated number of trips taken with free fares. If free fares were not available, 46% of the new trips would have been made by car, 22% would have been made by other modes, and 32% would not have been made at all. New trips were made by a younger and more male population than the systemwide average. In addition to the 41,000 new trips, it is estimated that 12,000 trips (7% of total weekday ridership and 24% of peak period ridership) were diverted from peak periods to off-peak periods. Thus, ridership increased a total of 87% (53,000 trips/weekday) during fare free times. Of the estimated 114,000 daily off peak trips after the free fare program, 18% were made by riders who never used RTD before, 25% were made by riders who said they had used it only during peak periods, 16% were made by people who reduced their off-peak use, 23% were made by riders whose usage did not change, and 18% were made by people who increased their off-peak use. Total system ridership (including weekdays, weekend days, and holidays) is estimated to have increased 32%.

RTD estimated that $3.7 million in revenue would be lost in 1978 due to the free fare scheme. Early reports in 1978 indicated that this figure was accurate. This was a decrease of 37% from anticipated revenues without the free fare programs. Operating costs were expected to increase by less than $370,000 but no statistics were available to confirm this. The increased operating costs were attributed to extra buses put into service to accommodate increased passenger loads, and to vandalism by young riders. Increased vandalism (seat-slashing, window-breaking), lack of available seating, decreased driver courtesy, and poorer on-time performance were all cited by surveyed riders as detrimental side-effects of the free-fare program. Despite significant increases in transit patronage and shifts away from the automobiles, reductions in VMT and pollutant emissions in the region were estimated to be less than 1%. Pollutant emissions and VMT in the CBD may have realized more significant changes, but this report did not attempt to quantify these changes.

692. Weary, K.E., J.E. Kenan, and D. K. Eoff. Final Report: An Evaluation of Three Month Trial 25¢ Flat Fare in Los Angeles County. Prepared in cooperation with Southern California Rapid Transit District, California Department of Transportation, Federal Highway Administration, et al. July 26, 1974. 36 pages. TRANSIT FARE CHANGES,* TRANSIT SCHEDULING/ FREQUENCY, BUS ROUTING/COVERAGE. OBSERVED RESPONSE. MODE CHOICE, AUTO OCCUPANCY. ENVIRONMENT.

Between April 1, 1974, and June 30, 1974, the Southern California Rapid Transit District and 7 municipal transit companies serving the Los Angeles County area codified and reduced their complicated fare/zone system by instituting a flat 25¢ adult fare, a 15¢ student/children fare and a 10¢ senior citizen fare, with a 10¢ interline transfer charge. The average fare was thereby reduced from 34¢ to 23¢. During the same period, SCRTD added 175 buses to their existing 40 routes and initiated 2 new routes, raising the average weekly bus miles traveled from 1,206,684 miles prior to the program to 1,316,157 miles at the termination of the experiment. Of the municipal companies, one added a new route and another revamped its route structure, increasing the average bus miles traveled by all 7 municipal lines from 2,316,570 miles per week between April 1 and June 30, 1973, to 2,462,129 miles per week between April 1 and June 30, 1974. In 1970, the number of annual transit rides per capita in the SCRTD service area was 28.33.

SCRTD base ridership was extrapolated from a 1968 81% sample survey, and ridership after the fare and service changes was estimated through the application of conversion formulae based upon an on-board survey of actual fares paid on April 4, 5, 8, 9, and 10, 1974. Ridership of 6 municipal lines was calculated in a similar fashion (the City of Commerce utilized a direct count) and all were added to the SCRTD data. The April, May, and June 1974 ridership was 27.9% over the comparable 3 month figure for 1973. This increase was presumed to be due in part to the fuel shortage which started to ease by April 1974. Judged more significant was the ridership increase of 17.2%, representing 101,000 passengers daily, between the April 1, 1974, date of the fare change and June 30, 1974. The comparable increase on SCRTD routes only was 18.2%, while the passengers per SCRTD bus mile went from 2.62 to 2.75. Bus patron profiles were calculated from 2,395 "before" and 3,246 "after" interviews of riders at 157 area bus stops. Small upward shifts were observed in round trips made per week via transit, percent males, and percent under 30 years of age. Purpose of trip varied little. Rider income and car ownership both rose. The primary reason non-captive riders gave for choosing transit changed from "more convenient" to "cheaper". Of all new riders, 59% previously made the trip by driving an automobile, 21% as an auto passenger, 10% did not make the trip and 10% did not respond (percentages adjusted to total 100%).

Before/after traffic volume and auto occupancy counts were taken at 75 screenline stations along 4 traffic corridors during mid-March, late April, and May 1974. Over the 5 week study period traffic volumes rose 3% to 4%, and the average auto occupancy fell from 1.30 to 1.26 persons/vehicle along freeways while remaining stable in non-freeway traffic. Because day-to-day variations in traffic volume counts ranged as high as 5%, and because of the relative easing of the gasoline shortage during this period, the traffic volume increases and the auto occupancy declines are given little significance; although the decline in freeway auto occupancy may indicate diversion to transit motivated by flat fares acting on relatively long distance trips.

TRANSIT MARKETING/BROKERAGE

Types of Transit Marketing and Brokerage

Transit marketing and brokerage are included within the class "Actions to Improve Transit." In a broad sense, transit marketing covers not only informational and promotional activities, but also all other actions keyed to making public transit service a more salable product. A narrower definition is used here, however, and covers the following different types of marketing:

1. Promotional and informational campaigns conducted to introduce the public to new transit services or other transit service changes. Such campaigns can include news releases, informational and promotional advertisements, free bus tickets, house-to-house distribution of schedules, and display advertising (24# 35, 40, 113, 114, 193, 230, 283#, 401#, 524, 573, 574#, 691#).

2. Campaigns or continuing programs of public information, including distributions of maps, pamphlets, and schedules; telephone information services; information booths and displays; and posting of information at bus stops; for the purpose of disseminating information on public transit services and how to use them (15*, 119, 167^{+}).

3. Advertising campaigns designed to improve the social acceptance of riding public transit, to raise the level of awareness concerning transit services, and to foster favorable attitudes about the convenience, comfort, and relative cost of using transit (15*, 84, 574#, 691#).

4. Provision and promotion of multi-trip tickets and passes, at or below the equivalent single trip fare, to encourage and facilitate fare prepayment and pass distribution through public outlets and employers (52, 138*, 150, 180, 266, 378*).

Brokerage is the process by which an outside party aids ridesharing development by overcoming to various degrees the obstacles to carpooling, vanpooling and bus usage. Transportation brokerage acts as a link between those with a demand for service and those who do or might supply service. Brokerage organizations may also be service providers. Functions of transportation brokers may include:

1. Disseminating information about new and existing ridesharing opportunities and advocating their use through advertising (176#, 462, 506, 543, 556*, 586#, 637, 658, 696*).

2. Providing personalized matching services, both among members of pool groups and, where applicable, between pool groups and suppliers of vans or bus service (176#, 462, 556*, 586#, 637, 660, 696*).

3. Lessening administrative responsibilities on the part of vanpoolers by providing assistance in matters pertaining to bookkeeping, driver responsibilities, insurance, maintenance and legal requirements (176#, 556*, 586#, 637, 660, 696*).

4. Eliminating risk by guaranteeing to underwrite costs associated with the dissolution of unsuccessful vanpools and sometimes by underwriting marginally unprofitable pooling arrangements (176#, 556*, 637, 660, 696*).

5. Providing on-going monitoring and nurturing of shared ride arrangements to maintain high visibility for pooling modes and to cope with participant attrition and other specific problems.

Carpooling programs not part of a full scale brokerage activity are treated in the topic area "Carpooling Encouragement Activities[a]".

Traveler Response Summary

Informational/promotional campaigns are an important ingredient in developing ridership on new or modified transit service. To be attracted and served, potential riders must be made favorably aware of the increased travel opportunities afforded. Some attraction of additional ridership to existing services has been achieved through promotion with an emphasis on information dissemination. In two applications distribution of carefully designed route maps and schedules led to immediate off-peak and selected route ridership gains that were still at the 3 percent level after 4 months. Other campaigns that included information dissemination as an adjunct were less successful. Transit service users are not a static clientele, because of mode shifts and workplace and residence changes, indicating need for periodic informative promotion. No lasting patronage gains attributable to general advertising or fare promotions for well established services have been isolated, but complimentary transit passes may hasten ridership growth on newly established routes.

Marketing fare prepayment options such as passes or ticket books has led to increased use of these payment methods. The benefits perceived by purchasers are convenience of payment and cost savings, probably in that order of importance. The most successful programs have led to use of prepayment by 20 to 30 percent of system riders and offer sales both to major employee groups through their employers and to the general public. Neither sales technique appears more successful than the other, although employer based sales have the additional advantage of providing an impetus for employer subsidization of employee transit use.

Offering prepayment options at a discount, whether by the transit operator or by employers, has had a substantial effect on their use in several cases. Special 20 percent discounts on prepayment options increased concurrent sales 50 to 200 percent in two cities, while 40 percent discounts had not quite double the impact. Temporary pass and ticket book discounts have also resulted in short term ridership gains. Long term effects are less clear, although in at least one instance transit ridership was up 4 to 5 percent among targeted employees 8 months after the discount ended. In Boston, 23 to 34 percent of employer subsidized passholders previously commuted via other

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a/ A "Carpooling Encouragement Activities" digest was provided in Edition I of this Handbook (510). For "Carpooling Encouragement Activities" references see Chapter III of this current edition. In particular "Evaluation of Carpool Demonstration Projects, Phase I Report", by F.A. Wagner, provides comprehensive and recent carpool program information (674).

modes versus 10 percent program wide. In Jacksonville, the transit mode share at employment sites offering subsidized passes was 20 percent versus 5 percent at firms offering no discount.

Multimodal transportation brokerage programs are a recent innovation in helping overcome the information barriers and other impediments to forming various types of ridesharing arrangements. Brokerage programs aim to decrease single occupant auto travel, but with reduced emphasis on costly expansion of peak transit service. As a general rule, employer oriented programs are more successful than area-wide efforts, and the degree of employer involvement and support is a primary determinant of the level of success. Initial results are widely varied, ranging from negligible mode shifts in a major multi-employer program to a decrease in single occupant auto mode share from 65 percent down to 18 percent at a large downtown employer. A non-employer oriented program run by the transit provider has helped achieve a 3 percent peak period vanpool/buspool mode share and other shifts to ridesharing in the San Francisco Golden Gate corridor.

Response to Marketing of Service Changes

The contribution of promotional activities, or lack thereof, to the results of introducing new or modified transit services can only be surmised. Traveler responses to the promotion and to the service changes themselves are necessarily concurrent, and have not been separately quantified in any analysis encountered. Assessment of how well an informational/promotional campaign has served to inform and encourage the target population typically depends on such measures as the percentage of persons in the market recalling the campaign or adopting attitudes that were promoted.

It is reasonable that a new transit service cannot attract users unless and until information concerning the new service is disseminated. Promotion of new services thus undoubtedly speeds ridership and revenue growth, which in itself can be the difference between early project success or termination. Moreover, the promotion of favorable information logically may induce more people to try the new service and thereby afford added usage even after completion of initial service development. In contrast, a lack of promotion may result in exposure of potential riders to largely neutral or negative views of new service.

Promotion of commuter rail improvements in Philadelphia included media news items and advertising, a movie and a speakers' bureau, special events, personalized sales promotion, and publications, all at a 1965 cost of $240,000. At the start of the project, one third of the households in the service area knew changes were being made on the railroad. Newspaper articles were the source of awareness for 60 percent of these households, registering six times the impact of any other source. Awareness dropped gradually to 7 percent as fewer and less dramatic changes were made. Awareness was higher for actual and potential users of the service; gradually decreasing from 51 to 10 percent for actual users and from 42 to 4 percent for those judged to be potential users (43, 573, 574#). Opening of the Skokie Swift rapid transit extension in Chicago was accompanied by a 1964 $70,000 promotional effort including a press inspection trip, news articles, inaugural ceremonies, media advertising, and communications to riders. A survey showed 96 percent of Skokie residents able to identify the alliterative name "Skokie Swift", and 82 percent felt the Skokie Swift to be very important to residents (114).

Planners and users of the Atlanta peripheral parking/shuttle bus combination felt promotion of the service was inadequate. No more than 14 percent of all users learned of the service through advertising. Interestingly, initial 5 percent ridership growth per month was increased to 9 percent when promotional handouts were distributed through users and downtown businesses. A second handout coincided with 6 percent growth, suggesting loss of effectiveness with repetition of the technique (35).

A comprehensive promotion program was undertaken in St. Louis as part of establishing new express routes and a crosstown route. In addition to media articles, advertising and displays, free tickets and schedules were distributed house to house within a quarter mile of each route. A subsequent survey showed 41 to 62 percent of service area residents to be familiar with the new service (691#). Transit promotion initiated in conjunction with expanded freeway express service in Minneapolis led to 92 to 96 percent awareness among transit riders on corridor arterials. The promotion took the form of media advertising and brochure mailings to service area residents and also to corridor auto drivers identified through a license plate survey (401#).

An interesting aspect of the Boston, New York City (New York Central Harlem Division), and Philadelphia (Operation Reading) commuter railroad service demonstration projects was that ridership gains tended to accrue fairly steadily, whether service changes involved service expansion, service trimming, fare reductions, or fare increases (377#, 574#, 628#). One possible explanation, among others, is that the public interest and feeling of attention to problems that was generated continued to have a favorable impact so long as the inherent advantages of the service and an overall impression of service improvement were maintained.

Response to Information Campaigns

It may be significant that those information distributions shown to have produced ridership gains on pre-existing transit services provided comprehensive information on relatively complex systems or sub-systems. One of the few cases monitored and reported on involved improvement and comprehensive dissemination of transit service information for a Pittsburgh neighborhood. A multicolor, user-oriented transit route map of the Penn Hills area was prepared in response to findings that Penn Hills residents had a lower-than-average opinion of available transit information and that it did indeed require consultation of two or three separate route schedules to determine how to best use the available multi-route service. The neighborhood route map folder included a map showing pertinent downtown bus stop locations and a consolidated schedule. Distribution was through local stores and agencies, and a local newspaper insert. While the peak period ridership gain was nominal, off peak patronage registered a 6 percent gain at first, and still showed a 3.5 percent gain after the civil disturbances of April 1968 (15*).

A distribution of 150,000 downtown Pittsburgh transit guides showing all downtown transit stop locations, made in connection with a multimedia campaign promoting shopping via transit, resulted in mixed and inconclusive results. A study of the regular telephone information service concluded that it served existing users more than potential users; 78 percent of all callers already possessed timetables (15*). Map and schedule distribution together with complimentary passes in San Antonio, TX did not result in increased transit trip making (see "Response to Fare Promotions").

A two week saturation campaign was undertaken to inform residents of available bus service within and between 5 rural British towns. A total of 6,600 color coded brochures depicting routes and transfer points were distributed on buses and another 5,000 were distributed through post offices, shops, libraries and bus stations. Two weeks after distribution, 71 percent of all riders had obtained a brochure; 48 percent of these from the buses, 26 percent from shops or post offices, 7 percent from libraries and 2 percent from bus stations, with the rest unsure as to the source. Ridership on affected routes had increased 12 percent after four weeks and slipped to 3 percent after seventeen weeks when compared to control routes. The effect on transfer ticket sales was more pronounced, registering a 30 percent increase after four weeks before declining to 10 percent above control route sales after seventeen weeks. No follow up distribution was attempted to test the effectiveness of repetition of the campaign or to inform new riders or residents (193).

Response to Advertising Campaigns

No lasting ridership gains in response to general advertising have been isolated, and results are mixed concerning the ability of advertising to improve attitudes toward riding public transit. A $50,000 newspaper, radio, and television advertising campaign in Pittsburgh stressing transit service comfort, convenience, service, information, and economy was accompanied by target area ridership declines of from 1 to 8 percent. Before and after attitudinal surveys identified worsened public attitudes toward most aspects of transit service. While the deteriorating situation was undoubtedly related to the April 1968 civil disorders, the institution of an exact fare requirement and talk of fare increases, it was considered significant that the advertising failed to stem decreasing public acceptance. The advertising featuring convenient, pleasant transit service may have created a credibility gap by meshing poorly with circumstances (15*). In contrast, following promotion of Reading commuter rail service as "faster", this theme was mentioned by 36 percent of rail users interviewed as compared to 26 percent earlier. The advertising campaign involved was tied in with a service improvement program, but not with speed increases per se (574#).

A survey of 214 bus users and 41 nonusers in Ithaca, NY, found that approximately 55 percent were unaware of any promotional activities on behalf of the local, four-route bus system. Recent advertising had included occasional newspaper display advertisements with a free-ride-to-downtown coupon, and public service radio announcements on a more or less continual basis (588*). After the basic route development promotion for new radial express routes to St. Louis suburbs, described earlier under "Response to Marketing of Service Changes," one route was selected for a major follow-up campaign. Display signs were placed on bus exteriors and at bus stops, large advertisements were placed in two community newspapers, "Kelly Girls" were hired to visit homes in the service area, leaving promotional packets with one free ticket, and bus operators handed out packets to all regular customers. Immediately after the campaign and the period during which free tickets were valid, ridership increased 3.4 percent above the gain experienced by the entire group of new express routes. Some 3 months after the campaign, ridership subsided, returning the route to its approximate precampaign position relative to the other express lines and indicating that the effect had worn off (691#).

Response to Fare Promotions

Any impact of complimentary transit passes on the long term patronage of well established service is very small, but complimentary passes may hasten ridership development on newly instituted routes. In a detailed study conducted in San Antonio in 1972, 489 packets containing an introductory letter, a transit map, schedules and two complimentary passes were distributed to alternate residences within three blocks of four separate radially oriented routes in demographically differing areas. Only 24 percent of the passes were used. No increase in transit trip making was found to have resulted from the pass distribution and only 6 percent of the pass users were not regular riders. Where time of use was recorded, the distribution was as follows:

Peak periods	32%	Weekday	81%
Midday	54	Weekend	19
Early/late	14		

A one month promotion involving the distribution of 30,000 passes through utility bill mailings led to no significant ridership increases in Kalamazoo, MI. In Oakland, CA half of the 100 to 150 passes per month distributed by hospitality groups such as "Welcome Wagon" returned to the farebox. For Oklahoma City, a return rate of only 1 to 2 percent of the 600 passes offered each month is reported. No data exist in these two instances on patronage impacts. A small, later terminated hospitality group distribution program in Sioux Falls was estimated to have been attracting one new regular rider per 5 passes distributed (84).

Two separate mailings of complimentary passes in 1969 and 1970 in Sacramento were designed to introduce a new cross-town line to service area residents. Following the 1970 (second) mailing, the ridership increase achieved was six times the average ridership increase for the new route and four times the ridership increase recorded during the same period the previous year (84). Complimentary pass distribution was thought to be a worthwhile part of a new St. Louis express route promotion otherwise judged not cost effective (see also "Response to Advertising Campaigns" and "Cost Effectiveness") - (691#).

Response to Area-Wide Fare Prepayment

Marketing of fare prepayment options such as weekly or monthly passes or trip ticket books to the general public has, to varying degress, increased their use. In some cases, especially when special discounts have been offered, short term ridership increases have resulted. Long term ridership effects are not well documented. They appear insignificant in most applications, but it may not be valid to apply this observation to programs offering permanent, significant discounts. Most purchasers are prior transit users who do not significantly increase their transit travel rate after switching to fare prepayment. The most significant benefit obtained from prepayment programs addressed to the general public appears to be ease of fare collection for both riders and transit authorities. Over 90 percent of all transit systems offer some form of prepayment to riders. In one out of five of these systems, fare prepayment is used by a minimum of 20 percent of boarding riders. Few systems achieve greater than 50 percent usage (266).

Demonstration projects in Phoenix and Austin were designed to test the short and long term effects of 20 and 40 percent monthly transit pass and multi-trip punch card discounts on sales of prepayment options and on patronage. The short term sales increases obtained are listed below:

	Monthly Pass Sales		Ticket Book Sales	
	% Increase	Elasticity	% Increase	Elasticity
Austin 20% discount	55%	-2.0	200%	-4.9
Austin 40% discount	104	-1.4	417	-3.2
Phoenix 20% discount	170	-4.5	124	-3.6
Phoenix 40% discount	1,632	-6.5	177	-2.0

The elasticity values given here are the price elasticities of pass and ticket sales; quite different than fare elasticities of total ridership. They indicate, excepting monthly pass sales in Phoenix, that the 20 percent discount was more effective dollar for dollar than the 40 percent discount (138*). A fare increase in Sacramento translated into a 14 percent discount for pass buyers where there previously had been no discount, increasing pass sales immediately from 1,000 to 3,000, then more gradually to 4,000. This constituted 20 percent of all system riders (150). The Phoenix, Austin and Sacramento cases show considerably greater market response than would be suggested by the market penetration elasticities[b/] of +0.4 to +0.5 which have been modeled using the fare prepayment discount experience from 62 United States fare prepayment plans (384).

The high short term sales increases in Phoenix and Austin did not translate into increased long term patronage. Although the 20 percent discount led to 63 and 15 percent increases in boardings in the months during and following the sale in Phoenix, respectively, long term transit trip rates of new purchasers who previously rode transit did not increase relative to prior rates. Furthermore, the maximum new ridership attributable to riders attracted by prepayment was less than one half of one percent in both cities. Still, 15 percent of those purchasing passes and punch cards for the first time during the discount period continued to do so one year after the demonstration (138*).

A study of express bus riders using a 40-trip ticket in Detroit found that although 19 percent had not been riders prior to its introduction, only 2 percent became riders because of the option. The remainder indicated they would have started using the bus anyway. Ten percent of all ticket users indicated they rode the bus more frequently (mostly previous cash fare or 10-trip ticket patrons) while 2 percent rode less frequently (mostly previous monthly pass users). Introduction of monthly passes in

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b/ A market penetration elasticity in this case indicates the proportional change in the percentage of total riders using fare prepayment for a one percent change in the discount rate of the prepayment plan over cash fare. If total ridership does not change, the market penetration elasticity will be the same as the price elasticity of the prepayment instrument sales. See Appendix A for further discussion of elasticity measures.

Portland was thought to have had little patronage impact. A different type of pass, a one dollar family pass in Pittsburgh permitting unlimited weekend travel for four persons, reportedly increased Saturday ridership by 22 percent and Sunday ridership by 45 percent (266).

Results of fare prepayment in Europe give evidence of significant ridership response to permanent discounts, although many of the prepayment schemes were begun concurrently with fare changes, blurring results. In Birmingham, England, a 3 percent annual patronage decline was halted with the introduction of a 27 percent discounted monthly pass. With an 11 percent discount over regular fares, monthly passes in London increased transit riding among those purchasing them by one quarter to one third. Monthly pass availability in Paris reportedly led to ridership increases of 1 to 2 percent on subway lines, 2 to 3 percent on rail lines, 10 percent on suburban bus routes and 40 percent on urban bus routes (52). On the other hand, fare elasticities for prepayment options in London and Paris have been estimated to be only one third to three quarters the corresponding elasticities for regular fares (384).

Response to Employer-Based Fare Prepayment

For any given degree of discount, transit pass programs emphasizing distribution through employers do not appear to engender markedly more or less response than programs oriented toward general public sales. Nevertheless, the most successful fare prepayment programs have combined general sales with employer-based sales for maximum participation. Moreover, employer-based fare prepayment provides an obvious, useful mechanism for employer subsidy of employee transit fares. As in the case of area wide schemes, pass sales are dramatically affected by whether or not the pass is offered at a discount when compared to the regular cash fare. The availability of transit passes offered at a discount has affected mode choice. Results should be viewed as tentative as few programs have been evaluated (150, 378*, 666).

In Boston, a transit pass program utilizing monthly payroll deduction encompassed 117 employers and 17,500 rapid transit and light rail patrons by 1976, 1½ years after its inception. Expansion of the program to the general public, the addition of bus patrons and continued growth to 740 employers led to 73,000 monthly pass sales by early 1981. This represents approximately 30 percent coverage of the system's adult riders on any given day and about 50 percent coverage of transit users at participating firms (378*).[c/] In Sacramento, the addition of employer based sales to a successful area-wide program had no discernable long term effect, relative to the general trend, on the proportion of affected employees who used monthly passes. In the two years following initiation of employer involvement, and with the impetus of a further pass purchase savings of 20 percent as compared to 14 percent before, total sales rose from 4,000 to about 7,000.[d/] The employer program impact is unclear, and employer sales accounted for only 2,000 of the total (150).

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c/ Post-1976 Boston transit pass information obtained directly from Massachusetts Bay Transportation Authority.

d/ Excluding almost 3,000 purchased by the County Welfare Department for distribution to recipients.

Discounts offered to pass purchasers have a profound impact on sales, and have resulted in ridership increases. Boston's monthly pass offers an inherent discount of 17 percent for daily users. In 1976, transit use among passholders was 8 percent higher relative to the "before" condition, 3 percent representing riders new to transit and 5 percent representing increased use by former infrequent riders (378*). Recent information indicates that the proportion of passholders previously commuting by other means has risen to 10 percent,[e/] although the impact of normal ridership turnover on this statistic is unknown. In Sacramento, employers distributing passes received them at 75 percent of the cost to others during a three month period, and these savings were passed on to employees. The table below lists the percentage of employees in participating firms buying passes in the last month of the 25 percent discount and the month following the discount for those in the CBD (excellent transit service), on the CBD periphery (good service) and in outlying areas (poor service) (150):

Sacramento Program Status	CBD[1/]	CBD Periphery	Outlying Areas
During discount	15.3%	3.8%	0.9%
After discount	8.5	2.5	0.4

[1/] For firms offering over-the-counter sales. Corresponding before:after percentages for firms with payroll deduction sales were 2.3%:2.1%.

The 3 month discount served to attract 40 employers out of the ultimate 66 into the program, after a slow start of 9 employers participating out of 140 contacted. A 9.5 percent short term ridership increase among employees of participating employers was stimulated by the discount, 7.5 percent representing mode shifts after correction for normal turnover and 2.0 percent representing additional transit trips by prior transit users. Transit riders attracted by the 3 month discount exhibited an attrition rate twice normal, but 60 percent were still using the bus 8 months later, representing a 4.5 percent longer-term employee ridership gain (150).

Pass use and mode shifts to transit are substantially more prevalent among those employees receiving direct transit subsidies from their employers. In Boston, 23 to 34 percent of employer subsidized passholders formerly commuted by other modes compared to 10 percent program wide. One employer, the Massachusetts Port Authority, undertook an internal evaluation which revealed that the provision of a 50 percent subsidy increased pass use among its 300 employees from 30 to 150, 26 percent of whom had not previously used transit.[f/] In Jacksonville, employees of 3 firms offering 43 percent subsidies on transit pass purchases averaged a 19.8 percent transit mode share compared to a 4.5 percent mode share among employees of firms selling passes without a discount. Des Moines has extensive employer involvement in pass sales with over 30 employers offering 10 to 100 percent subsidies (666).

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e/ Massachusetts Bay Transportation Authority, op.cit.

f/ Ibid.

Response to Paratransit Service Marketing

It is reasonable that marketing of paratransit services is particularly crucial as compared to marketing of regular transit. Due to the relatively recent introduction of the paratransit concept, the nature of paratransit service is unknown to many potential users. Also, paratransit clientele are often more narrowly defined population subgroups than are transit patrons as a whole. Analysis of the effects of pararansit marketing is scarce, but initial results are encouraging. Most promotions to date have dealt with reduced fare schemes, since paratransit services in general are costly to operate and charge relatively high fares.

In Rochester, a direct mailing to 17,000 homes announced "50/50 Week", when offpeak paratransit fares would be halved from their normal one dollar value. Overall weekly ridership rose from 1,700 to over 2,000 during the week and never fell below 2,000 after the promotion ended. Other fare incentives reportedly reaped unspecified patronage gains. A second successful marketing technique in Rochester involved free service between two newly opened senior citizen high rise apartment complexes and a shopping center. Project planners pursuaded a supermarket chain to underwrite the one trip per week service on an experimental basis. Positive results led the chain to pay the full cost of the eventual three trips per week necessary to meet demand. A similar shoppers' bus operated successfully in Syracuse (521).

Response to Transportation Brokerage Programs

Transportation brokerage organizations have been established in several urban areas, each with a somewhat different focus and methodology. Table 40 lists general attributes of many of these programs. Brokerage provides increased opportunities for ridesharing by overcoming problems of information and coordination which confront those for whom driving alone is not necessarily the preferred mode, but for whom regular transit service is often not a viable or desirable option. The relative infancy of the brokerage concept makes definitive conclusions premature. Early results have been diverse, and present a very mixed picture.

Degree of employer interest and involvement is a primary determinant of brokerage program success. In Minneapolis, 25 percent of the employees in those firms actively participating in a brokerage program submitted applications for ridesharing matches, compared to 5 percent of employees in non-participating firms. Figure 23 traces employee response rates in the Minneapolis demonstration. In Knoxville, extensive involvement by the Tennessee Valley Authority led to large increases in ridesharing among employees, while the degree of response to an areawide program in the same city was said to relate to the level of employer interest at each firm contacted. In Portland, carpooling increased from 21 percent to 34 percent of the workforce in companies exposed to an employer oriented program versus an increase from 11 percent to 17 percent among employees subjected solely to a mass media campaign (462, 556*, 637, 696*).

The brokerage program with the broadest scope of services and incentives, and arguably the most successful, is oriented almost exclusively toward the 3,000 plus central headquarters employees of the Tennessee Valley Authority in downtown Knoxville. The program grew from one express bus in late 1973 to ten carrying 330 people and 6 vanpools carrying 69 people one year -- and one fuel shortage -- later. The number of employees carpooling increased from 900 to 1200 during the same

Table 40
Characteristics of Brokerage Programs
(176#, 254, 556*, 586#, 637, 660, 696*)

	Knoxville TVA	Knoxville Citywide	Minneapolis	Golden Gate	Maryland DOT	Norfolk
Focus	Employer	Employer	Employer	Areawide	Areawide	Employer
Modes	Transit Buspools Vanpools Carpools	Transit Buspools Vanpools Carpools	Vanpools Carpools	Transit Buspools Vanpools Carpools	Transit Vanpools Carpools	Transit Buspools Vanpools
Program Elements						
A. Matching	A	A	A	A	A	A
B. Media Advertising		B		B	B	
C. Worksite Advertising	C	C	C	C	C	C
D. Employee Presentations			D			D
E. Telephone Information	E	E	E	E	E	E
F. Vehicle Leasing Assistance	F	F	F	F	F	F
G. Ridesharing Incentives	G					

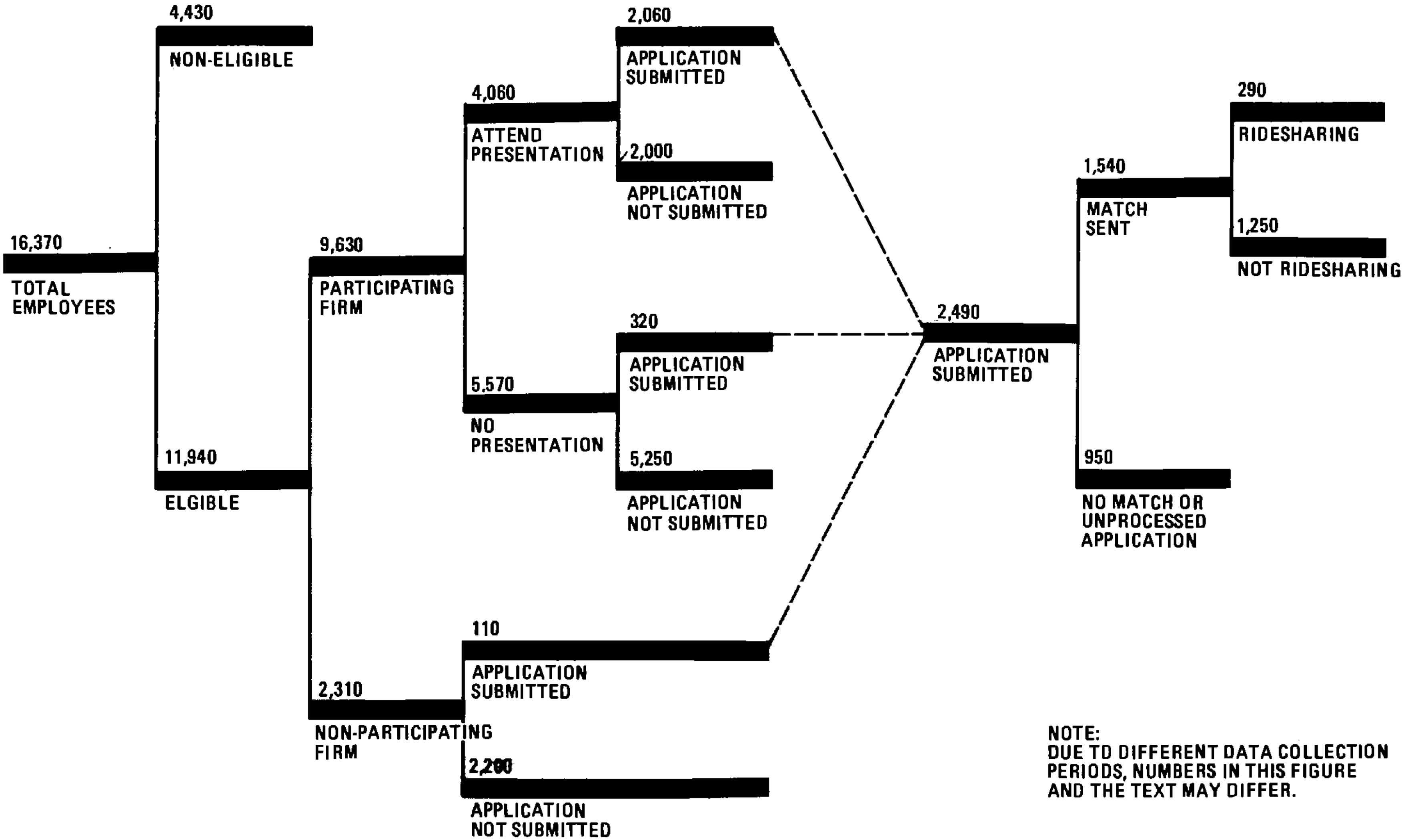

Figure 23
Ridesharing Development in Minneapolis
(556*)

period. Bus and vanpool subsidies, and preferential, inexpensive carpool parking, were then introduced. By the end of 1976, 23 express buses, 18 vanpools, and 436 carpools were carrying 950, 2400 and 1400 employees, respectively, while site employment grew by 400. The dramatic mode shifts which occurred are shown by the TVA employee modal usage percentages given below for pre-brokerage, brokerage without monetary incentive, and brokerage with monetary incentive conditions (696*):

	Pre-Brokerage	Brokerage, No Monetary Incentive	Brokerage, Monetary Incentive
Drive alone	65%	42%	18%
Carpool	30	40	41
Vanpool	0	2	7
Express Bus	0	11	28
Regular Bus	3	3	3
Other	2	2	3

The success of the TVA project spawned a city wide brokerage program in January 1976. By June 1977, 47 vanpools were carrying 450 commuters to 12 firms. Over 18,000 people had requested and received carpool match lists. A random sample indicated that 13 percent of the lists were used to make initial contacts with the intent of ridesharing, but that only 3.3 percent of those using the lists (approximately 80 persons) actually entered into ridesharing arrangements (637). The ridesharing demonstration in Minneapolis, targeted for suburban multi-employer sites, met with little success. After one year of operation, there were approximately 250 new carpoolers out of over 16,000 employees, representing an 11 to 13 percent increase in carpool mode use at the two sites examined. Eight vans were placed in service over the course of the year, but by the end of the year only five remained in service and four carried fewer than six passengers. Approximately 2 percent of total site employees and 19 percent of those supplied with matches had joined or formed carpools or vanpools (556*).

The Maryland DOT ridesharing program has placed about 1,975 commuters in 139 vanpools and helped form an estimated 6,000 carpools over a five year period. The Golden Gate Bridge, Highway and Transportation District formed 30 vanpools with 290 persons over the course of 8 months (see the digest "Vanpools/Buspools"). Both organizations also promote other high occupancy modes (176#, 586#). Existing commuter patterns to the Newport News, VA core area, dominated by industrial employment associated with a major shipyard, help illustrate the potential for multi-modal ridesharing. Even in the absence of any formal brokerage procedure, long commute distances and congested road conditions have fostered the following peak hour modal uses:[g/]

Single occupant auto	20%
2 person carpool	35
3+ person carpool	9
Vanpool	15
Buspool	8
Transit	12
Other	1

g/ Information obtained from City of Newport News, Virginia.

Underlying Traveler Response Factors

The trip making decision process of the urban dweller can be described as consisting of "mobility choices", such as the choices of residential location and number of cars to own, and "travel choices", which involve the day-to-day decisions about when, where and how to travel. The travel time, cost and convenience characteristics of alternative modes influence mobility choices to some degree. They influence travel choices to a very large degree, at least among those whose mobility choices have not made them "captive" to a particular mode (640). However, whatever influence the characteristics of alternative travel modes have on these choices is dependent on the urban dweller's knowledge and perception. How travelers respond must turn on what information they have; thus the marketing role of transit informational campaigns and brokerage operations.

Based on the assumption that the users of existing transit services are a static clientele, it has been common to think that informational campaigns are superfluous except for new services. There is evidence that this basic assumption is wrong. A survey of bus riders using the Shirley Highway Busway into Washington, DC, taken 3 to 5 years after initial opening of the various individual bus routes, indicated that 57 percent of the riders had started using the service at the time of a residence or workplace location change rather than upon inception of the busway route serving them (397#). The attrition rate among workers riding poverty-area-to-employment-area bus services was found to be between 4 and 11 percent per month (145#). Surveys in the Philadelphia region identified major turnover in commuter railroad passengers from month to month (574#). At the end of a 6 month period of stable bus ridership volumes on the San Bernadino busway, concurrent with opening of the facility to carpools, it was found that 19 percent of the bus riders were persons who had changed mode or route during the period, and another 5 percent were making new trips (140#). Surveys of Sacramento employees showed that over a span of 12 months approximately 30 percent of all transit commuters stopped taking the bus to work and were replaced by a group that previously used other travel modes (150). Findings of this nature lead to the conclusion that potential new transit users must be constantly informed and attracted.

The information on the travel patterns of other commuters that is necessary for an individual to initiate ridesharing is at least as difficult to obtain as transit service information. Interpersonal influences including reluctance to travel with strangers or to assume a lead role in organizing ridesharing arrangements, and uncertainty as to the risks and responsibilities involved, are also thought to be major obstacles to ride-sharing. All of these are important areas addressed in brokerage operations. Employee meetings, matching services, and vehicle leasing and monitoring all serve to overcome the information barriers, discomfort and uncertainty associated with forming group travel arrangements.

With respect to fare prepayment, the convenience of eliminating change handling and exact change uncertainties is often as important to pass and multi-ride ticket purchasers as any travel cost discounts that accrue. In Tulsa, 42 percent cited convenience as the primary reason for prepayment, while 32 percent cited cost and 24 percent said both. Only 2 percent of respondents indicated that neither convenience nor cost was a primary factor in their decision to use prepayment options. Based on anticipated trip making on the survey day, slightly less than one-half of all travelers chose the most economical form of fare payment. Shorter term daily and weekly passes tend to be more popular than monthly passes, thought to be attributable to the lower up front cost and uncertainty about longer term travel needs (266). The factors which come into play when employees receive employer transit prepayment subsidies have received little or no study, and the effects of possible peer pressure and automatic versus out-of-pocket payment are completely unknown.

Prior Mode, VMT, and Related Impacts

The impact analysis of transit marketing actions has generally not been taken further than identification of the first order effects described in the earlier sections of this digest. Marketing of service changes in particular is a supportive activity, and for further information on results of the primary actions reference should be made to the impact discussions in the applicable transportation system change digests.

Prior mode data for those opting for all types of ridesharing arrangements in a comprehensive brokerage-type program are scarce, but can be inferred for the Knoxville TVA brokerage program from the mode split data given under "Response to Transportation Brokerage Programs." Prior modes of TVA and Knoxville citywide vanpoolers are listed below (637), and other vanpool prior mode data is presented and discussed in the "Sources of New Ridership" section of the "Vanpools/Buspools" digest.

Knoxville Vanpooler Prior Modes	Citywide	TVA
Drove alone	36%	45%
Drove with family member	3	2
Carpool	58	36
Bus	0	11
Other	3	6

As already noted, traveler response to transportation brokerage programs has been mixed. The impacts are thus similarly varied. The low levels of ridesharing induced by the Minneapolis brokerage program preclude any significant impacts on mode split or congestion. It is estimated that VMT was reduced by 10,056 vehicle miles daily through vanpooling induced by the citywide program in Knoxville, a savings worthwhile but modest in the areawide context (556*, 637).

The overall Golden Gate Bridge, Highway and Transportation District and Knoxville TVA program impacts are quite substantial. Golden Gate brokerage activities are but one part of the total spectrum of the District's multimodal activities. Traffic south across the Golden Gate toward San Francisco, between 6 AM and 10 AM, serves as a yardstick of results. When the District became multimodal in 1970, a ferry service was added that carried 1,500 peak period passengers by 1977. In 1972 the Marin and Sonoma County commuter bus service was acquired, and the peak period bus passenger flow across the bridge increased over 5 years from 4,000 to 8,300 in 1977. The 3+ passenger carpool count rose from 900 vehicles in 1974/75 to 1,600 in 1976/77 upon being accorded free toll and use of the 3.8 mile with-flow secton of the Route 101 priority lane (with impetus given by a transit strike and emergency matching program). By 1977 a club bus program was serving 800 commuters with 20 buses areawide, and the District's vanpool program as of May 1978 served 285 in 30 vans. The 20 of these vans that cross the Golden Gate added 0.5 percent vanpool mode split to the ridesharing pattern illustrated by the Spring of 1977, inbound 6 AM to 10 AM count (176#):

Mode	Vehicles	Persons	Mode Split
1 person auto	15,500	15,500	36%
2 person auto	3,950	7,900	19
3-5 person auto	1,300	4,250	11
6+ person auto/van	40	300	1
Transit	225	8,300	26
Buspool	15	500	2
Ferries	N.A.	1,500	5
	21,030	38,250	100%

Figure 24 depicts the changes in selected commuter travel characteristics wrought by the TVA Knoxville headquarters brokerage program. One program impetus was avoidance of new parking construction. TVA employees in January 1977 required 1,066 parking spaces, just under half the November 1973 requirement of 2,195 spaces despite a 15 percent growth in staff. The program in 1977 was saving 31,000 daily VMT after accounting for primary and access mode travel, a 51 percent savings compared to what continuation of the modal patterns of 1973 would have produced. The corresponding net fuel savings is 460,358 gallons of gasoline annually, 135 gallons per employee. In addition, it is estimated that the travel speeds on adjacent I-40 are 10 mph higher during TVA start and finish times than they would be under pre-project mode split conditions (696*).

Cost Effectiveness

In general, transit service informational campaigns and the marketing of new services have been judged, by the project staffs involved, to be worth the cost in terms of the knowledge imparted (15*, 114, 574#, 691#). Less specific advertising and promotional campaigns have, in individual cases, been deemed a poorer investment (15*, 691). The $7,600 cost of preparing and disseminating the Penn Hills neighborhood map and consolidated schedule in Pittsburgh was recovered within 6 months by the increased farebox revenues generated (15*).

The temporary revenue gain induced by intense follow-up promotion on a suburban express route in St. Louis did not appear to be commensurate with the expense, but the distribution of free-ride tickets was found to be a low cost promotional device. The free rides that regular patrons obtained were counterbalanced by return fares paid by the added increment of riders attracted (691#). However, an evaluation of the full cost versus fares attracted by a "Welcome Wagon" type pass distribution in Sioux Falls led to program termination (84).

The short term revenue loss of Sacramento's 25 percent discount on passes sold through employers was an estimated $11,900. This loss was recovered from the fares

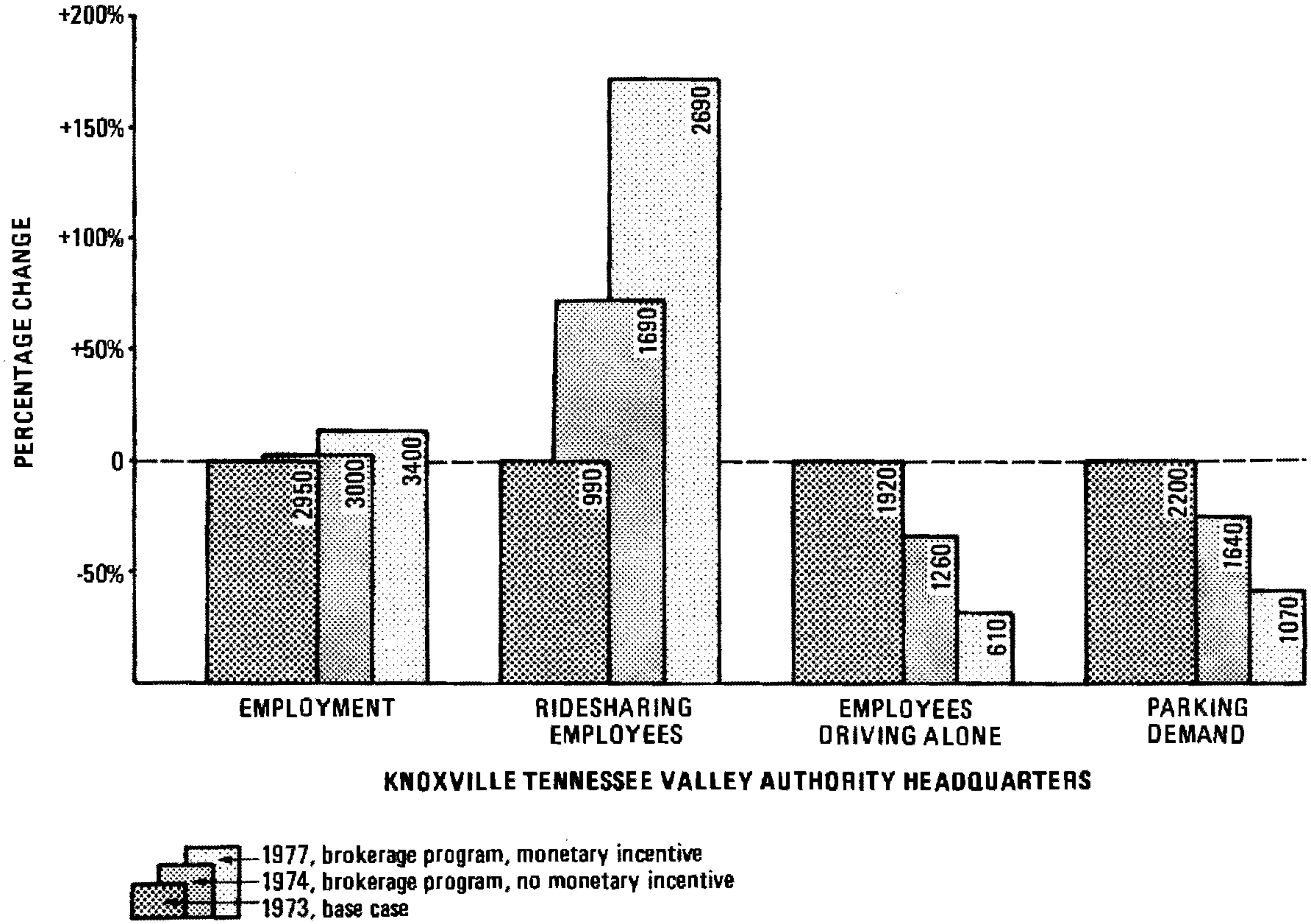

Figure 24
Changes in TVA Travel Characteristics
(696*)

of new riders attracted in 7 months.[h/] Taking into account a 6 percent monthly attrition for riders attracted by the discount, an ultimate net revenue gain of $18,500 was expected. The 1980 Sacramento Regional Transit District "steady state" costs for their total (general public and employer) fare prepayment program were $1,147 per month for pass production and administration of 100 pass outlets; 11¢ per instrument (150).

The cost effectiveness of transportation brokerage is often difficult to measure owing to different perceptions of alternative costs. For instance, the Golden Gate demonstration may have incurred high administrative costs on a per van basis, but it was expected to be more cost effective in the long run than expanding the bus fleet and providing subsidies to serve the same riders (176#). Transportation brokerage has proven very cost effective at TVA in Knoxville. It is estimated that over $600,000 in annual parking construction and maintenance costs and $400,000 to $800,000 in annual employee travel costs were saved at TVA for an annual program expenditure of $125,000, including bus ticket and vanpool subsidies, bus line guarantees, carpool parking and administrative fees, but not any internal credit union administrative costs (696*).

Media Effectiveness

Newspapers were identified as being the most effective conventional media in two suburban service informational campaigns, but radio advertising was recalled best in the small city of Ithaca, NY. Handouts incurred the lowest cost per Golden Gate vanpool application received. During "Operation Reading" in the Philadelphia area, persons were judged favorably influenced by promotion if they reported positive attitudes, trial usage of railroad commuter service, or future intended increased usage. The cost per household favorably influenced in the peak month of advertising, March 1966, was $0.13 for newspapers, $0.32 for radio and $0.46 for television (574#). Skokie, Illinois, residents first learned about the Skokie Swift rapid transit extension via the following sources, in the percentages indicated (114):

Suburban newspapers	51%
Major Chicago papers	19
Radio	5
Television	3
Friends and other sources	22

In Ithaca, awareness of public service radio advertising ranged from 72 percent in the under-18 age group down to 29 percent in the over-65 group, while awareness of merchant-sponsored newspaper advertising did not exceed 14 percent in any age group (588*). Newspaper advertising proved a costly means of attracting vanpoolers in the Golden Gate corridor, but was better than community meetings, fair booths and free

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h/ Without a strike the recovery period would have been an estimated 5 months.

van rides. The estimated direct cost per application received is given in the following tabulation for each means of vanpooling promotion utilized (176#):

Campaign	Applications	Cost-per-Application
Employer contacts	231	$ 17
Fairbooths	0	(508)
Public take-one holders	1	211
Toll booth handouts	46	13
Bus handouts	46	13
Free van ride	2	304
Community meetings	10	710
Downtown demonstrations	84	17
Shopping center demos	3	100
Newspaper advertising	44	215

Experience gained during development of poverty area bus routes consistently showed that specialized procedures are required in advertising, promoting, and providing service information to minority communities. Conventional route and schedule information, and conventional mass media approaches, were of little value. What seemed to work better were more direct approaches; through churches, manpower agencies, community functions, and person-to-person mechanisms, handled by individuals with an existing liaison to the targeted communities (145#).

Additional References

For additional information on Transit Marketing/Brokerage consult references:

15*, 22, 24#, 25, 35, 38, 40, 43, 52, 65, 84, 102, 103, 113, 114, 117, 119, 132, 138*, 143, 150, 153, 164, 167+, 176#, 180, 183, 193, 202, 204, 225, 230, 238, 240, 241, 242, 254, 266, 283#, 284, 301, 319, 330, 378*, 424, 495, 503, 504, 506, 521, 524, 543, 547, 550, 551, 556*, 573, 574#, 586#, 588*, 614, 618, 621, 622, 630, 647, 654, 655, 657, 658, 660, 666, 674, 691#, 692, 696*.

See also the references entered in the Chapter III cross-reference lists under "Consumer Preference Analysis."

15. Allegheny County, Port Authority of. Advertising and Promotion Demonstration Program. Sponsored by Urban Mass Transportation Administration, U.S. Department of Transportation; Project No. PA-MTD-7. 1970. 122 pages. NTIS No. PB-194-500. TRANSIT MARKETING/ BROKERAGE*, TRANSIT FARE CHANGES. OBSERVED RESPONSE. VOLUME.

The Port Authority of Allegheny County, Pennsylvania conducted a 1967-68 demonstration project in which concepts and techniques were developed to advertise, promote, and provide information on their existing transportation system. Emphasis was placed on increasing off-peak ridership. The Port Authority at the time operoted 183 transit routes with an average weekday ridership of approximately 360,000. In 1970, the number of annual transit rides per capita was 65.5.

An attitudinal survey was conducted in selected areas at the outset to provide needed input for project planning. The results led to 2 basically different approaches, one concentrating on better information dissemination and the other on advertising to improve the perception of transit service. A ridership simulation model was developed to quantify expected ridership variations in response to variables such as weather, season, work or school holidays, and secular patronage trends, thereby providing a more accurate basis for identifying promotional campaign impacts. Unfortunately, certain events occurred during the project whose impact could not be readily quantified or controlled. These included a work stoppage affecting riders in the Penn Hills project area, the April 5-10, 1968, civil disorders and curfew which led to protracted negative effects on patronage, and the July 23 institution of exact fare, which was isolated as a negative ridership factor affecting some routes.

The initial attitudinal survey found that Penn Hills residents had a particularly low opinion of the transit information program, and, in fact, the existing multi-route service was poorly described by the available timetables. A multicolor transit map and consolidated schedule was prepared for the Penn Hills area and distributed via a local newspaper insert and upon request. Prior to the civil disorders, a 6% gain in off peak patronage and a marginal gain in peak ridership were recorded on the Penn Hills routes. Later analysis showed the off peak gain to have slipped to 3.5%, still statistically significant, while the peak period gain was 0.4% (statistically insignificant). Increased farebox revenues recovered the $7,600 cost in 26 weeks. Later, a downtown transit guide was prepared showing downtown transit stops and shuttles. Some 150,000 copies were distributed in connection with a Christmastime $65,000 newspaper, radio and TV campaign stressing the economy and social acceptability of shopping via transit. The ridership response on the routes examined was mixed and inconclusive.

Between these 2 informational campaigns were a $47,000 "Summer Fun" multi-media campaign stressing Port authority comfort, convenience, service, information, and price; a $2,200 campaign in black-oriented newspapers and radio stressing public transit ownership and service to the black community; and a $3,700 local radio and newspaper campaign in McKeesport stressing McKeesport involvement in the transit operation. Ridership declines from 1% to 8% were registered with statistical reliability ranging from not reliable to marginal reliability. Followup attitudinal surveys showed deterioration in the public perception of almost all aspects of transit service. The study concluded that the civil disorders in Pittsburgh had affected attitudes on the social acceptability of public transit and that the exact fare requirement and talk of fare increases affected attitudes toward the cost of using transit. The advertisements not only failed to improve attitudes but may have created a credibility gap as citizens saw ads featuring good transit service when in fact they felt the situation was deteriorating.

138. Crain and Associates. Transit Fare Prepayment Demonstrations in Austin, TX and Phoenix, AZ. Sponsored by Transportation Systems Center, U.S. Department of Transportation. June 1979. 238 pages. TRANSIT MARKETING/BROKERAGE*, TRANSIT FARE CHANGES. OBSERVED RESPONSE. VOLUME. REVENUES/DEFICITS.

Demonstration projects were conducted in Austin, TX (1976 pop. 308,000) and the Phoenix, AZ urbanized area (1975 pop. 908,000) to test the effects of discounts, increased sales outlets and promotion on the use of prepaid fare options and in turn on ridership. Both rapidly growing sunbelt state capitals, Austin has a core that continues to generate substantial travel, while Phoenix is characterized by low density dispersed employment sites. The 63 Austin buses serve 22,000 daily riders and the 150 Phoenix buses carry 30,000 trips per day. Prior to the demonstration, 9% of Austin riders and 15% of Phoenix riders opted for fare prepayment. The main payment options were:

		Austin	Phoenix
Adult fare	(peak/off peak)	.30/.15	.40/.40
Monthly pass	(unlimited)	$15.00	$18.00
	(peak only)	$10.00	not offered
	(off peak only)	$ 6.00	not offered
10-punch card		not offered	$ 3.75
20-punch card		$ 3.00 (2 punches/peak trip)	$ 7.50 (ended in 9/78)

Discounts on prepayment options of 20% were offered during March 1978 in Austin and February 1978 in Phoenix, while 40% discounts occurred during October 1977 in Austin and October 1978 in Phoenix. Phoenix purchasers could obtain up to two months-worth of cards or passes during each of the sales. Over the course of the demonstration, the number of sales outlets in Austin was expanded from 26 to 47 while Phoenix increased the number of outlets from 89 to 117 prior to the first discount period. In Austin $40,000 and in Phoenix $58,000 were spent on media and on-board advertisements, billboards, utility bill mailers and shopping center promotions.

Short term ridership and pass sales increased in both systems, as would be expected due to the inherent fare decrease. Procedural errors marred patronage estimates in Austin, but in Phoenix boardings were up 63% during the 20% discount month and up 15% the following month compared to pre-discount figures. Most of the increase was due to increased trip rates among prior riders. The table below gives sales and elasticity values for the main prepayment categories.

	Prior to discount	With discount	Percent increase	Elasticity
Austin 20% discount (2nd)				
20-punch card	1,000	2,995	200%	-4.9
Unlimited monthly pass	41	46	12	-0.5
Peak monthly pass	125	212	70	-2.4
Austin 40% discount (1st)				
20-punch card	1,000	5,167	417%	-3.2
Unlimited monthly pass	40	112	180	-2.0
Peak monthly pass	135	245	81	-1.2
Phoenix 20% discount (1st)				
10-punch card	4,200	9,400	124%	-3.6
Monthly pass	60	162	170	-4.5
Phoenix 40% discount (2nd)				
10-punch card	4,600	12,722	177%	-2.0
Monthly pass	60	1,039	1,632	-6.5

Long term results were less encouraging. Although one year after the demonstration, 15% of new purchasers continued to use prepaid options, their monthly attrition rate was 11% as compared to 6% for long term purchasers. Furthermore, trip rates of the former group did not increase relative to the "before" condition. Even if all people riding transit for the first time and using prepaid options to do so were attracted solely by prepayment, the long term patronage increase would be only 0.25% in Austin and 0.33% in Phoenix. The most cost effective advertising strategies were those targeted for existing riders. Outlet expansion apparently accounted for some additional fare prepayment; distance to an outlet was found to be a determinant of pass usage.

378. Massachusetts Bay Transportation Authority, et. al. Pre-Paid Transit Pass Program Study.[a] Sponsored by Urban Mass Transportation Administration, U.S. Department of Transportation. March 1976. 57 pages plus exhibits and appendices. TRANSIT MARKETING/BROKERAGE*, TRANSIT FARE CHANGES. OBSERVED RESPONSE, BACKGROUND INFORMATION. VOLUME, MODE CHOICE. REVENUES/DEFICITS.

Begun in March 1974, MBTA's prepaid transit pass program enabled employees to obtain rapid transit and light rail passes through monthly payroll deduction of their employment sites. The program was later expanded to include sales through banks to their customers and the general public, and through colleges to their faculty and students. The monthly payroll deduction amounted to the equivalent of 17.5 round trips per month. Passes were usable throughout the day and all days of the week, but were not legally transferable. Initially, the inclusion of bus transit was felt to involve too many complexities and was not undertaken. As of 1981, bus passes are available.

Information in this study was obtained through MBTA records and survey samples of pass program participants, non-participants and drop outs. In addition, random observations were made at two of the most heavily used rapid transit stations. The table below details the growth of the program since its inception with one employer and 550 passholders.

Year[1/]	No. of employers	No. of passholders
1974	17	6,000
1975	117	17,600
1977	405	18,900
1978	730	28,600
1981[2/]	740[3/]	73,000

[1/] end of year except 1981 (May)

[2/] includes bus passes and sales to general public not previously available

[3/] plus over 50 banks and 10 colleges

In addition, as of May, 1981, 11,000 monthly commuter rail passes permitting free transfer to the rapid transit system were sold. The free transfer option was identified as a factor in ridership and revenue increases of 3% and pass use by 50% of daily riders on commuter rail operations after its 1977 introduction.

In 1976, 3% of transit pass users had previously commuted by other modes, while increased riding among former casual riders resulted in an additional 5% increase in transit use among passholders. Since then, 56 employers have begun partially or fully subsidizing the cost of the passes and the proportion of passholders formerly traveling by other means has risen to 10% overall, and between 23% and 34% among employers offering subsidies. Approximately 30% of adult daily riders on the system now use passes. About 60% of employees in participating firms use transit for the journey to work and one half of these are passholders.

On an annual round trip basis, surveys in 1976 found that for the 210 trips paid for, pass users averaged 333 trips (250 work, 83 non-work) as compared to 307 trips (234 work, 73 non-work) prior to the program. Attitude surveys revealed that 87% of participants were "very satisfied" with the program and 2% were "not satisfied". The 3 primary advantages cited by users were boarding speed, no need to carry change and monetary savings. Employers spend from under $250 to over $2,000 in program start up costs and from under $150 to over $500 in monthly administration costs, exclusive of subsidies. As an adjunct to the program, a variable work hours program involving 285 companies and 84,000 employees has been initiated to relieve overcrowding on the transit system.

[a] In addition to information from the cited report, this review contains supplementary, post 1976 information obtained in discussions with project staff and from an updated summary paper.

556. Sherman, Len. Interim Evaluation of the Minneapolis Ridesharing Commuter Services Demonstration. Cambridge Systematics, Inc. Sponsored by Urban Mass Transportation Administration, U.S. Department of Transportation; Contract Number MN-06-0008. March, 1979. 152 pages. NTIS PB 295-189. TRANSIT MARKETING/BROKERAGE*, CARPOOLING ENCOURAGEMENT ACTIVITIES, VANPOOLS/BUSPOOLS. OBSERVED RESPONSE. MODE CHOICE, AUTO OCCUPANCY.

In June 1977, the Metropolitan Transit Commission (MTC) of Minneapolis-St. Paul initiated a 2-year ridesharing project. The objective was to diminish single-occupant auto commuting through the implementation of a comprehensive brokerage program targeted at suburban multi-employer work sites. The metropolitan area has widely dispersed employment with only 17% of area jobs in the 2 downtowns, 50% in suburban locations and the remainder in outlying communities. Three sites, with between 3,600 and 8,700 employees each, were selected for the demonstration. All were characterized by relatively congestion-free access, abundant free parking and short commute distances for most employees. This report covers first year experience at 2 of the sites. Pre-demonstration travel surveys revealed the following distribution of one way commute distances for solo drivers:

	South Central Minneapolis	Pentagon Park/Normandale
10+ miles	18%	40%
20+ miles	2	7

MTC and a non-profit contractor were responsible for overall management and for marketing and matching services associated with carpooling. Vanpool marketing and formation were sub-contracted to an outside firm. The marketing strategy consisted of 4 phases: 1) introduction of the program to employers through personal contacts, 2) meeting with interested employers to distribute pre-demonstration travel surveys and to arrange for employee presentations, 3) employee presentations on company time to promote the ridesharing program and to distribute ridesharing applications, and 4) matching compatible employees to form carpools and vanpools. People whose employers chose not to participate were informed of the brokerage service through posters, information booths and literature distribution. All aspects of vanpooling, including van provision, maintenance, insurance, driver selection, training and record keeping were established by the subcontractor, minimizing employee risk and involvement. Incentives for vanpool drivers included free personal commuting, subsidized personal van use and a portion of the 10th and 11th passengers' fares.

The demonstration has met with little success in generating new ridesharing. Contributing factors are believed to include ease of auto commuting, reluctance of small employers to participate (the median employer size at one site was 5 workers), wide variance in start/end times and reluctance on the part of people to form pools with employees of companies other than their own. The number of employees carpooling to the two sites increased 13% and 11% (from about 14% to 16% of total commuters at one site and from 11% to 12% at the other). In all, 329 employees began carpooling in the first year, some of whom dropped out through attrition. Eight vans were placed in service during the first year, but at the time of the report only 5 were still operational and 4 carried 6 or fewer passengers. Nearly 50% of vanpoolers dropped out of the program within 6 months, largely due to changes in employment conditions. One vanpool dissolved due to personality conflicts.

The importance of the brokerage concept in generating interest in carpooling was thought to be substantial. Of employees eligible for carpooling (i.e., office-bound and not on rotating shifts) 51% of those who attended employee presentations submitted applications, versus 6% of those who did not attend presentations given at their work site and 5% of those whose employer chose not to participate. This statistic may be somewhat misleading as all presentation attendees were urged to submit applications. Those who did not attend presentations and thus put the most effort into submitting an application may have been more committed to continue the process. Be that as it may, the marketing techniques employed appear to have stimulated interest. Over 80% of those submitting applications were sent matches. Wide geographic areas were considered compatible; project administrators felt it better to let the individual decide what constituted prohibitive circuity. Approximately 15% of those provided with matches joined carpools. An important innovation in the project was the inclusion of follow-up phone calls to those sent match lists. It was felt that in addition to prodding potential carpoolers (only 15% had contacted others on the list at the time of the follow-up call), the calls helped identify those who had lost interest so they could be removed from the list. After one year the number of active names on file was roughly equivalent to the number of people who had lost interest.

588. Stopher, Peter. R. and Arnim H. Meyburg. User and Non-User Perception of a Small Urban Area Bus System: An Exploratory Investigation. Cornell University. May 1973. 25 pages. TRANSIT MARKETING/BROKERAGE.* OBSERVED STATIC SITUATION. TRAVEL CHOICE.

An exploratory study was performed in the urban area of Ithaca, New York, to determine the efficacy of currently used marketing strategies for a small urban area bus system and to obtain user rankings of certain aspects of the bus service. Ithaca had a population of a little over 26,000 persons, and was served by 7 buses running on 4 separate routes (3 routes at the time the survey began). The fare was a flat 25¢, covering 75% of the operating costs. Ridership had increased 12% in the 2 years preceding the study. The transit system carried nearly 300,000 riders a year; an average of approximately 11 rides annually per capita.

Interviews for the study were conducted on buses and at households on streets within 200 yards of 19 separate bus stops in October 1972 and March 1973. A total of 255 persons were successfully interviewed, 156 on buses and 99 in their homes. Among those interviewed were 214 bus users and 41 non-users. The Ithaca Community Transit System at the time spent only 1/4 of 1% of total revenues on advertising and promotion. Recent transit service advertising included newspaper display advertisements, of which there had been 4 in August and September 1972. These were sponsored by the Downtown Businessmen's Association and provided a free bus pass for a trip downtown. Public service radio advertising was provided by a popular and rock music station on a more or less continual basis.

Approximately 55% of all respondents, (51% of the bus users and 70% of the non-users) were unaware of any promotional activities on behalf of the bus system. The percentage of all respondents aware of the radio advertising ranged from 72% in the under-18 age group down to 29% in the over-65 age group. Awareness of the newspaper advertising did not exceed 14% in any age group. Nearly half of all respondents learned about the bus system by observation, 26% from friends, 14% from the free bus maps, 5% through advertising, and the remainder learned from bus drivers or else could not remember. Almost 20% of all respondents and 65% of non-users did not know that a free system map existed, while 56% of users had their own copy. Of bus users, 85% knew both the location of the nearest bus stop and the departure times, while 13% knew the stop location but not times. Among non-users, 17% knew both, 61% knew the stop location only, and 22% knew neither.

The demographic characteristics of the bus users and non-users differed greatly on the basis of the sample. The bus users were predominantly female, almost half under 23 years old, nearly half from non-car owning households (and therefore could be considered "captive" transit users) and over half from households with fewer than 3 members. In contrast, non-users had an almost equal sex split, almost all were over 23 years old, all lived in households with an automobile, and 3/4 came from households with 3 or more members. Among bus users, over half the sample used the bus less than 4 times a week, with the most common trip purposes being shopping (34%), work (26%), and school (21%). In ranking level of service characteristics on a 5 point semantic scale, 40% of survey respondents expressed dissatisfaction with comfort while waiting for the bus, 37% with frequency, 26% with storage for parcels, 17% with routing, 2% with ticketing, and less than 1% with driver helpfulness and politeness. On the whole the dissatisfaction percentages did not vary much by trip purpose. Those making school trips tended to be more dissatisfied and those making leisure trips less so than workers or shoppers across the full range of travel characteristics. Women were more dissatisfied than men with service frequency while the reverse held for provisions for parcel storage.

696. Wegmann, F.J., A. Chatterjee, and S.R. Stokey. "Evaluation of an Employer-Based Commuter Ride-Sharing Program." Transportation Research Board Special Report, Transportation Research Board, Washington, DC. Number 184. 1979. Pages 43-49. TRANSIT MARKETING/ BROKERAGE*, VANPOOLS/BUSPOOLS, CARPOOLING ENCOURAGEMENT ACTIVITIES. OBSERVED RESPONSE. MODE CHOICE, AUTO OCCUPANCY. ENERGY, REVENUES/DEFICITS.

Late in 1973, a citizen's meeting in West Knoxville, Tennessee, led to a major ridesharing program developed by the Tennessee Valley Authority for its employees who commute to Knoxville. The TVA is a major employer in the Knoxville area, with roughly a third of its employees residing in West Knoxville. The program first utilized commuter express buses for its service, then went on to add carpools and vanpools to ultimately attract a ridesharing total of 2686, or 79%, of the TVA's employees.

The first commuter express bus was put into operation on December 3, 1973, and was highly successful. Joint efforts between the city administration and the TVA employees proved effective in promoting ridesharing and, by the end of 1974, there were 10 express buses and 6 vanpools, all of which were primarily serving TVA employees. In January, 1975, an incentive program was initiated whereby commuter bus tickets were discounted by one-third, carpools received preferred and inexpensive parking, and vanpools were subsidized for every TVA employee rider. Following initiation of this program, there was an immediate reduction of 12% in the number of TVA employees driving to work. By January, 1977, there were 23 express buses and 18 vanpools serving TVA employees.

There were three stages in the development of the TVA program that are significant for purposes of comparison: the first stage is represented by the level of ridesharing in November, 1973, prior to any formal program; the second began with the introduction of express buses and vanpools which were encouraged by the TVA but without formal incentives; the third stage began with institution of incentives and is represented by the leveling off of ridesharing increases that had occurred by January, 1977. The mode-shares for the various commuting alternatives available to TVA employees are given below for each of these three stages:

Mode	November 1973	December 1974	January 1977
Drive Alone	65.0%	42.0%	18.0%
Regular Bus	3.5	3.0	3.0
Express Bus	0.0	11.0	28.0
Carpool	30.0	40.0	41.0
Vanpool	0.0	2.3	7.0
Bicycle, Walk, Etc.	1.5	1.7	3.0
Total (N = No. Emps.)	100%(N=2950)	100%(N=3000)	100%(N=3400)

By 1977, TVA employees required 1129 fewer parking spaces than in 1973, even though total employment had increased by 450. Similarly, 575 fewer spaces were needed in 1977 than in 1974, with an employment increase of 400 persons. If the modal use patterns of 1973 and 1974 existed with the 1977 employment level, the TVA would have required an additional 1463 or 793 additional parking spaces, respectively, to meet its needs. The annual cost savings of not having to build and maintain these spaces was estimated at $628,206 and $337,820, respectively, for the two modal use patterns. The estimated annual cost of the ridesharing program was about $125,000 (administrative costs not identified), demonstrating a substantial savings for the employer. Total employee cost savings over the November 1973 and December 1974 modal use patterns were estimated as $814,500 ($240 per employee) and $506,500 ($149 per employee) assuming full relief from auto ownership fixed costs in the computation. Other findings included fuel savings (460,358 gallons over the 1973 level of ridesharing; 238,758 over the 1974 level) and higher vehicular operating speeds in the corridors well-served by ridesharing.

CHAPTER III

BIBLIOGRAPHY OF SELECTED REFERENCES

CHAPTER III

BIBLIOGRAPHY OF SELECTED REFERENCES

This chapter contains the bibliography of the Handbook. It consists of two sections. The first section provides 1) a cross-reference list for each of 25 kinds of transportation system change and 2) a cross-reference list for each of 9 types of traveler response. The second section is the alphabetical bibiography itself. For directions pertaining to the use of the cross-reference lists and the alphabetical bibliography, see "Use of the Bibliography and Cross-Reference Lists" in Chapter I, page 25.

FHWA HANDBOOK CROSS-REFERENCE LISTS

System Change Cross-Reference List[a/]

Area Auto Restraints --

10, 28, 51, 58, 97, 141, 147, 165, 186, 194+, 199, 201, 219, 224+, 231, 243, 258, 263, 264, 265, 271, 285, 330, 360, 374, 379, 380, 383, 460, 463, 464, 465, 476+, 488, 499, 510, 512, 537, 549, 564, 582, 606, 654, 669, 675#, 679, 685, 712

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a/ Reference numbers followed by an asterisk (*) denote papers for which reviews are provided in Chapter II under the corresponding topic heading. Reference numbers followed by a number sign (#) denote papers for which reviews are provided in Chapter II under a topic heading other than the one corresponding with the particular key word in question. Reference numbers followed by a plus sign (+) denote papers reviewed in the first edition of this Handbook.

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b/ Reference numbers followed by a number sign (#) denote papers for which reviews are provided in Chapter II. Since the traveler response categories are not used as topic headings, the reference entry in the alphabetical bibliography should be consulted to determine the system change topic heading the review is under. Reference numbers followed by a plus sign (+) denote papers reviewed in the first edition of this Handbook.

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APPENDIX A

ELASTICITY DISCUSSION AND FORMULAE

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ELASTICITY DISCUSSION AND FORMULAE

The Elasticity Concept

Elasticity is a convenient, quantitative measure of travel demand response to price and service changes which influence demand. Elasticity measures are found throughout the transportation literature and have been reported and used in various sections of this Handbook. When used with caution, elasticities provide a satisfactory means of quickly preparing first-cut, aggregate response estimates for a number of types of system changes. When considering demand for transportation there are a number of elasticities of interest, including elasticities describing traveler response to changes in the overall amount of transit service, transit frequencies, transit fares, vehicular tolls, parking charges, and gasoline costs.

For elasticity measures to be applicable, the transportation system change must be a relative one. In other words, it must involve a quantifiable percentage increase or decrease in the system parameter involved. For example, while elasticity measures can be used to described the response to a change in the overall amount of transit service, they cannot be used to describe the response to a new bus system.

Transportation elasticities are informally adopted from the economist's measure "price elasticity." The price elasticity of demand is loosely defined as the percentage change in quantity of commodity or service demand in response to a 1 percent change in price. Thus, for instance, a price elasticity of -0.3 indicates that for a 1 percent increase in the price of a good or service, there is an 0.3 percent decrease in the demand for that good or service. The negative sign signifies an inverse relationship between price and demand, i.e., an increase in price results in a decrease in demand.

If a 1 percent change in a parameter causes a greater than 1 percent change in demand, demand is said to be elastic. If a 1 percent change in a parameter causes a less than 1 percent change in demand, demand is said to be inelastic. Many but not all transportation system changes elicit responses that are so-called inelastic. Figure 25 illustrates the different categories of demand response that can be caused by a 1 percent change in a system parameter.

Measures of Elasticity

There are three different methods commonly found in the transportation literature for computing elasticities: the point elasticity, arc elasticity and shrinkage factor methods. Point elasticity is derived directly from the economist's definition of elasticity. Mathematically, it is described by the following formula:

$$\eta_p = \frac{dQ}{dP} \cdot \frac{P}{Q}$$

Where η_p is the elasticity at price P, and Q is the quantity demanded at that price.

In practice, lack of information on the functional relationship between P and Q (the shape of the demand curve) precludes the computation of point elasticities from empirical data. Therefore, other formulations have been developed which allow the use of observed changes in price and associated demand.

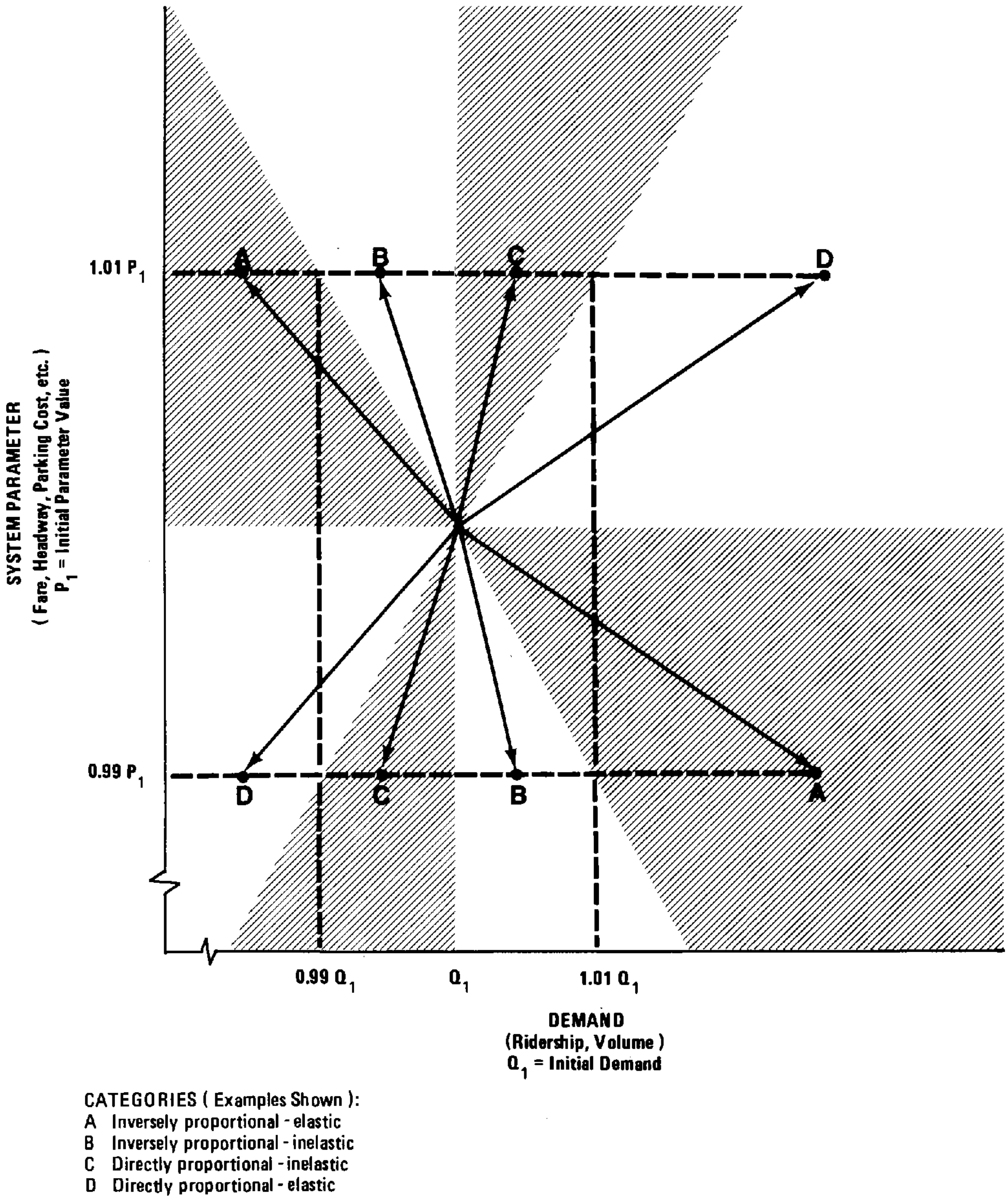

Figure 25
Categories of Demand Response to System Parameter Changes

The measure which most nearly approximates point elasticity and one frequently employed is arc elasticity. It is defined by a logarithmic formulation and, except for very large changes in P and Q, is closely approximated by a mid-point (or linear) formulation which makes use of the average value of each independent variable (71, 149).

log arc elasticity:

$$\eta = \frac{\Delta \log Q}{\Delta \log P} = \frac{\log Q_2 - \log Q_1}{\log P_2 - \log P_1}$$

mid-point (or linear) arc elasticity:

$$\eta = \frac{\Delta Q}{(Q_1 + Q_2)/2} \div \frac{\Delta P}{(P_1 + P_2)/2} = \frac{\Delta Q(P_1 + P_2)}{\Delta P(Q_1 + Q_2)} = \frac{(Q_2 - Q_1)(P_1 + P_2)}{(P_2 - P_1)(Q_1 + Q_2)}$$

where η is the elasticity, Q_1 and Q_2 are the demand before and after, and P_1 and P_2 are the price or service before and after.

Arc elasticity is based on both the original and final values of demand and price or service. The logarithmic formulation has been used whenever elasticities have been calculated directly from available data in this second edition Handbook. Similar values carried over from the first edition Handbook were computed using the mid-point formulation.

A third form of elasticity, historically used in reporting response to transportation system changes, is the shrinkage factor or shrinkage ratio. It is defined as the change in demand relative to the original demand divided by the change in price relative to the original price, or in mathematical terms:

$$\eta = \frac{\Delta Q/Q_1}{\Delta P/P_1} = \frac{(Q_2 - Q_1)/Q_1}{(P_2 - P_1)/P_1}$$

Shrinkage factors present certain conceptual difficulties. For example, consider a specific experimental transportation price reduction or service expansion and the accompanying travel volume increase. Assume, for illustrative purposes, that the demand returns to its original level if the price is raised or the service reduced back to its original state as a second experiment. Logically, the elasticity in this hypothetical example should be the same for both experiments, and it is if arc elasticity is computed. However, if the changes in price or service are moderately large, the corresponding shrinkage factors will be different. Shrinkage factor guidelines that are in common use are reported in this Handbook, but arc elasticity conversions are given where possible.

Differences Between Elasticity Measures

When the percentage change in price or service is small, all the methods for computing elasticity give approximately the same value. Large changes, however, result in different values of elasticity depending on the formula used. The table below gives elasticity values calculated for different fare changes and an assumed log arc elasticity of -0.300.

Percent fare change	Log arc elasticity	Mid-point arc elasticity	Shrinkage factor
-50%	-0.300	-0.311	-0.46
-30	-0.300	-0.303	-0.38
-10	-0.300	-0.300	-0.32
+10	-0.300	-0.300	-0.28
+30	-0.300	-0.302	-0.25
+50	-0.300	-0.304	-0.23
+100	-0.300	-0.311	-0.19

Figure 26 illustrates the differences in the three measures of elasticity for an initial point price elasticity of -0.30 (384).

For both point and arc elasticities, an absolute elasticity value greater than 1.0 signifies an elastic relationship while an absolute value less than 1.0 indicates an inelastic relationship. This is not necessarily the case for the shrinkage ratio as the transit fare reduction example below illustrates (188). The loss of revenue in the example shows that increased ridership was not great enough to offset the fare decrease in terms of revenue; an inelastic relationship between fare and ridership.

Initial fare = \$0.40	Initial ridership = 1,000	Initial revenue = \$400
Final fare = \$0.25	Final ridership = 1,500	Final revenue = \$375

Shrinkage ratio = -1.33
Log arc elasticity = -0.86

Use of Elasticity in the Handbook

Elasticities should not be taken or used as precise predictive measures. They simply serve to indicate the likely order of magnitude of response to system change, as inferred from aggregate data on the experience in other, hopefully comparable, instances. However, they can be very useful in providing first-order estimates of the changes in demand which may be expected for certain price or service changes.

The formulae for applying arc elasticities to predict traveler response are not the same as for applying shrinkage factors. Given a proposed transportation system change, to compute the new travel demand which may be expected given an arc elasticity value thought to be applicable, the equations to use are:

log arc elasticity:

$$Q_2 = 10^{\eta(\log P_2 - \log P_1) + \log Q_1}$$

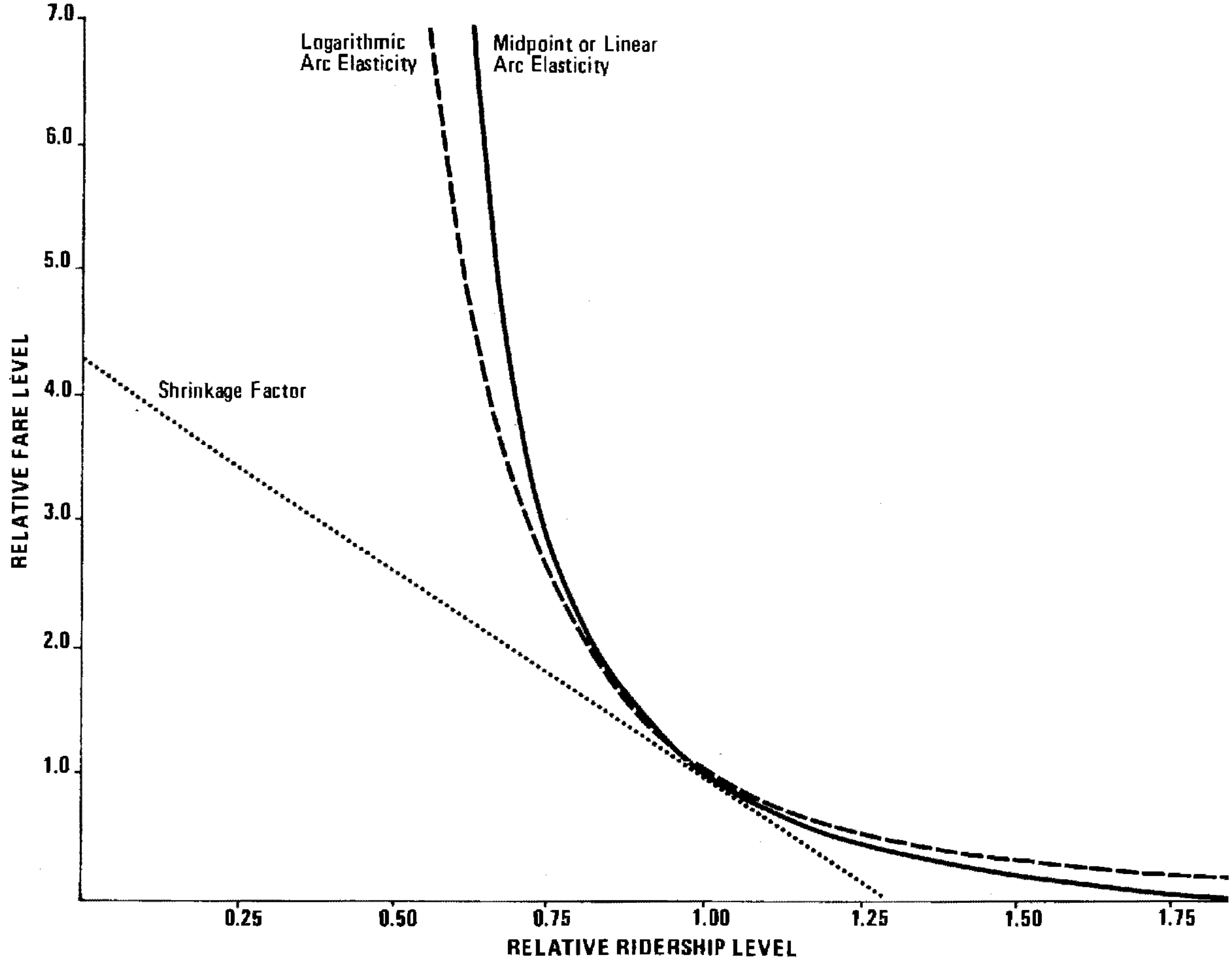

Figure 26
Elasticity of Demand Curves Based on Initial Point Elasticity of -0.30
(384)

mid-point (or linear) arc elasticity:

$$Q_2 = \frac{(\eta-1)\,P_1\,Q_1 - (\eta+1)\,P_2\,Q_1}{(\eta-1)\,P_2 - (\eta+1)\,P_1}$$

where η is the arc elasticity, Q_1 and Q_2 are the demand before and after, and P_1 and P_2 are the price or service before and after.

Following is an example of arc elasticity application:

Assume that a transit operator with a daily ridership of 21,000 (Q_1) is interested in increasing fares from 35¢ (P_1) to 45¢ (P_2), and that the applicable fare elasticity (η), arc formula, is -0.40. The new ridership (Q_2) which could be expected following the fare increase, as estimated using fare elasticity, would then be computed as shown:

log arc elasticity:

$$Q_2 = 10^{-0.4\,(\log 45 - \log 35) + \log 21{,}000} = 19{,}000$$

mid-point (or linear) arc elasticity:

$$Q_2 = \frac{(-0.4 - 1.0)\,(35)\,(21{,}000) - (-0.4 + 1.0)\,(45)\,(21{,}000)}{(-0.4 - 1.0)\,(45) - (-0.4 + 1.0)\,(35)} = 19{,}000$$

Thus the estimated decrease in daily ridership would be 2,000 passengers.

Source material constraints have precluded exclusive use of arc elasticities (or the closely comparable point elasticities) in this Handbook. Where elasticities derived using other formulations are given, the type is indicated, if known.

The reader must be alert to major definitional differences among this Handbook and other references with respect to elasticity as shown in the following table:

Handbook	Mayworm, et al (384)	Bly (71)	Dygert, et al (188)
shrinkage ratio	shrinkage factor	shrinkage ratio	arc elasticity*
fare or service elasticity* (or log or linear arc elasticity)	arc elasticity* (log or mid-point)	fares elasticity* (or arc, or linear arc elasticity)	"Kemp...definition of arc elasticity"
point elasticity*	point elasticity*	point elasticity*	point elasticity*

The forms principally used in the respective publications are indicated by an asterisk. Note that the discussions of arc elasticity properties in Dygert, et al pertain only to what are termed shrinkage ratios/factors or growth ratios/factors elsewhere.

*U.S. GOVERNMENT PRINTING OFFICE : 1981 0-522-855/70