LOW COST URBAN TRANSPORTATION ALTERNATIVES:

A Study of Ways to Increase the Effectiveness of Existing Transportation Facilities

VOLUME I

RESULTS OF A SURVEY AND ANALYSIS OF TWENTY-ONE LOW COST TECHNIQUES

Prepared by

R.H. Pratt Associates, Inc.
Kensington, Maryland

January 1973

Prepared for
Office of Urban Transportation Systems
Assistant Secretary for Policy, Plans, and International Affairs
U.S. Department of Transportation
Washington, D.C.

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UNITED STATES GOVERNMENT

Memorandum

DEPARTMENT OF TRANSPORTATION

OFFICE OF THE SECRETARY

DATE: June 7, 1973

In reply refer to:

SUBJECT: Pratt Study

FROM : Acting Assistant Secretary for Policy, Plans, and International Affairs

TO : The Secretary

I am pleased to transmit a report on "Low-Cost Urban Transportation Alternatives," the culmination of a research contract directed toward more efficient utilization of existing transportation facilities, a subject of considerable interest to the Department and the Secretary's Urban Transportation Advisory Council.

The study was initiated by the Office of Urban Transportation Systems and supported by the Urban Transportation Advisory Council, whose recommendations on low- and non-capital alternatives were consistent with those of the study and led to Secretary Volpe's endorsement of the concept. Moreover, you have supported the application of a number of these approaches to the transportation problems in some of our largest cities. The study was designed to evaluate in a systematic manner a number of low- and non-capital approaches to the improvement of urban transportation systems. In addition, one of the most promising of these approaches--busway applications--was given an in-depth treatment to document the experience of a number of existing operations.

The principal investigator, John Dupree of R.H. Pratt Associates, Inc., received valuable assistance from John Lundin, Carl Rappaport, Charles Hedges, and Raymond Weil, all of the Office of the Secretary, Edward Fleischman of the Federal Highway Administration and others throughout the Department, in turning out what should prove to be a useful and practical study.

The Department believes that this study is a step toward the more efficient utilization of the current extensive investment in urban transportation facilities.

Robert Henri Binder

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16. Abstract Volume I of this study details the findings of a survey and analysis of twenty-one low cost techniques designed to increase the effective processing capacity of fixed capital transportation facilities. The work reported in Volume I represents the initial phase of the study wherein a wide range of possible techniques were analyzed to determine whether any of the candidate techniques offered promise in satisfying the study objectives. Techniques were rated with particular attention to their potential processing efficiencies (volume increases or time reductions in moving people via existing transportation facilities). In addition, the evaluation considered various cost parameters, impacts on the disadvantaged, environmental and transportation safety factors, technical and institutional viability, and the expected response from travelers.

Techniques were grouped according to their all around ratings and case study analysis candidates were selected from the highest ranked group.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (Cont'd.)

LIST OF TABLES (Cont'd.)

LIST OF FIGURES

HOW TO USE THIS REPORT

Readers may use Volume I in two ways:

(1) If an overall review of a particular low-cost alternative is desired including costs, benefits, processing efficiency, institutional background, etc., the reader should locate the concept in the Table of Contents and turn to the appropriate page. Here the reader will find a complete discussion of each concept, starting with a brief one-page summary.

(2) If the reader is primarily interested only in those concepts deemed most useful, as reviewed and rated by this study, he should turn to Chapter 3 on ratings and rankings and select from those ranked most favorably. The reader may then turn to the appropriate discussion of these promising techniques in order to determine why each was ranked so favorably as well as learn about important weaknesses, expected costs, and other background information.

For background and an understanding of the study's scope and methodology, the reader is referred to Chapters 1 through 3.

PREFACE TO VOLUME 1

"Results of a Survey and Analysis of Twenty-One Low Cost Techniques" is Volume I of a two-volume report on a study of ways to utilize existing transportation facilities more effectively.

The study itself was a two part effort:

Part 1 involved the survey and analysis of twenty-one so-called "low cost" alternatives to continued investment in capital intensive facilities. The results of this phase of work are reported in Volume I.

Part 2 was undertaken as an intensive study of several of the most promising of the techniques identified in Part 1. These case study investigations and analyses are reported in Volume II.

STUDY SUMMARY AND MAJOR FINDINGS

Study Objectives:

This study of "Low Cost Alternatives to Increase the Effectiveness of Existing Transportation Facilities" is a first step investigation in defining and developing less costly, land consuming, and environmentally objectionable responses to continued growth in demand for transportation facilities. The premise of this study is that existing facilities may be utilized more effectively with revisions in operating techniques, technologies, or management.

Volume I of this two part report details the results of a survey and analysis of twenty-one concepts which appeared to offer promise as low-cost alternatives.

Volume II reports on the results of extensive case study investigations of busways, judged a most promising low-cost alternative.

Study Methodology Summary:

Twenty-one possible techniques for using existing facilities more effectively were selected after mutual consultation between the United States Department of Transportation and the study staff. These techniques are listed on the next page.

After selection, the study staff subjected each technique to a rigorous literature search and analysis in order to determine the all-around usefulness and acceptability of each technique. The criteria used to accomplish this, listed below, were selected deliberately to encompass a wide range of decision-making criteria ranging from the technical to the political, from the economic to the non-economic. The resulting discussion of each technique is therefore designed to objectively answer questions raised by a wide variety of interests, ranging from city planners to local citizen's groups. These evaluation criteria are listed below:

- User Price Impacts
- Implementation Costs
- Operating Costs
- Other Costs
- Indirect Economic Effects
- Impact on Disadvantaged
- Environmental Impact
- Safety Impact
- Speed or Time
- Volume
- State-of-the-Art
- Institutional Background
- Traveler Response

Evaluation and Ranking: Each of the twenty-one concepts were rated on their degree of positive, negative, or neutral impact as measured by the above criteria. Concepts were then ranked according to their cumulative ratings. From the most favorably ranked group, busway applications were chosen as the topic to be analyzed in greater detail through case studies and other investigations. This analysis is the subject of Volume II. The twenty-one techniques are listed below in the three groups which resulted from the rating exercise.

All Around Most Promising Techniques

- Exclusive Bus Lanes on Urban Arterials (Existing Facilities)
- Exclusive Reserved Lanes on Freeways for Mass Transit (Existing Facilities)
- Exclusive Busways on Specially Constructed Rights-of-Way
- Work Scheduling Changes
- Highway Traffic Engineering Systems Improvements

Less Generally Promising Techniques

- Paved Railroad Rights-of-Way
- High Capacity Transit Buses
- Organized Commuter Car and Bus Pools
- Freeway Metering, Monitoring, and Control Systems
- Free or Heavily Subsidized Transit
- Line Haul Feeder Systems
- Airport Access Improvements
- Automation of Bus Scheduling
- Economic Penalties and/or Incentives
- Urban Goods Movement Improvements
- Para Transit Service (Jitneys, Taxis, and Limousines)

Least Useful to Achieve Specific Study Objectives

- The Rail Bus
- Demand Actuated Transit Service
- Bus Traffic Signal Preference Systems
- Auto Driver Aids and Directions Systems
- The Minicar

It should be noted that the purpose of the ratings was to provide a simple screening technique for sifting out the techniques relatively more acceptable and technically practicable and promising. More details, qualifications, and limits on the rating scheme, evaluation criteria and related material can be found in Chapter I.

Principle Findings:

Three broad findings emerged from the survey of low-cost techniques.

(1) Low-cost alternatives provide a wide range of utility. Benefits related to increases in processing efficiency range from very marginal to order of magnitude improvements.

Some techniques were found to be extremely useful. Those ranked as "most favorable" may have sufficient benefits, under the right circumstances, to serve as effective substitutes for capital intensive convention solutions while costing relatively little. It was found that such techniques may prove useful both as short term solutions to vexing transportation problems and as components in long range planning to accomodate increased demand.

Most of the techniques reviewed were classified in a middle group exhibiting modest potential. While the cost of these techniques may be very little, their impact will typically not be sufficient to absorb normal growth in travel demand. They thus do not generally provide significant alternatives to more capital intensive approaches such as building new transit systems or, where acceptable, highway facilities. Many of these techniques had moderate to marginal benefits but also had important counterbalancing limitations. Of course in any given application circumstance the generalized drawbacks may not be relevant obstacles, while the benefits may be underestimated for the particular local transportation need.

When viewed in terms of the study context, namely concern with the effectiveness of low-cost alternatives for alleviating capacity-related urban transportation problems, a few techniques were not found to be useful at all. Again, even these techniques may find application to a specific community's unique requirements.

(2) As a group, mass transit oriented improvements would have the greatest impact. This is understandable since the potential to put 50 passengers into one transit vehicle represents a space economy of perhaps 20 to 1 over individual automobiles. The case study investigations detailed in Volume II indicated, for example, that a single lane of highway used exclusively by buses would provide corridor passenger carrying capacity in excess of almost any known level of demand.

(3) By and large, little or no serious research has been directed at low capital alternatives. As a result, communities are basically uninformed about the concept per se and implications for planning and community finances are not well understood. Perhaps by default then, capital intensive solutions are likely to be proposed as solutions to transportation crises that might be equally or better resolved through application of less expensive techniques.

CHAPTER I

THE CONCEPT OF LOW COST ALTERNATIVES

(1) Background:

The dominant feature of urban transportation development over recent decades has been the unchecked growth in demand for urban transportation services which has continually outstripped growth in the nation's transportation supply. As a result, congestion clogs the nation's urban highways, airports, and even certain rail transit facilities. Delay and crowding accompanies nearly every peak hour trip and the concomitant pollution of our environment by prevalent transportation modes only further degrades the quality of urban life.

The most frequent response to increases in demand has been to develop new capital intensive facilities such as highways, rail facilities and airports. Congress has enacted legislation making technical assistance and Federal funds available to local governments to plan and build such capital facilities, thus tending to reinforce this response to growth in demand.

In recent years, however, a reexamination of transportation planning and urban objectives has raised serious questions about such traditional responses to transportation needs. For example, the cost of such facilities has accelerated significantly, "often to the point where development costs may exceed benefits." The resulting environmental and neighborhood disruption has generated substantial public concern and, occasionally, active resistance.

Finally, continuous high annual expenditures devoted principally to meeting apparently insatiable peak period demand has raised serious questions about the wisdom and effectiveness of conventional capital intensive solutions to urban transportation needs.

Thus the objective of this study as stated in the original request for research proposals was:

> "To identify and describe . . . methods whereby existing transportation facilities (all modes) can be more effectively utilized to accommodate increased demand for service, as an alternative to constructing new facilities."

This study represents one of the first systematic efforts to define, analyze, and evaluate ways of using existing facilities more effectively.

As such, it was necessary in structuring the study to define what constitutes using existing facilities more effectively, or, in other words, what constitutes a useful "low cost" alternative. For the purpose of this study and perhaps others that may follow, the following criteria were used to focus the resulting analytical efforts.

(1) Using existing facilities more efficiently implies primarily concentrating on points in space or time where demand is in excess of capacity. As a general rule, this is most likely to occur in peak hours. Therefore the focus of the investigations was on techniques which might alleviate peak hour demand and assumes that, for the most part, off peak demand is well handled by existing facilities. While these conditions are not universally true, they do represent the most common and significant urban transportation problem. In many instances, the techniques discussed here may also be adopted for relief of strained urban transportation facilities during non-peak hours.

(2) Excessive demand occurs principally in urban areas and therefore the focus of this study is on urban transportation problems. (Time and funding limits restricted inquiry to urban <u>land</u> transportation problems.)

(3) To use existing facilities more effectively means, functionally speaking:

- speeding up person trips, or
- increasing volumes carried, or
- some combination which results in greater volumes carried at faster speeds.

Other concepts, such as lowering the cost of operating or building a facility were not felt to be directly consistent with project goals and were not considered.

Thus the investigations in this study were oriented towards techniques to increase the effective processing efficiency of existing facilities.

With these guidelines in mind, the study was then in a position to begin to select candidate techniques along with criteria for evaluating the relative efficacy of each technique in achieving these and other important community objectives.

CHAPTER II

STUDY METHODOLOGY AND OBJECTIVES

A. Selection of Concepts Reviewed:

A wide range of topics and ideas were initially suggested for analysis. The topics ultimately analyzed were selected after meetings between study personnel and United States Department of Transportation representatives. Budget constraints made it necessary to limit the list to 21 concepts. These were further divided into "established concepts" and "untested concepts," the latter being essentially untried or tested; whereas for the former sufficient real experience or other empirical data were available to provide a fairly firm understanding of the application implications of each technique. These twenty-one concepts and the advantages generally ascribed to each are as follows:

Established Concepts:

- Exclusive Bus Lanes on Urban Arterials (Existing Facilities)

  Here one lane is reserved for buses so as to facilitate their operations and, in some cases, to actually improve transit trip times. Lanes may be with flow or contraflow.

- Exclusive Reserved Lanes on Freeways for Mass Transit (Existing Facilities)

  A lane is reserved either counter to the flow of traffic or with the flow of traffic for the exclusive use of buses. Such exclusive bus lanes provide a way for buses to bypass congestion at exit points or at bridges and tunnels which would normally slow all traffic.

- Exclusive Busways on Specially Constructed Rights-of-Way

  This concept involves providing a segregated, permanent facility often built specially for this purpose (bus lanes, special ramps, etc.) for the use of buses and usually in conjunction with existing freeway systems. This can be a relatively capital intensive approach but is probably less expensive than providing sufficient highway laneage to carry the same volume of people by automobile.

- Work Scheduling Changes

  Staggered work hours and the four day work week reduce the extreme peaking of demand which now occurs during a few hours of each day. As a result, normal peak periods are less congested and existing facilities are able to accommodate more demand since it is spread over longer periods of time.

. <u>Highway Traffic Engineering Systems Improvements</u>

Systems of traffic control, signal operation, or traffic movement restrictions are designed to reduce street traffic delay or increase street traffic capacities by such means as maximizing traffic signal efficiency and minimizing inefficient and disruptive traffic maneuvers.

. <u>Paved Railroad Rights-of-Way</u>

Rail rights-of-way can be paved over for use by buses or other rubber tired vehicles at a fairly low cost. This provides a high capacity corridor free of congestion.

. <u>High Capacity Transit Buses</u>

Doubledecked or articulated buses are capable of handling greater numbers of passengers when demand is highest - - the peak periods - - thus avoiding the inefficient alternative of adding more buses and drivers in the peak hours while at the same time improving transit service characteristics.

. <u>Organized Commuter Car and Bus Pools</u>

By collecting commuters into carpools and buspools a smaller number of vehicles can be used to satisfy a given level of demand.

. <u>Freeway Metering, Monitoring, and Control Systems</u>

By limiting the amount of vehicles permitted on a freeway and/or controlling their spacing, freeways can avoid exceeding capacity limitations which result in time delays to the entire traffic stream. Ramp metering appears to be the only feasible technique developed to date.

. <u>Line Haul Feeder Systems</u>

Provision of more and improved feeder bus service or similar concepts would encourage use of the local circulation bus service as well as line haul facilities thus obviating the necessity for many private vehicles.

. <u>Airport Access Improvements</u>

Improved transportation service to and from airports would shorten total travel time and perhaps obviate the need for special purpose capital intensive facilities to serve airports.

. Urban Goods Movement Improvements

The changing of urban goods movement patterns through such low cost alternatives as revised truck delivery times and routes, freight consolidation, and other techniques may provide more street system capacity for other vehicles and/or result in speed improvements.

. Para-Transit (Jitneys, Taxis, and Limousines)

Jitneys, taxis, and limousines provide service in many ways superior to conventional transit service. Substitution of para-transit with a substantial amount of group riding would theoretically reduce highway vehicle space requirements.

. The Rail Bus

The rail bus is a dual mode vehicle that can travel on conventional roads and rail tracks. Use of the rail bus on under-utilized rail rights-of-way would provide a technique for creating a high volume transit corridor while still maintaining all or a major portion of rail service.

. Demand Actuated Transit Service

Demand actuated transit operates on the principle of providing service whenever and wherever requested. This would theoretically eliminate the need for many private automobiles and extend the mobility range of transit captives.

. Bus Traffic Signal Preference Systems

Emphasis on moving people rather than vehicles (which improves processing efficienty) involves allowing high capacity vehicles to control traffic signals to their advantage.

. Free or Heavily Subsidized Transit

Provision of free or heavily subsidized transit is thought to be one way that commuters can be attracted from private vehicles to more efficient processing systems such as mass transit.

Untested Concepts:

. Automation of Bus Scheduling

Attempts to revise transit routes and schedules are currently limited to minor modifications due to archaic practices. New techniques using computers would increase the ability of transit schedulers to change routes and schedules so that they better serve changing urban development patterns.

- Economic Penalties and/or Incentives

  Charging fees for use of congested facilities (bridges, downtown streets, parking space) during periods of peak demand provides a mechanism for discouraging congestion, encouraging use of low capital alternatives. It could be a source of revenue to subsidize other more efficient modes.

- Auto Driver Aids and Directions System

  Such systems are designed to guide drivers and autos along paths which represent the most uncongested available facilities in the urban street network. They utilize esoteric command and control technology in an attempt to minimize travel times and maximize the vehicle processing efficiency of the existing urban highway system.

- The Minicar

  Provision of large quantities of small vehicles on a trip rental basis for satisfying general transportation needs is thought to be one way of replacing large numbers of private vehicles and reducing the street and parking requirements for travelers.

B. Evaluation and Criteria:

Each technique nominated for study was evaluated according to a set of criteria which were designed to illuminate all the issues thought to be relevant to the interests of the diverse audience envisioned for this study. Therefore, the resulting evaluation touches on the political and social impacts as well as assessing the usual technical and economic merits. The evaluation design was deliberate in its efforts to clarify as many as possible of the issues which pertain to transportation decision-making. An explanation and brief discussion of each evaluation criterion utilized follows:

- User Price Impacts
  User charges are defined here in a fairly limited sense. They refer essentially to direct costs associated with passenger trips by a particular concept or mode. This does not take into account the value of the user's transportation time, opportunity costs, long-run investment alternatives, or other very indirect costs. It does include taxes as reflected in gasoline or other prices, depreciation of personal automobiles and other similar costs. User price evaluations were based on whether or not passenger travel costs as defined here increased, decreased, or stayed the same for comparable journeys.

- Implementation Costs
  The discussion of implementation costs is designed to provide an estimate of the initial capital required for introduction of each concept. As such, the values and estimates tend to be rough,

based on as much empirical experience as is available, or as can be deduced. For any particular application there may be a substantial variation in the actual implementation costs. Whenever possible, costs were specified in common units. Favorable evaluations were reported when little or no initial costs were involved, while the most unfavorable evaluations occured when capital and start up costs approached that of the usual capital intensive solutions such as highways.

- <u>Operating Costs</u>
  Estimates provided here are designed to indicate the range of costs that would be associated with the day-to-day maintenance and operation of a particular system or concept. Again, these data are based on as many empirical observations as are available. Variations in local costs (such as for labor) will affect the actual costs of operation in a particular community. Costs were compared on a before-after basis, with favorable evaluations reported when net costs to a particular agency or group declined.

- <u>Other Costs</u>
  This is a general category of other disbenefits which may be particularly important to mention. No attempt is made to develop marginal, vague, or long range impacts due to the limits of the study. All impacts reported were considered a negative influence.

- <u>Indirect Economic Effects</u>
  Indirect economic effects are all those of a prominent nature not covered by the other discussions. Figuring most prominently in this category are those associated with deferred or avoided investment in capital facilities by a community and the dollar value of time saved by individuals. It was rarely feasible for this study to quantify these economic effects or to delve as deeply as would be desirable into such positive long range benefits as reduction in welfare, changes in land use and values, etc. Positive values were associated, for example, with techniques capable of absorbing many years of new demand, while negative values were assigned if capital facilities demand was aggravated.

- <u>Impact on Disadvantaged</u>
  In this portion of the review are discussed those benefits which accrue to members of the community who are normally considered disadvantaged. Included in this category would be the aged, the poor, the unemployed, and the handicapped. Greater mobility for these groups resulted in favorable evaluations.

- <u>Environmental Impact</u>
  In cases where the total level of environmental pollution is increased or decreased by the concept under discussion, then comment on environmental impact is made.

- Safety Impact
  The incidence of accidents may be increased or decreased for users or others affected by a particular concept or system. Any evidence of such effects is noted here.

- Speed or Time
  The discussion here concentrates on improvements in the speed of vehicles and the time savings to users as the result of introduction of a particular concept. Negative evaluations were reported when travel times slowed for the affected users over their previous experience.

- Volume
  This evaluation is concerned with analyzing the ability of a facility to more effectively handle the volume of demand with a given quantity of facilities. Improvements in the number of persons carried per hour or redistribution of demand over time were considered positive effects. In many cases the projected volume represents a theoretical range.

- State-of-the-Art
  Discussion of state-of-the-art is primarily designed to identify those concepts or technologies which require substantial additional research and development before they can be said to be practical and operational.

- Institutional Background
  A wide variety of institutional factors will influence the chances that any particular concept will be implemented. Among these influences are unions, political groups, lobbying groups, transit authorities, private bus operators, citizen groups, federal, local and state regulatory bodies, and many other organizations. Those institutional barriers which pose real threats to the adoption of the particular concept under discussion are cited. Wherever possible information on past experience is given.

- Traveler Response
  A brief appraisal of public response and acceptance in the form of demand for the service or system operating characteristic provided was made.

C. Presentation of Evaluation:

A separate chapter is devoted to each concept studied.

At the beginning of each chapter a one page synopsis of findings is found.

Part II of each chapter provides a technical analysis of each concept analyzed according to the evaluation criteria just discussed. At the conclusion, a passage of summary and critique is used to present a concise judgment on each technique. If data is inadequate for final judgment, the issues needing clarification are identified. It should be noted that the summaries of the three busway related techniques discussed in Chapter's IV, V, and VI are very preliminary as compared to the material presented in Volume II, the in-depth case study of these topics.

D. Data Sources:

The objectives, timing, and funding of the study for the most part limited data sources to published literature with occasional phone calls and interviews providing additional insights and data on poorly documented topics. The majority of the published data on "established concepts" was in the form of demonstration reports, surveys and field investigation reports, etc. In the case of "new concepts" or theoretical schemes, consultant's feasibility studies were specifically sought whenever available so as to permit as realistic an appraisal of implementation prospects as possible.

In some cases it was necessary for the study staff to model costs, performance or other characteristics, since a number of factors thought to be important had not been evaluated satisfactorily or at all by earlier studies.

A judgment on data reliability is noted in a right hand column of the one page summary sheet which precedes each concept narrative and evaluation. Readers are cautioned that, in cases where data is poor, clarification through more experimentation may lead to differing judgments about each concept.

E. Summary of Study Methodology Objectives:

The objective of each investigation was to develop sufficient hard data so that a decision was possible on the relative merits of each technique as related to a particular need measured by the evaluation criteria. In some cases data was not available in meaningful terms and extensive searching and manipulation was necessary in order to obtain and convert data to standard units of measure consistent with the intent of each evaluation criterion and capable of being meaningfully related to the balance of the discussions. In other cases, it was not necessary to pursue extensive documentation since the resulting degree of accuracy would be spurious in light of earlier, less precise data, indicating only a marginal effect -- whether positive or negative. Thus the discussion under each specific evaluation criterion is designed to:

- provide the most accurate and up to date information possible on the relative merits of each technique vis-a-vis each evaluation criterion, in order that concepts might be compared with other techniques according to common judgment factors;

- quantify the degree and extent of benefits in standard terms so that readers with varying degrees of expertise can quickly and easily comprehend the extent of the costs or benefits involved.

The presentation and organization of the data may be one of the major contributions of this study. Only a few of the resource studies used in this analysis addressed the full range of technical and non-technical issues represented by these thirteen evaluation criteria. Similarly in few studies were the issues quantified or presented in similar, comparable terms or formats. The attempt made here, not always successful, was to digest available material, empirical and non-empirical, develop models if necessary, and present the results in a comparative language which will provide summary answers to a wide audience of professional and lay readers and transportation decision makers.

CHAPTER III

RATINGS & RANKINGS

A. The Rating Approach:

The study design called for a comprehensive case study investigation of the most promising of the surveyed concepts. In order to isolate the more promising concepts, a simple rating methodology was developed around the evaluation criteria. Each concept was given a rating of between plus two and minus two depending upon the relative merit of that concept vis-a-vis the evaluation criteria. A "plus one" or "minus one" value meant that the concept was marginally to moderately beneficial or, if negative, disadvantageous. A "plus two" or "minus two" value meant major advantages or disadvantages. An "0" rating meant effectively no or insignificant changes from present conditions.

In one case - volume processing capacity - three positive values were established. "Plus one", "two" and "three" reflected, respectively, minor, moderate to major, and order of magnitude improvements. This was done for two reasons. First, there appeared to be a very wide range of improvement possible. Second, volume processing improvement was central to the idea of using existing facilities more effectively and thus it was felt important to clearly differentiate these disparate levels of impacts.

Scores were weighted by multiplying by 2 in instances where the evaluation criteria were particularly critical to achieving the goals of the study.

The weighted variables were:

- Implementation Costs
- Speed or Time
- Volume
- State-of-the-Art (reflecting the desire to isolate techniques that are implementable now)
- Institutional Background (an assessment of the political cost of achieving implementation)

An additional judgment value on city size applicability was provided in ranking. This value was weighted at .5.

A list of evaluation criteria, values and weights is provided in Appendix A.

B. Rankings:

Summing of the ratings provided a relatively easy way of assessing the overall value of each concept and separating out the more desirable concepts from the less useful. This approach was not designed as a definitive exercise in ranking concepts; rather the intention was to find a simple and direct technique for separating out the more effective techniques from the others reviewed. The results presented here reflect that goal: no attempt is made to report or defend the relative ranking of each concept vis-a-vis other concepts. Instead, presented below are three groupings which were developed as the result of this unsophisticated rating and ranking process:

<u>All Around Most Promising Techniques</u>

- Exclusive Bus Lanes on Urban Arterials (Existing Facilities)
- Exclusive Reserved Lanes on Freeways for Mass Transit (Existing Facilities)
- Exclusive Busways on Dedicated Rights-of-Way
- Work Scheduling Changes
- Highway Traffic Engineering Systems Improvements

<u>Less Promising Techniques</u>

- Paved Railroad Rights-of-Way
- High Capacity Transit Buses
- Organized Commuter Car and Bus Pools
- Freeway Metering, Monitoring, and Control Systems
- Free or Heavily Subsidized Transit
- Line Haul Feeder Systems
- Airport Access Improvements
- Automation of Bus Scheduling
- Economic Penalties and/or Incentives for Using Certain Facilities
- Urban Goods Movement Improvements
- Para Transit Service (Jitney's, Taxis, and Limousines).

<u>Least Useful to Achieve Specific Study Objectives</u>

- The Rail Bus
- Demand Actuated Transit Service
- Bus Traffic Signal Preference Systems
- Auto Driver Aids and Directions
- The Minicar

C. <u>Qualifications and Conclusions About Ratings and Rankings</u>:

It is important to realize that these assessments of the value of each concept are not made in any absolute sense; rather these concepts were evaluated strictly on their capacity to serve as useful low cost alternatives to transportation capital facilities. Other important transportation related objectives may be well served by some of the less favorably ranked techniques.

One good example of the latter circumstance is "demand transit". Where provision of mobility for the transportation disadvantaged is the goal, demand transit would be a very useful technique. However, based on study findings, it does not appear in most circumstances to be a promising technique to serve as a substitute for capital intensive facilities.

A second pertinent example concerns automated bus scheduling. Automated scheduling may well be essential to cost effective transit operation. But once again, by itself, it is not very applicable to substitution of low cost alternatives for capital intensive transportation facilities. Yet automated scheduling may be absolutely necessary to successfully effect any low cost alternative involving bus transit.

Finally, it should be noted that a "system" approach was not investigated. In certain instances, various techniques when combined may offer advantages in excess of their individual merit.

Having presented these qualifications, some general conclusions can be presented regarding the evaluation and ranking. First, it is believed that the evaluation process did effectively separate out from those techniques studied concepts which would provide the most realistic opportunities to improve the use of existing facilities. Similarly, the evaluation has probably served a useful purpose by identifying those techniques with the least potential for success.

The bulk of the studied techniques fell into the middle group. Readers of this study should not disregard these approaches to using facilities more effectively. Instead these techniques should be carefully considered in light of whether the utility and advantages listed are particularly applicable to the local situation, and whether the disadvantages, costs, or obstacles discussed are critical or applicable to the particular application circumstance envisioned. In some cases, these middle group techniques may prove useful.

CHAPTER IV

EXCLUSIVE BUS LANES ON URBAN ARTERIALS (EXISTING FACILITIES)

Operating Description and Summary of Findings

This technique involves reserving a lane or other portion of the arterial street system for the exclusive use of transit buses. Lanes reserved may be with flow or contra-flow, with contra-flow lanes tending to be the more successful.

On congested urban arterials, the bus lane technique can increase bus speeds and reduce travel times. Control and signaling techniques need not be extensive on arterial applications.

There is some institutional resistance to implementation of exclusive bus lanes on arterials in the form of legal barriers and complaints from motorists and taxi operators.

Cross street traffic, signals, and other interruptions necessarily reduce travel time savings over comparable journeys on limited access roadway facilities. The contra-flow operation can, for a time, confuse motorists if proper advance warnings are not provided.

This technique is one of those selected for case study. The discussion which follows is the preliminary evaluation; the more thoroughly researched and detailed case study results are found in Volume II.

I. INTRODUCTION

The concept of using certain lanes on city streets exclusively for buses is not a new one. Historically, many cities have reserved lanes for the exclusive use of buses during the rush hours or other periods of the day. A newer and more dramatic version of this concept is to mark off the left hand lane of a one-way street for use of buses traveling in the opposite direction. This technique provides an uncongested exclusive busway on streets which, because they flow in the opposite direction of peak period traffic, may have under-utilized capacity.

Data used in the analysis of this concept comes from five exclusive bus lane projects:

1. Contraflow bus lanes, each approximately ten miles in length, on two roughly parallel main thoughfares in San Juan, Puerto Rico.

2. Contraflow bus lanes in the South Corridor area of Louisville, Kentucky, leading into the central business district, and used during rush hour periods by express buses.

3. An approximately ten block long contraflow bus lane in Madison, Wisconsin.

4. A 2.85 mile contraflow bus lane in Indianapolis, Indiana.

5. Contraflow bus lanes in Reading and Derby, England.

II. TECHNICAL EVALUATION

- <u>User Price Impacts</u>

In San Juan, Louisville, Indianapolis, and Madison fares were identical whether or not the exclusive bus lane was part of the route. No data was available on the English cities. It seems unlikely that fares would be changed under most applications.

- <u>Implementation Costs</u>

Implementation costs for the contraflow bus lanes are relatively small. Capital expense has been incurred primarily for signs indicating that buses only are allowed in the lane and that the buses will be moving opposite the flow of traffic. Some cost is involved in striping of the special lanes. These costs may include painting a double median line or painting diagonal stripes on the lane itself. In some cases special traffic posts were used to keep cars from inadvertently entering the bus lanes. Costs appear to run less than $10,000. Other items such as fringe parking lots, electronic signal control devices, and subsidies to buses have been included in contraflow projects and could enhance the likelihood of project success. They are not an inherent requirement, however, and in this review have been treated as separate concepts.

. <u>Operating Costs</u>

There are apparently no extraordinary operating costs associated with contraflow bus lanes on city streets. Unlike freeway applications, crews are not used to mark off lanes each morning. Instead permanent signing and striping is used.

. <u>Other Costs</u>

The principle "other cost" is that associated with prohibiting general traffic from using certain portions of the street system. This may not be a real loss if under-utilized streets are converted to busways. In addition arterial bus lanes may generate interference with left turns. Arterial bus lane service may provide the indirect economic savings associated with shortening transit rider travel time. Schedule reliability was also noted as a benefit of contraflow bus lanes on city streets. In Reading, England it is reported that contraflow bus lanes and the closing of main shopping streets to all traffic except buses and certain service vehicles have combined to reduce bus journey times and improve bus reliability. If the contraflow bus lanes are able to provide such user benefits as shortened travel times and improved adherence to schedules, they may well increase transit ridership by diverting commuters who formerly used automobiles. Diversion of commuters from auto to mass transit, the latter more efficient in terms of passenger volume per vehicle, would decrease the need for new capital intensive transportation facilities.

. <u>Impact on the Disadvantaged</u>

As opposed to reverse lane systems on freeways, contraflow bus lane transit improvements in the central city are more likely to serve low income passengers. However, none of the projects reviewed claimed to be directed at low income or other disadvantaged users and no project appears to be routed through a low income area. For example, while the South Corridor area of Louisville has a largely low income population, the exclusive bus lanes are used only by express buses. These express routes, expecially those serving fringe parking lots, depend on a group of passengers living farther out of the city with moderate incomes. A survey conducted at the fringe parking lot serving the Louisville express bus lane (XBL) showed that many of the riders were young females who earn $5,000 to $10,000. The lowest income groups then are not the primary users of the bus line.

. Environmental Impact

Deleterious environmental impacts can be reduced if total levels of vehicular emissions are reduced as a consequence of attracting former auto drivers to bus transit. Various levels of capacity utilization were reported on the projects. In Louisville, even with a thirty percent increase in daily ridership, buses were reported not terribly full. While the lack of full buses suggests limited environmental impact, the general trend in cities is for reduced bus ridership. The fact that this trend was reversed, even slightly, is encouraging. The San Juan project reported crowded buses and since this was allegedly due, in part, to increased transit system ridership, further improvements of a similar nature might draw sufficient numbers of auto drivers such that there would be a significant reduction in total vehicle emissions. In the immediate future, however, one would expect insignificant environmental impacts.

. Safety Impact

The safety of wrong-way bus lanes has not been conclusively established. Data from various cities is of a conflicting nature. In Reading, England, where in some cases main shopping streets have been closed to all traffic except buses, the change reportedly resulted in a marked improvement in the urban environment without reducing safety. Unfortunately, there is no quantifiable data provided in support of this statement.

In Indianapolis, the 2.85 mile exclusive southbound bus lane on a major north-south route was placed in operation in Spetember 1968. After the bus lane was in operation there was a substantial reduction in accidents. (See Volume II)

It should be noted that a main reason given for instituting the Indianapolis bus lane was to reduce the number of accidents occurring in the southbound lane of the avenue.

The Madison, Wisconsin data showed a short term reduction in accidents. The street with the busway, University Avenue, was converted to one-way operation concurrently with instituting the bus lane. In the prior year, 270 accidents occurred on the street. The year after the changes were made, 245 accidents occurred for a decrease of nine percent. For the subsequent two year period, November 1967 through October 1969, there were only twenty-six bus lane accidents while on the street 278 accidents were recorded.

While the above studies suggest that bus lanes do contribute to reducing accidents, it must be noted that certain types of accidents may be caused by the busways. In Indianapolis where the lane opened in September 1968, there was one 1968 accident involving a bus in the southbound lane. In 1969 the number increased to seven and in 1970 to nine. The majority of these accidents were the result of conflicts between southbound buses and eastbound traffic on the cross-streets. Apparently, some eastbound motorists were not anticipating the southbound buses. The NO RIGHT TURN signs and three lanes of northbound traffic may have misled motorists into believing that the street is one-way northbound only. The Indianapolis Transit System Inc. and the Indianapolis Department of Transportation will investigate this matter in the near future. Possibly some additional signing is warranted on the cross-streets.

The contraflow lane itself seems to work well and does not interfere with the through flow of traffic in other lanes. Provision for right hand turns by buses using these lanes is a problem, however, and led in part to the abandonment of one of three PM reverse lane routes in Louisville. This particular route had a difficult right turn for the bus in a congested area.

Traffic lights, cross traffic, and pedestrian conflicts will prevent average bus speeds on urban street contraflow lane systems from reaching the levels of those recorded on freeway exclusive lanes. Nevertheless the time savings may be quite significant, particularly if congestion is severe in the central business district. For example, if average bus speeds increase from seven m.p.h. to fourteen m.p.h., travel time will be cut in half. In those cases where the bus travels in part on a high speed freeway and in part on CBD arterials, the time savings may result only from one-way applications on the congested arterial portion of the trip if the freeway is not particularly congested.

One serious travel time or speed limitation was observed on the San Juan lanes. Both local and express buses use the lanes, and there is a tendency for the express buses to be delayed as the local buses make their more frequent stops to receive or discharge passengers. Thus, there is a loss of express bus schedule reliability. The possibility of routing local buses away from the contraflow lanes was rejected, however, since time savings gained by having both classes of bus routes on the lanes were still significant.

- Volume

While all experiments reviewed claim an increase in volume carried as a result of the contraflow bus lanes, the only definite figures obtained were for Louisville which reported a thirty percent increase in net passengers in the neighborhoods served by the contraflow bus lanes since their inception, November 1, 1971.

While the Louisville volume has increased, project officials question whether the increase is sufficient to cover the increased costs of the new service (see Table 4-1). Any Louisville deficits are covered by UMTA, but other cities may need to generate more passenger volume to finance the XBL's if these lanes involve additional bus routes rather than re-routing of existing bus lanes.

An uncongested busway has a very high potential capacity. Actual volumes recorded on some exclusive busways (on freeways) approach 25,000 passengers per hour; theoretical studies have placed volumes at over twice that figure. However, the cross-street traffic and other interferences on urban street systems would probably reduce these figures for arterial exclusive lanes. No definitive data is available on potential volume at this time.

- State-of-the-Art

Exclusive bus lanes may be easily and quickly implemented without requiring application of sophisticated technology. The contraflow bus lanes can be supplemented by other equipment to increase vehicle speed. The techniques, such as preferential traffic signal control seem to be technically feasible but have not been adequately demonstrated.

- Institutional Background

It is apparent that multi-agency cooperation is essential in implementing the exclusive use lane concept on central business district streets. In San Juan, Puerto Rico, the program was implemented through the close cooperation of five agencies: The Public Works Department, Highway Authority, Metropolitan Bus Authority, Planning Board, and Police. There was almost no Federal funding of the project except for Federal Highway Administration funds to construct a part of the exclusive bus lanes through an interchange. In Louisville, however, the Federal government through the Urban Corridor Demonstration Program used UMTA and FHWA funds to support a multi-modal program. The bus lanes system was one of the suggested improvements and one of the first to receive funding, under the Early Implementation Program of the Urban Corridor Program. The privately owned transit company in Louisville has adequately served the area but has financial restraints preventing any experimentation. Not only is all the money for the Demonstration Project from the Federal government, but also the government has agreed in addition to reimburse the transit company if there is any loss of revenue under the experiment. The City of Louisville, as previously mentioned, pays nothing.

One institutional problem of potential concern relates to the use of the bus lane by unauthorized vehicles. While ninety-five inbound buses use the exclusive bus lane in Indianapolis, traffic counts indicate

TABLE 4-1

LOUISVILLE RIDERSHIP FIGURES

(Effect of the Three Express Routes Using the Reverse Lane)

For the two weeks prior to the implementation of the reverse lane:

Average total number of daily AM adult passengers on all the routes serving the neighborhoods now served by the additional express buses:	.365

First day of express bus operation:

AM adult passengers on express and regular buses	523
AM adult passengers on express buses	245

Thus

Number of express riders who are new to transit	158
Number of express bus riders who switched from other routes	87

NOTE: Recent figures indicate a 30% increase in transit ridership with the new service. For the service to pay for itself over the length of the demonstration period, the express buses will have to carry 1860 passengers daily at 40¢ a ride who formerly did not use transit.

that there are in total 150 to 200 vehicles per day using the bus lane. It follows that from fifty-five to 105 vehicles are using the lane illegally. The Indianapolis Police will not ticket unauthorized motorists found using the bus lane unless the motorist is actually observed making an illegal maneuver to enter the bus lane. The Police Department has taken this position because signs designating the southbound lane exclusively for buses have not been erected along the route. The Indianapolis DOT plans to erect these signs in the near future.

Public reaction to the exclusive bus lane appears to be neutral and low keyed in most of the cities studied. In Indianapolis, local taxi-cab companies voiced some opposition to the designation of the southbound lane for buses only, but no formal action has been taken. However, in Madison there was a negative, highly vocal reaction, apparently brought on by exceptional circumstances -- a bus-pedestrian accident -- in that city. Controversy arose when a student lost her leg in an accident with a bus traveling in the exclusive lane. A suit was brought, and the lane was ruled illegal by a Circuit Court in 1969. The City appealed to the State Supreme Court, but the unfavorable decision was upheld.

The Court ruled that the city does not have "the right to discriminate against the general publics' use of a one-way lane in a street for the benefit of only buses and taxi-cabs." If the city wants this right, the Court said, it must seek it from the legislature. Currently, a proposal to permit these lanes is before the legislature. Meanwhile, the lane is functioning almost the same as it did before the Court decision. In order to conform with the ruling, the lane has been redesignated a "Limited Use Lane" which any vehicle may use if, in doing so, it does not violate any official traffic signs. A series of "one-way" and "no turn" signs impede vehicles from entering the bus lane from cross-streets and are also set up so that a vehicle entering the lane at its beginning cannot legally exit till its terminus. Thus, interference with buses in the lane is minimal.

- <u>Traveler Response</u>

Of all bus lane facilities, arterial operations have received the most lukewarm response from the public. This is probably best explained by the less significant travel time advantages for buses using arterial lanes. However, in San Juan a fairly enthusiastic response to the service has been noted with claimed increase in patronage.

Well planned arterial bus lane facilities which minimize travel time and provide reliable service would probably be well received.

III. Summary and Critique

Reverse bus lanes on city streets differ from dedicated bus lanes or reverse one-way lanes on freeways in that cross traffic and other interruptions limit the average operating speed to a lower level than achievable on freeway-type service. Nonetheless, in some urban environments bus travel time delay may be most significant on the arterial portion of a trip; improved bus speeds on arterials may save more time than using an out-of-the-way freeway, or no freeway may be available.

There is some indication that arterial reverse lanes pose certain safety hazards and are disruptive of non-transit vehicular travel. Clearly, the place and manner of application helps to determine what benefits and problems will result from reverse bus lanes.

At this point, the data base leaves several important questions unresolved. Among these are:

- Under what conditions can significant bus travel time savings be achieved with minimum non-transit vehicle penalties?
- Are there measures that can be taken to improve safety and eliminate driver confusion?
- Are there a substantial number of severely congested urban arterial street networks where significant savings are possible or are there only a few unique urban environments where these applications might prove useful?

CHAPTER V

EXCLUSIVE RESERVED LANES ON FREEWAYS FOR MASS TRANSIT (EXISTING FACILITIES)

Operating Description and Summary of Findings

This concept involves reserving a lane of a limited access multi-lane highway for the exclusive use of buses. Again lanes may be reserved with or contra-flow, although experiments cited here are predominantly contra-flow.

Separation from other traffic is accomplished in the experiments through the use of combinations of temporary and permanent barriers. Safety has not been a problem to date.

Significant increase in travel speeds have been noted while the potential increases in number of passengers that can be carried per lane are very impressive. Often the advantages of the exclusive bus lane are achieved with very short exclusive lane facilities through bottlenecks or other points of congestion.

This technique is one of those selected for case study. The discussion which follows is the preliminary evaluation; the more thoroughly researched and detailed case study results are found in Volume II.

1. INTRODUCTION

In many metropolitan areas excessive auto demand during the peak periods heavily overburdens the urban freeway system. As a result, traffic is often subject to substantial congestion and delay. High occupancy vehicles such as carpools and buses are not exempt from these delays. One concept for providing fast, reliable transportation during these periods, without building new freeways, involves permitting high occupancy vehicles to use a reserved lane during congested periods. The obvious objective of this technique is to allow those vehicles which carry a great many people to maintain high average speeds on the uncongested traffic-way provided.

Two approaches have been advanced for exclusive lane usage:

1. Reservation of a lane in the most heavily traveled side of the freeway. In this approach all or part of a lane of traffic is reserved for high occupancy vehicles, usually at the critical "bottleneck" portion of the freeway during the peak period. It may be sufficient to reserve lanes through very short bottleneck areas such as toll-booths or sections of the freeway where demand exceeds design capacity.

2. Use of an opposing lane. In this approach a lane in the least heavily traveled side of the urban freeway is reserved for high occupancy vehicles. For example, in the AM peak, a lane on the outbound portion of the freeway, usually next to the median strip, is reserved for high occupancy vehicles to travel inbound against the traffic flow on the outbound lane. In this way, the exclusive use lane does not subtract from the total previously existing capacity on the congested portion of the freeway.

A number of experiments and tests of these principles have been performed. The results indicate the time savings for high occupancy vehicle patrons to be very substantial. Several of these experiments provide substantial data by which judge these concepts. These are listed below. Note that all but one of the experiments involved the use of an opposing lane, thus the discussion which follows is slanted toward that type of application.

1. <u>New York/New Jersey</u> - A two and one-half mile bus lane utilizing a lane reversed in the opposing portion of the freeway is currently in use on Route I-495 in the morning. This lane was introduced in December 1970 and runs south from the Lincoln Tunnel.

2. <u>The Southeast Freeway, Boston, Massachusetts</u> - Again, A lane in the least heavily traveled portion of the freeway was reversed for use as an exclusive busway. In this experiment, 8.2 miles of freeway were reserved. The experiment started May 24, 1971 and was ended October 1971 due to an alledged safety hazard associated with operation in darkness as the result of long winter nights. The facility was reopened in the Spring of 1972 and closed again in the Fall of 1972.

3. Long Island Expressway - The exclusive bus lane on Long Island consists of two miles of a normally outbound lane as a facility for inbound buses during the morning peak to avoid a normally congested portion of the inbound lanes. This lane extends two miles from the Queens Mid-Town Tunnel. The lane was initiated in October 1971.

4. The Oakland Bay Bridge - On the Oakland Bay Bridge seven hundred feet of toll-booth approach is reserved so that the buses can proceed directly through the toll area without the normal queuing associated with the automobiles attempting to pass through the facility. In December 1971, this facility was expanded to three lanes with two lanes reserved for carpools. In addition, all three lanes after passing the toll-booth will merge into one exclusive lane for high occupancy vehicles which will extend to the actual bridge facility.

It should be noted that in many cases, the most congested portion of a freeway might well be that area immediately preceeding the entrance to the central business district. This is especially true when the access to the central business district is over a bridge or through a tunnel. Exclusive lanes need not run the entire length of the freeway. It is often only in these close-in areas that congestion severely retards travel time, and provision of such facilities as exclusive bus lanes in small portions of the freeway network may be sufficient to substantially alleviate delay for high capacity vehicles.

11. TECHNICAL EVALUATION

. User Price Impacts

User prices for use of buses are not expected to change since the extra cost associated with developing these lanes is minimal. However, it was noted that in some instances bus companies were charging higher fares such as is done on express bus service.

. Implementation Costs

Major capital costs associated with such plans are essentially signs and traffic cones or posts. Traffic posts are priced at $15.00 per placement, with posts being placed at forty foot intervals. This cost includes the cyclindrical tube and the labor for drilling a hole in the pavement and inserting a pipe sleeve. Sign costs will depend on local requirements. Figures from Boston indicate a cost of about $1,200 a mile for signs. No other specific data is available at this point. The total cost of preparing the wrong-way lanes in Boston and on the Long Island Expressway as well as the Bay Bridge experiment in San Francisco appears to be less than $50,000 each. The costs associated with the New Jersey section of I-495 appear to be somewhat higher but they are not separable from more aggregate data.

Some reverse bus lanes may become permanent features; hence the signs and lights used should be of a more permanent design. This will raise implementation costs (but not necessarily operating costs) and is designed to indicate the reverse lane more clearly, thus increasing safety.

Prior to implementation, it is necessary to undertake some traffic survey and design work. If success of the project is dependent on increasing transit ridership over present levels, traffic analyses need to include verification that appropriate potential usage exists. The potential for more transit ridership is high given the travel time advantages shown to date. In all, implementation of this concept is extremely inexpensive.

- Operating Costs

There are costs associated with maintaining the exclusive lanes. Specifically this involves deploying and collecting the cones at some appropriate time interval. The minimum operating cost is associated with the Bay Bridge experiment where the cones are not removed except on weekends. Higher day-to-day costs are incurred on the other three contra flow freeway exclusive bus lanes. In these instances the cones are laid down each morning from a moving truck and picked up at the end of the peak period. In addition, it is necessary to align cross-overs before and after these lanes are in use. The Boston and Long Island experiments estimated that it costs about $500 a day to maintain a crew for changing lanes twice each day. Data is not available on the other experiments. These high costs are to some extent a function of the primitive and often hasty arrangements surrounding implementation. More permanent facilities would replace manual procedures with electronic signs and other automated control techniques which would reduce these costs somewhat.

Some reduction in bus operating costs may be achieved through more productive use of equipment and facilities. For example, three-fourths of the bus companies using the I-495 facility reported a decrease in paid driver overtime. Less stop and go driving may also result in reduced wear and tear on mechanical parts. Higher average operating speeds may result in more trips per bus run, thus generating more revenue per day.

- Other Costs

The principle "additional cost" of concern is associated with removing a lane of traffic from general use. In many cases the lane will not be missed. In other instances, more evenly balanced traffic flows will mean that the removal of a lane will subject some motorists to further delay.

- Indirect Economic Effects

Potential indirect economic benefits from the reversed bus lanes are substantial. Data available suggests commuters are attracted to buses using special reserved lanes because the buses are fast and reliable. Reduction of the ratio between the number of vehicles/number of people transported is evident from the exclusive lane facilities now in operation. Within certain constraints discussed later, this means more people can be accommodated on existing road facilities.

Another important indirect economic benefit associated with exclusive lanes is improved transit service schedule reliability. Avoiding congestion enables bus operators to adhere to schedules, allowing service which is more attractive to potential patrons and less costly to the operator.

- Impact On The Disadvantaged

Transit service of this type is aimed more at suburban commuters. While there may be many low income individuals using the service, any benefit to the disadvantaged would accrue as an indirect effect.

- Environmental Impact

The environmental impact is directly related to the degree of substitutability of bus transit for automobile usage. While evidence indicates that such preferential service does attract automobile commuters, no specific estimates of environmental impacts are available to date due to the small scale of implementation.

- Safety Impact

Accident data, to date, is favorable to exclusive bus lane experience. The Boston and Long Island experiments report no accidents on AM service. The I-495 facility police report that I-495 accident rates have declined since implementation of the facility.

A representative of a transit operator using the Oakland Bay Bridge facility states that sideswiping accidents have declined.

More detail on this important consideration can be found in Volume II.

- Speed or Time

The principle benefit of this technique is the reduction in total trip time for transit buses. Necessarily the actual application determines the amount of time saved. However, data from the experiments, to date, indicate significant time savings are possible through this approach (see data below).

	PROJECT	LENGTH OF EXCLUSIVE LANE	SAVINGS IN TIME ON THAT LINK	PERCENT DECREASE
1.	Long Island Expressway	2 miles	4.5-15 min.	22% to 75%
2.	Boston Southeast Freeway	8.7 miles	14 min. (est.)	58%
3.	New Jersey I-495	2.5 miles	7.75-10 min.	30-40%
4.	Oakland Bay Bridge	Approx. 1 mile	8-10 min. (est.)	(not available)

(N.B., all these facilities operated in the AM peak only.)

Since the first three projects above involve the use of lanes in the minor direction of traffic flow, it is assumed that travel times for non-transit vehicles in the peak direction are not adversely affected. The Boston reverse lane program provides some data on non-transit vehicle movement. On the AM inbound lane (traffic moving in the same direction as the bus), bus savings were fifteen minutes, while non-bus vehicles saved 3.5 minutes. Slight savings were also shown for peak direction automobile traffic on I-495 from New Jersey to New York City.

It is expected that the sites selected for the reverse lane experiments would have peak hour flows very heavily weighted in one direction. For example, the 1969 peak hour distribution for the Boston freeway was:

7-8:00 AM	Northbound	71%
	Southbound	29%
4-5:00 PM	Southbound	62%
	Northbound	38%

In terms of speed, transit vehicles are constrained in the case of New Jersey's I-495 and the Long Island Expressway to speed limits of 35 m.p.h. Since interference is minimized, average speeds remain close to this limit and this represents a substantial advantage over normal freeway travel times during the peak periods.

Higher speed limits are avoided, in the case of these reverse lane applications, to minimize accident probability and maximize throughput.

- Volume

The exclusive lane facility provides substantial additional capacity where an opposing traffic lane can be utilized. Under certain conditions there may be a significant net gain even when lanes in the main direction of travel flow must be used. The following table presents a theoretical range of capacity which could be provided by exclusive lanes (Table 5-1).

Experience suggests that these theoretical advantages can be achieved in actual practice. In the New Jersey experiment, admittedly servicing the New York City commuter-shed, 25,800 passengers per hour were recorded in the peak hour.

It is also suspected, and corollary studies would confirm that the bus becomes a more attractive mode when service is via a reserved lane. Thus, bus ridership may increase while automobile usage is to some corresponding extent reduced. For example, data from the Boston experiment showed that both the number of buses using the freeway and the average number of passengers carried per bus increased, suggesting that the competitive advantage enjoyed by vehicles traveling on the exclusive lane appealed both to commuters and the private bus operators.

- State-Of-The-Art

All equipment for implementing the reverse lane system is avilable:

- Changeable signs and traffic posts
- Lighted lane directional signals
- Traffic separators - posts (placed in hole) or cones (free-standing)

- Institutional Background

The nature of exclusive use lanes requires a rare degree of intermodal cooperation which is not always enjoyed. The project in New Jersey, while administered by the Tri-State Transportation Commission, also involves the New Jersey Department of Highways, Port of New York Authority, and New Jersey Turnpike Authority. It is part of the federally funded Urban Corridor program. This, in itself, is a significant indication of the need for pan-modal cooperation since the urban corridor was a special effort to pool modal funds from the FHWA and UMTA programs to support experiments requiring support from more than one Federal agency. Similar inter-organizational cooperation was observed in the other experiments.

Table 5-1: Potential Volumes on Exclusive Lanes

ASSUMPTIONS: The maximum number of cars that can be processed per lane per hour is 2,000.[a]
All buses have 53 passengers.[b]

Bus				Car	
Headway Btwn. Buses	Buses Per Hr.	Passengers Per Hr.		Passengers Per Car	Passengers Per Hr./Lane
5 sec.[c]	720	38,160		1	2,000
8 sec.	500	25,000	Average Passenger/ Car Figure		
10 sec.	360	19,080		1.5	3,000
30 sec.	120	6,360		2	4,000
1 min.	60	3,180		3	6,000
5 min.	12	636		4	8,000
				5	10,000
				6	12,000

[a] Highway Capacity Manual

[b] Maximum seated capacity, large GMC bus. Assumes that standees on some trips are balanced by under utilized vehicles on other trips to generate average trip load figures.

[c] Headways of less than 5 seconds are occasionally experienced on some busways.

In order to provide for widespread implementation of exclusive use lanes, it would appear that assurances will be needed that all involved agencies at the local level will act in concert and that federal funds can be made available for both highway and mass transit phases of the work.

- Traveler Response

One of the major findings of the study of busways detailed in Volume II, was that substantial numbers of auto users could be persuaded to switch to that bus service demonstrating time advantages over normal trips. Exclusive bus lane service on freeways are ideally suited to achieve these substantial time savings.

III. SUMMARY AND CRITIQUE

This was found to be a very promising low cost alternative and readers are referred to Volume II for greater detail developed from case study investigations.

CHAPTER VI

EXCLUSIVE BUSWAYS ON SPECIALLY CONSTRUCTED RIGHTS-OF-WAY

Operating Description and Summary of Findings

In certain cases, a special roadway would be constructed for the exclusive use of buses. These facilities are operationally similar to the temporary reversed lanes on freeways discussed in Chapter V.

Such facilities are fast, can process large volumes of people and are extremely safe.

The capital costs associated with building such facilities are similar to that associated with building a standard automobile facility and therefore is a more expensive alternative than adapting an existing roadway for use as an exclusive bus lane. As a result higher transit volumes may be a prerequisite to justifying the high capital costs associated with specially constructed busways.

This technique is one of those selected for case study. The discussion which follows is the preliminary evaluation; the more thoroughly researched and detailed case study results are found in Volume II.

I. INTRODUCTION

This discussion covers an exclusive right-of-way for buses which is provided on a permanent basis. The so-called specially constructed busway involves building a special facility of some type for buses. In two cases this has meant building long, separate lanes for buses. In another case, it has meant building a separate ramp facility.

Three cities and their projects have been used to gather data for this analysis. They are:

1. An eleven mile exclusive busway to be built between Los Angeles and El Monte on Interstate 10 (the San Bernardino Expressway).

2. An 8.8 mile exclusive busway on Shirley Highway, Virginia for commuter traffic to Washington, D.C.

3. An exclusive on-and-off bus ramp into the central business district of Seattle, Washington used by some of the buses in a special "Blue Streak" system.

In all three cases, however, it should be noted that provision of a total bus system service concept was integral to building the special capital facilities.

II. TECHNICAL EVALUATION

- User Price Impact

Costs to users do not differ substantially over regular bus fares. Federal grants and subsidies have been used in some instances to drop fares and thus make the service more attractive. It is not unreasonable to expect, in the absence of subsidy, that "premium" or "express bus" fares may be justified.

- Implementation Costs

The cost for four miles of the exclusive bus lanes on the Shirley Highway was approximately $0.82 million per mile of two lane busway. In addition, the Shirley project included $200,000 for a feasibility study and $4.6 million for buses and related costs (non-construction costs).

The cost for the eleven mile, two lane San Bernardino exclusive busway averages out at $0.322 million a mile and includes these costs: site preparation, drainage, paving, fencing the right-of-way, and access gates. However, costs increase to $1.048 million per mile when these costs, specific to the site, are added: railroad track relocation, bridges and structures, barriers and retaining walls, busway control signals, railroad signal system, freeway modification, and access construction. It should be noted that the cost estimates for San Bernardino were prepared in 1969 and have been revised upward since then in response to inflation. Extreme caution should be exercised if these cost figures are used since there is such substantial variation possible.

Right-of-way costs will add substantially more cost where land must be purchased. It seems fair to say that capital costs of a specially constructed bus roadway are about the same as for a similar automobile roadway.

It may be significant to note that in the two cases where separate roadways were set aside, land and even a partially built but unusable two lane roadway existed.

- Operating Costs

Roadway maintenance data is not available for special busway facilities. It does not seem unlikely that these costs would exceed those for normal roadway. Bus operators are likely to improve the productivity of both employees and vehicles as detailed under the operating cost discussion in "Exclusive Reserved Lanes on Freeways for Mass Transit."

- Other Costs

Other costs are insignificant.

- Indirect Economic Effects

Indirect economic benefits from specially constructed bus lanes are substantial. Reduction of the ratio between the number of vehicles/number of people transported is evident from the exclusive lane facilities now in operation. This can be partly explained by the general rule that commuters are attracted to buses if buses are fast and reliable (less delays and deviations from schedules). Such dedicated busways have not only demonstrated travel time advantages but also increased bus scheduling reliability in the absence of traffic delays. This suggests that priority for the movement of people rather than vehicles is readily achieved with this technique.

One analysis based on the Shirley Highway facility suggested that as a result of the attractiveness of busway, the total indirect benefits attributable to an exclusive busway (if it is in operation only for three years) are $12.24 million, as opposed to the $7.57 million cost figure for the busway.[1]

- Impact on the Disadvantaged

There are two conflicting factors in the possible relevance of exclusive busways as an aid to low income commuters. Bus ridership is composed largely of lower income people; thus it seems that any improvement in bus service would aid this group. However, exclusive bus lanes on freeways have tended to link the suburbs with the central business district. As a result, this faster bus service may not affect transit routes in the inner city where lower income groups are concentrated. Positive effects may be the result of coincidences with the travel pattern of the disadvantaged.

- Environmental Impact

Pollution and congestion may be reduced as a result of the exclusive busways. One bus on the exclusive busways may hold as many people as forty-

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[1] Donald A. Morin and Ronald J. Fisher in "American Road Builder," December 1970.

five cars operating on the adjoining freeway. Interestingly enough the new buses being provided to the Shirley Highway experiment by UMTA are equipped with special "environmental improvement kits" to reduce harmful emissions. There is no specific data on pollution reduction at this point. However, until widespread implementation occurs, the effects will be minimal.

- Safety Impact

The use of exclusive lanes for buses seems to have generated few safety problems and the accident record is certainly better than for automobile traffic on the adjacent freeways.

One potential safety problem was identified for Shirley Highway. It involved getting the buses back into the traffic stream at the end of the reversible lane section. The Highway Department made arrangements for the State Police to provide an officer to make sure cars allowed the buses to merge safely. After one day of this surveillance, it became evident that the buses would have no problem merging. Use of the exclusive lanes by unauthorized vehicles turned out to not be a significant problem, as very few violations occured.

- Speed or Time

Time savings for bus systems using specially constructed exclusive facilities are substantial, as the following data indicate:

Facility	Distance Traveled	Auto Time	Bus Time On Non-Expressway Route	Bus Time	% Time Saving by Express Bus
Blue Streak	9 mi. - Fringe pkg. lot to CBD	-	25-35 min.	15 min.	40-57% over similar bus service[2,3]
Shirley Highway	8.8 miles	25 min.	-	15 min.	40% over automobile time[3]
San Bernardino (Projected savings)	12.5 miles	36-40 min.	-	18-20 min. (projected)	50% over automobile time[3]

[2]Some savings for Blue Streak services is attributable to buses utilizing the freeway (on a non-exclusive basis) as opposed to local arterials. Some time savings is associated with the use of the special Blue Streak ramp. It is not clear what proportion of savings is due to use of the ramp and what proportion is treaceable to the change in route.

[3]Note that this is travel time for the freeway/busway only, and does not include walking and waiting for the bus, or bus or auto times on local streets.

- Volume

The potential passenger volumes that can be carried on the exclusive bus lanes (XBL's) are significantly greater than the volume carried on freeway lanes used by cars (see Table 5-1). These projections may be matched by actual usage eventually, if the growing popularity of such service is any guide. Interestingly, much of the new patronage is from people who formerly commuted in autos (see Table 6-1).

- State-Of-The-Art

No technological problems evident.

- Institutional Background

A major institutional consideration in the building of XBL's is that a relatively large capital investment is required for construction and this fact almost certainly necessitates Federal assistance.

Such projects also require a high degree of cooperation between local and Federal agencies. Highway officials must produce not only the facility itself, but also must insure proper uncongested access and egress.

Transit company cooperation, of course, is needed in setting up exclusive bus lane service. Thus far cooperation in Washington, D.C. and Seattle has been obtained by underwriting the operating deficit. It is questionable whether all potential operations could count on such subsidies; and it is not known to what extent, in the absence of these subsidies, bus operators would be willing to establish service on new routes utilizing exclusive bus lanes.

A particular objective of various projects has been the diverting of automobile commuters to public transit. This often requires special planning. The San Bernardino funding includes money for two fringe parking lots. The Seattle Blue Streak service currently has one 500 car park-n-ride lot. Parking is available at no cost. The lot is completely filled, and bus riders are now parking on the side streets. Additional space is needed and the City of Seattle is working to get State funds for construction of a 1,000 car lot. There is a need for park-n-ride facilities to serve the Shirley Highway exclusive bus lanes. A survey of Shirley bus riders showed that sixty percent of the bus users have a choice between the bus system and their own automobiles. Thus, there is much potential for diversion of auto users. The survey showed that eight-three percent of present bus users now walk to the bus stop. Only eight percent park-n-ride. If fringe parking facilities were built, the ridership on the bus might well expand, as the data from Seattle suggests.

- Traveler Response

As in the case of freeway bus lane applications, a fairly enthusiastic response to bus lane service has been noted. This again is a response to the substantial time savings possible with an exclusive bus lane.

Table 6-1: Patronage of Exclusive Busways.

	No. Daily Bus Trips	Total Daily Passenger Volume	Total AM Peak Hrs. Passengers	Total Peak Hr. Passengers	Success of Project in Diverting Auto Drivers
Seattle (entire Blue Streak Service)	81	12,000	N.A.	N.A.	Sampling in fringe parking lot showed 76% of patrons formerly drove autos to CBD
San Bernardino (estimates)	N.A.	17,000	--	4,000	N.A.
Shirley Highway	108		8,100		According to an early survey of those making the trip previously, 44% drove alone, 33% used other buses, 23% carpooled.[a]

[a] See text footnote 2.

III. SUMMARY AND CRITIQUE

Specially constructed bus lanes appear to be fulfilling their potential to move large numbers of commuters at high average speeds. Diversion of auto commuters to buses, more productive vehicles than cars, is a major benefit of the exclusive bus lanes.

The significant right-of-way acquisition and construction costs of the exclusive bus lanes, however, suggests that alternatives might be more desirable.

Two key questions requiring answers are as follows:

1. How many freeway systems could support construction of dedicated rights-of-way within existing rights-of-way?

2. How many corridors have sufficient transit travel demand to justify the fixed capital and right-of-way costs associated with specially constructed busways?

More detail on this topic may be found in Volume II.

CHAPTER VII

WORK SCHEDULING CHANGES

Operating Description and Summary of Findings

Work hours or days worked are shifted from familiar patterns so that employees of cooperating firms distribute demand for transportation facilities. The resulting reduction in peak period transportation demand would alleviate pressures for new facilities designed solely to serve existing heavy peak period demands.

The limited evidence now available suggests that important efficiencies might be realized at little or no cost.

Unfortunately, there has been a great deal of resistance, especially from employers, and as a result only limited success with introducing this concept has been achieved.

I. INTRODUCTION

Work scheduling changes may reduce the degree of peaking in transportation use that occurs during the normal workday. By changing the hours of the workday, and/or shifting the actual day to be worked by a certain percent of employees in the central business district or other high density employment areas, demand for transportation facilities in these places should be less peaked than is currently the case. For fixed work schedules, the hour changes may take either of two forms: (1) staggering of hours or (2) the four-day work week. Note that the four-day work week itself involves staggering hours in that the workday for a portion of the work force might then be ten hours, 8:00-6:00 or 7:30-5:30 for example, rather than eight. While each of these concepts have been adopted by certain firms and businesses, the absence of large scale, city-wide, well organized staggered work hours or workdays application makes it hard to measure the full impact on the central business district.

Another possible work scheduling change is "gliding work hours." Under this system, employees are free to report to work at any time within a given set of hours, say 7:00 AM to 10:00 AM, and to leave when they have completed eight hours of work. The system is now being operated by some employers in Germany who like the system and say that the response from employees is very favorable. The employees have to use time cards (which were not required previously) but do not seem to mind this too much. Obviously, this work hour setup could not be equally well applied to every employment situation, but is mentioned here because it seems to be very promising in some circumstances. It is not mentioned further in this paper due to lack of specific details on cost, processing efficiency, and application feasibility.

The best before-and-after data available on a large scale staggered work hours program is from lower Manhattan, involving changed work hours for 60,000 people working for seventy different employers. These people compose fifteen percent of the approximately 450,000 employees in lower Manhattan (the "financial district").

Another large scale staggered hours program conducted by Federal government offices in Southwest Washington, D. C. and Crystal City, Virginia, will also be discussed, although before-and-after data are not available. Large scale and so far unsuccessful efforts to stagger work hours in London, England and Atlanta, Georgia, will also be mentioned along with projections on four-day work week efficiencies in the Los Angeles, California area.

II. TECHNICAL EVALUATION

- <u>User Price Impacts</u>

Costs to the user may change with changed work schedules. The obvious case of changed user costs is the substitution of a four-day week for the present five-day week. All other things being equal, commuting costs would be reduced by one-fifth since only eight weekly commuting trips would be needed rather than the present ten trips.

However, changes in working hours due to a four-day, forty-hour work week or staggering of work hours may lead to changes in mode of transportation and resulting changes in commuting costs. For example, the "before" surveys in Crystal City showed that some of the employees whose hours were being changed were thinking of switching from bus to auto. This may be expected when transit schedules tend to concentrate service in the existing rush period and are not altered. Since staggering of workdays or hours reduces the number of employees reporting to work at any given time, the number of people available for carpools will also be reduced. This may result in more employees driving to work alone, thus raising their out-of-pocket transportation costs.

- Implementation Costs

Costs to those businesses or government agencies implementing staggered hours are slight, if any. There may be certain one-time implementation charges associated with organizing employers and employees so that sufficient numbers are affected to produce the desired results.

The Downtown Lower Manhattan Association spent $50,000 implementing their program. Although a specific cost breakdown is not available, the study involved before-and-after data collection as well as surveys and information programs.

Costs to transit companies would be affected by the introduction of changed work schedules. There are many qualifying factors involved in determining whether it costs a bus company more to operate on a schedule which has an extreme peaking of demand, or one which has less extreme peaking but requires bus runs quite early in the morning, later at night, and possibly fairly heavy scheduling on weekends. So while it is not easy to determine conclusively which scheduling method would be least costly to transit companies, it is possible to state that the implementation costs (the costs of doing a scheduling study and carrying out the changes) are quite large, enough to discourage many bus companies from making the changes. This is one factor delaying such a program in Atlanta, Georgia.

It should also be pointed out that public transit would have reduced patronage as a result of the four-day week since only eight rather than ten commuting trips per worker would be made.

- Operating Costs

The only administrative operating costs would be those associated with follow-up surveys and these costs would be essentially one-time charges. For bus operators, new costs may be higher or lower, depending on the effect of new hours on patronage and number of runs needed.

- Other Costs

Some firms and employees questioned about a work schedule change have indicated that they felt it would have a negative impact on them. In London staggered hours were actually instituted among 21,419 staff of one hundred forty-five firms. The organizing of the project was done by the British Ministry of Transport rather than by a smaller local merchants' group. The Ministry met much opposition to changing work hours. As a result, all those firms that accepted were made part of the project despite their diverse geographic locations. Seventy-two percent of the firms approached by the government group claimed that staggering would result in loss of business efficiency -- contacts with customers, branches, factories and business associates would be limited. The surveyed firms wanted to maintain business hours and maximize periods for intercontinental communications. Twenty-three percent of the firms also stressed staffing problems; firms may have had recruitment problems and felt they could not risk losing present employees by adopting new hours, nor would they wish to impede further recruitment by adopting what employees regard as unattractive hours. Some firms (no percent given) reported that their employees were very opposed to an hours change. Present patterns were more important to them than a chance of more comfortable transportation. Currently, however, (the London project was done in 1959) unemployment is a problem and it seems unlikely that an employee would quit over an hours change.

The staggered hours project for Atlanta, which has not yet passed the planning stage, also indicated certain potential disadvantages.[1] The idea of staggering hours was originally backed by the Chamber of Commerce which obtained funding for the project and employed consultants to do a feasibility study. The consultants proposed a plan which, according to cordon counts and projections, would substantially reduce peak rush hour congestion. The recommended plan involved six employers (a federal government agency, city and county offices, and a large department store) and 11,000 employees. Among those reasons listed by employees in opposition to the plan are:

(1) Difficulty of adjusting present carpooling arrangements: Many people rode in with others whose employers were not being asked to change to staggered hours. A survey recorded in the feasibility study showed that 27.2 percent of employees surveyed were in carpools.

(2) Bus scheduling: The federal agency (Post Office) employees, particularly, rely on buses since they are mostly lower income. Authorities in Atlanta were not confident that they would be able to effect major schedule changes to accomodate work hour changes given the system wide impact on bus operations.

Atlanta has few really large firms, and medium size firms along with public contact firms, such as the department stores are less likely to experiment. Interference with goods and supply deliveries schedules, existence of restrictive nationwide labor contracts that would require renegotiations and tie-ins with national headquarters were other contingencies mentioned by Atlanta firms opposing a change in hours.

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[1] For Atlanta data, see: Wilbur Smith and Associates "Staggered Hours, Atlanta Metropolitan Area, Phase I - An Investigation Into Feasibility," 1968 and "Staggered Hours Plan, Atlanta Metropolitan Area (Phase II),"1970.

- Indirect Economic Effects

Indirect economic savings, while not quantifiable in this study, are likely to be quite substantial since the reduction of peak rush hour congestion will delay or possibly eliminate the need for constructing new fixed facilities to handle increased traffic flows. Also, in most cities, the spreading of demand over longer periods of time should result in shortened travel times. In New York, however, this did not occur on a large scale, since subway travel times are not greatly effected by congestion.

It is possible that on-the-job productivity may increase with work hours changes. Various employers who have shifted to the four-day work week report less absenteeism and less reporting for work late. The Manhattan staggered work hours program also yielded favorable data on employee output.[2] The 60,000 employees altered their work hours from the prevailing 9:00-5:00 workday to an 8:30-4:30 workday. Questioning of the supervisors involved showed that seventy-one percent felt the new 8:30-4:30 schedule had resulted in no change in business efficiency, while twelve percent felt efficiency had increased and seven percent felt it had decreased. Further 24.6 percent of the supervisors said that under the new work hours employees are at work earlier (in relation to the starting time) than they were before the hours change. Of the supervisors, 54.9 percent said employees come in at the same relative time, while 11.6 percent said employees come in later. Also, surveys conducted for the lower Manhattan project showed a marked employee preference for an earlier workday than the standard 9:00-5:00 day. Eighty-five percent of the employees preferred the new schedule, while only eight percent disapproved. The study attributes this to the worker's desire to have more of the day to spend with family and friends. This employee satisfaction may have influenced most workers to come to work early or on-time, as reported above. Reduction of congestion on transit facilities, subway stations, restaurants, elevators, and stores, as detailed under "Processing Efficiency" is another factor likely to contribute to employee satisfaction.

- Impact on Disadvantaged

It appears that there would be no specific benefits which accrue to disadvantaged groups that would not also accrue to others using the staggered work hours system. Further, it should be noted that since proportionately more low income commuters rely on bus mass transit, any work scheduling changes should be accompanied by appropriate transit scheduling changes to allow these people to reach work on time. Given the reluctance of operators to reschedule, this may work to the disadvantage of low income groups.

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[2] For more information, see "Staggered Work Hours Project in Lower Manhattan" by Brendan O'Malley and "Staggered Work Hours in Lower Manhattan - First Anniversary Report - April 1971" prepared by Downtown Lower Manhattan Association and the Port of New York Authority.

- Environmental Impact

The plan does not include a change in transportation mode, so no specific impact can be forecast. However, some possible impacts are:

(1) Reduced peak hour traffic volumes might result in decreased congestion, thus reducing emissions from idling engines.

(2) Reduction of congestion might cause some people to switch from mass transit to the auto mode, thus increasing automobile emissions.

(3) If the four-day work week is adopted, the number of work trips per commuter per week will be reduced, thus reducing commuter trip caused air pollution.

(4) The four-day work week is expected to involve a three-day weekend since union demands stress that the extra day off not be in the middle of the week. The three-day weekend would most likely mean more trips taken by family groups who often use cars or campers or other recreational vehicles for these trips. This would mean that the head of household would drive more miles per week than he does now and possibly that the family would purchase another vehicle for their increased needs.

All these suggestions are possibilities, but more data are needed to predict whether they will become realities of consequence.

- Safety Impact

The four day work week would both reduce the number of work trips made each week and distribute those made over a greater range of times. This would undoubtably decrease the number of work trip accidents. The increase in the three-day weekend type of leisure activities presumably allowed by the four-day work week might lead to a corresponding increase in leisure trip accidents. This circumstance is really a separate issue, however, as it is a cost more properly balanced against the benefit of more useable leisure time.

- Speed or Time

According to interviews with Manhattan commuters operating on the staggered work hours schedule, the changed schedule has not resulted in an appreciable reduction in commuting time. The probable cause for this (as mentioned above) is that in the case of fixed rail facilities, headways and average operating speeds are not as significantly affected by congestion and excessive volume.

Although commuters do not generally perceive it, there is evidence that some commuters have reduced travel time due to staggering of hours. A transportation study, part of the Downtown Lower Manhattan Staggered Work Hours Program, surveyed travel times for various inbound commuter trains and subway lines arriving at key stations, plus the interstate Port Authority Trans-Hudson transit system. Findings showed that an increasing pattern of train delays (five minutes or more off schedule) developed as the morning peak period progresses. Generally, rail delays were found to be minimal prior to about 7:30 AM and subsided rapidly after 9:20 AM. Thus, Manhattan employees using the rail systems encountered greater and more frequent delays for a 9:00 AM starting time compared to an 8:30 start. These findings mesh with surveys of supervisors which showed that 24.6 percent of the supervisors said that their employees report for work earlier (in relation to starting time) under the staggered hours than previously, as opposed to only 11.6 percent who said employees come in later. However, the actual time saved per commuter is probably fairly small, only about one hour per month.

Data presented below under "Volume" shows significant reductions in projected peak volumes for two cities which have substantial commuting by automobile, Atlanta and Los Angeles. However, while it can be said that there should be some time savings due to decreased congestion and associated delay, no data are available to document this impact. Such information would greatly help in analyzing the advantages to be gained by instituting work hour changes in these cities.

- Volume

Changed work schedules allow reductions in peaking at major transportation facilities. Although in New York, at least, this peaking reduction affords little time saving, commuters do feel that commuting is more comfortable than previously. The first four of the following charts show some data quantifying the changes in volume.

Figure 7-1 shows the volume changes connected with the staggering of work hours for 4,500 City of New York employees.[3] Before-and-after turnstile counts at eleven lower Manhattan subway stations were used in plotting the graph, which shows a fourteen percent reduction in the PM peak rush hour volume for these stations. Counts were measured over ten minute intervals, and AM data was not used because turnstile counts were not taken after 9:00 AM, although a significant portion of the activity occurs then. Figure 7-2 records turnstile count results for three major lower Manhattan stations in the AM. Here a nine percent decrease in maximum peak volume is recorded. Figure 7-3 shows PM passenger volume at the Port Authority Trans-Hudson Terminal, and also shows an approximate nine percent reduction in maximum peak volume. Figure 7-4 provides some indication of the reduced congestion in public facilities other than the subway. It records the drop in passengers waiting for elevator service in a big lower Manhattan office building.

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[3] Transportation Administration, The City of New York.

Figure 7-1: SWHP - NYC DATA ON STAGGERED WORK HOURS EFFECTS
PM Data - Total Excluding One Station
(11 Stations w/o Fulton St. - IRT Lex. Ave.)

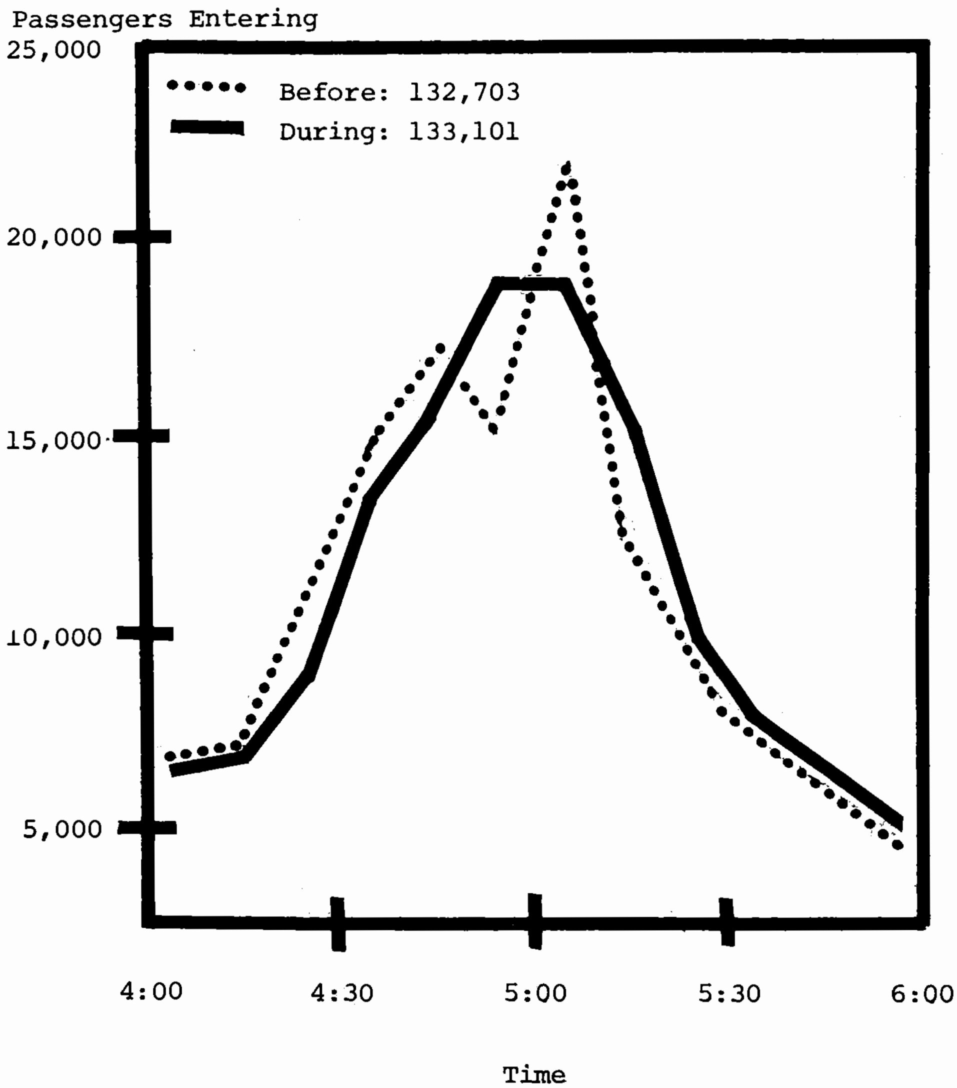

Figure 7-2: Staggered Work Hours Project
New York City Transit Authority Turnstile Counts

Total for Three Major Downtown Stations - AM
- IRT Lexington Ave. - Wall St. Station
- BMT - Broad St. Station
- IRT Seventh Ave. - Wall St. Station

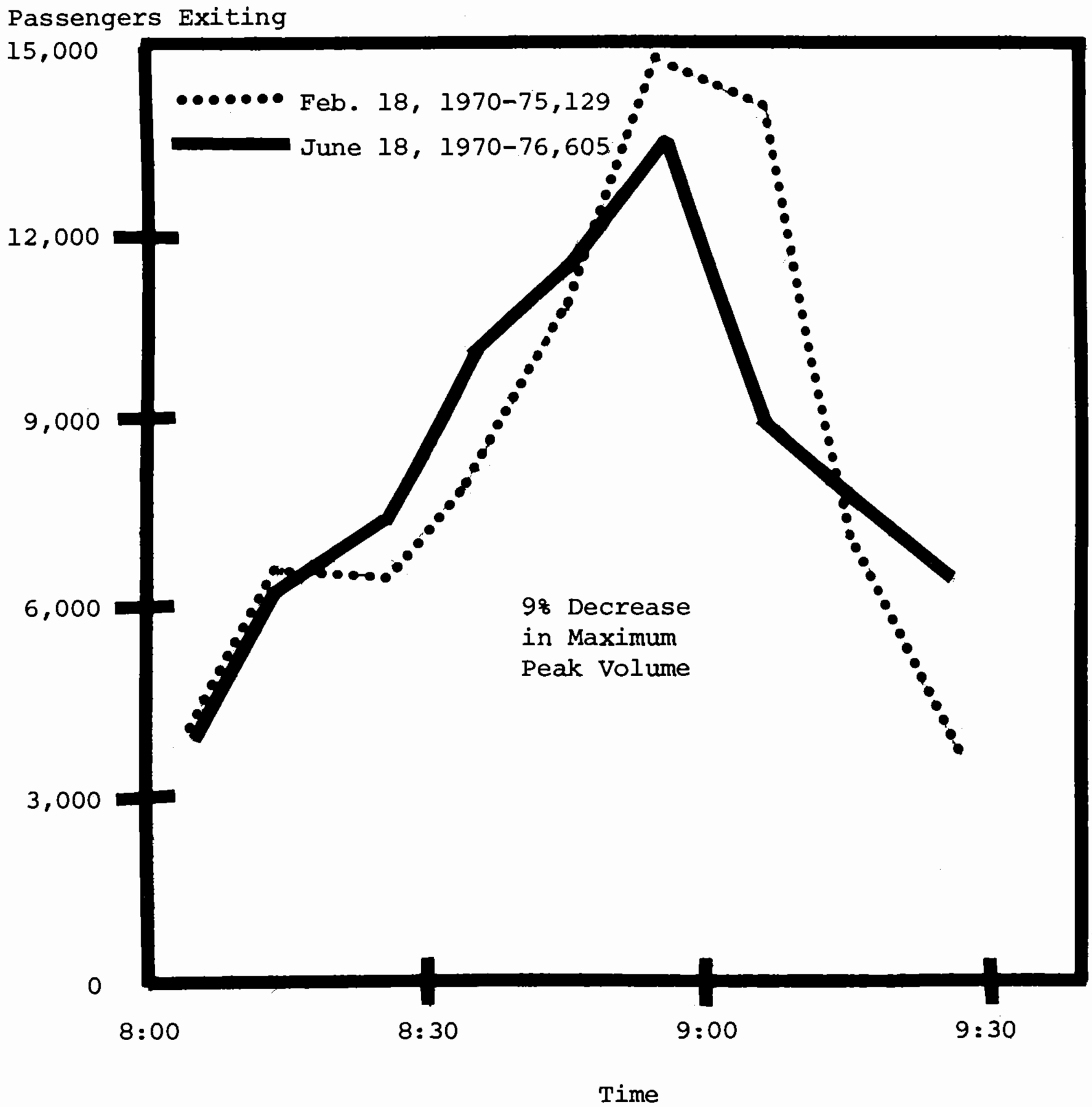

Figure 7-3: Effects of Staggered Work Hours Path Hudson Terminal

PM Passenger Volumes

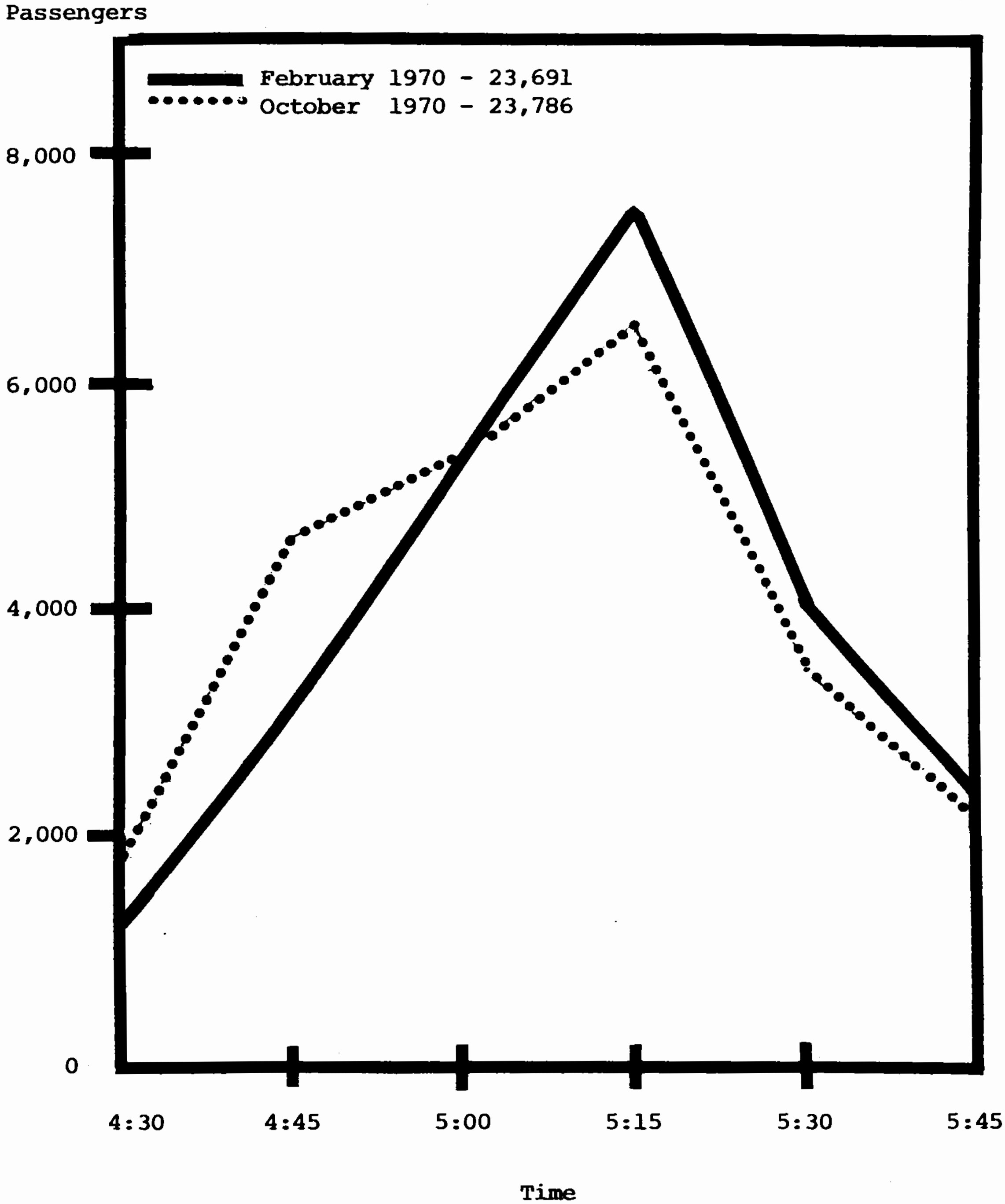

Figure 7-4: Morgan Guaranty Trust Bank Elevator Operations

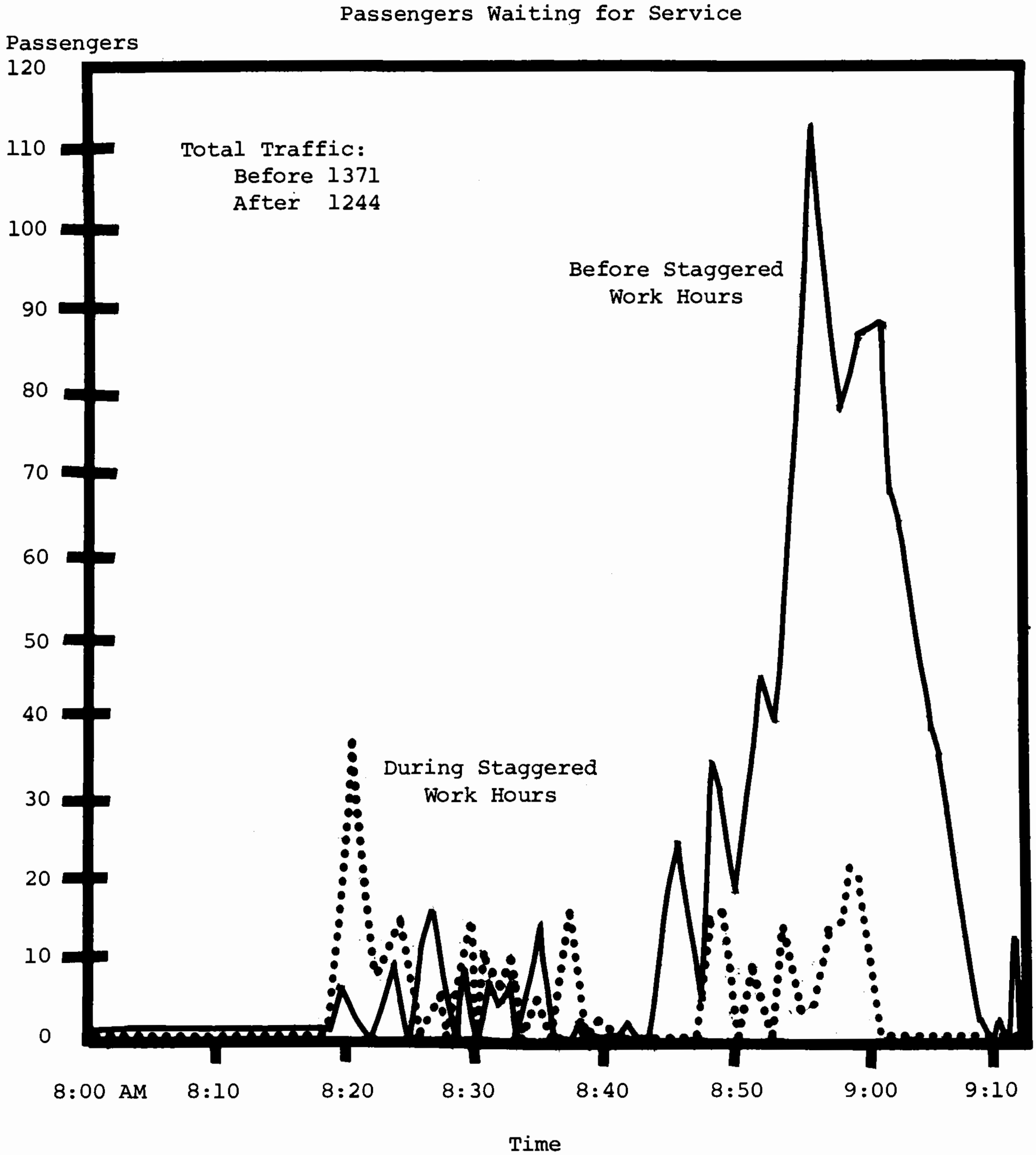

Figure 7-5 and table 7-1 show cordon counts and projected volume reduction with work schedule changes in Atlanta and Los Angeles. The Atlanta data involved work hour changes for employees of six employers -- three private firms -- and three public agencies, a total of approximately 11,000 employees, some of whose hours would be shifted by as much as forty-five minutes while others would only be shifted by fifteen minutes. A reduction of almost seventeen percent in the cordon volume for the busiest half-hour is suggested by these projections. The busiest hour records a twelve percent reduction in volumes. The "before" volume measured for the peak hour in the cordon was 22,550 vehicles, the new volume estimated was 19,900. Thus, changing of hours for only six employers and a total of 11,000 employees would generate an important decrease in peak rush hour volume. Table 7-1 shows AM peak period Los Angeles central business district cordon volumes as affected by variations on percentage of workers who work four days a week and the percentage of those workers who are actually working on a given day. The data was prepared with the assumption that the employee working a four-day week started work one hour earlier and finished one hour later than previously; thus he might not cross the cordon during the given peak hours (7:00 AM to 9:00 AM).

The optimism of these projections should be tempered by real applications data.

- State-of-the-Art

No problems anticipated.

- Institutional Background

The major institutional consideration is probably related to the autonomy of most organizations in the central business district. While the Manhattan staggered hours project was implemented with great success, similar attempts in London, England and Atlanta, Georgia were unsuccessful. In both cases lack of cooperation among firms and employees seemed responsible for the failures of the projects.

In London staggered hours were actually instituted among 21,419 staff of one hundred forty-five firms. However these firms were scattered all over the central business district rather than concentrated in one portion of the business district, as in the case of lower Manhattan area project. The affected London workers in the project were a very small percentage of the over 1,000,000 persons commuting to London by rail and road on an average day.

The staggered work hours for Crystal City, Virginia and Southwest Washington, D.C. both worked well, although no specific data on time savings, volume processed, or costs are available. Lack of before-and-after data is largely due to the fact that both these projects were developed to provide optimal processing efficiency for employees moving to newly opened office complexes. Thus, "before" data were meaningless. The fact that the staggered hours were tied in with new work locations is significant-- it appears that employee resistance to the shifted hours was decreased by the fact that the new locations would involve changes in travel patterns anyway, regardless of whether actual hours of work were shifted. Another prime factor in the acceptance of the changes was that all the arrangements were made by one large group--

Figure 7-5: Total Traffic Volumes - Plan A for Staggered Hours
PM Peak Period (One Way) - Atlanta

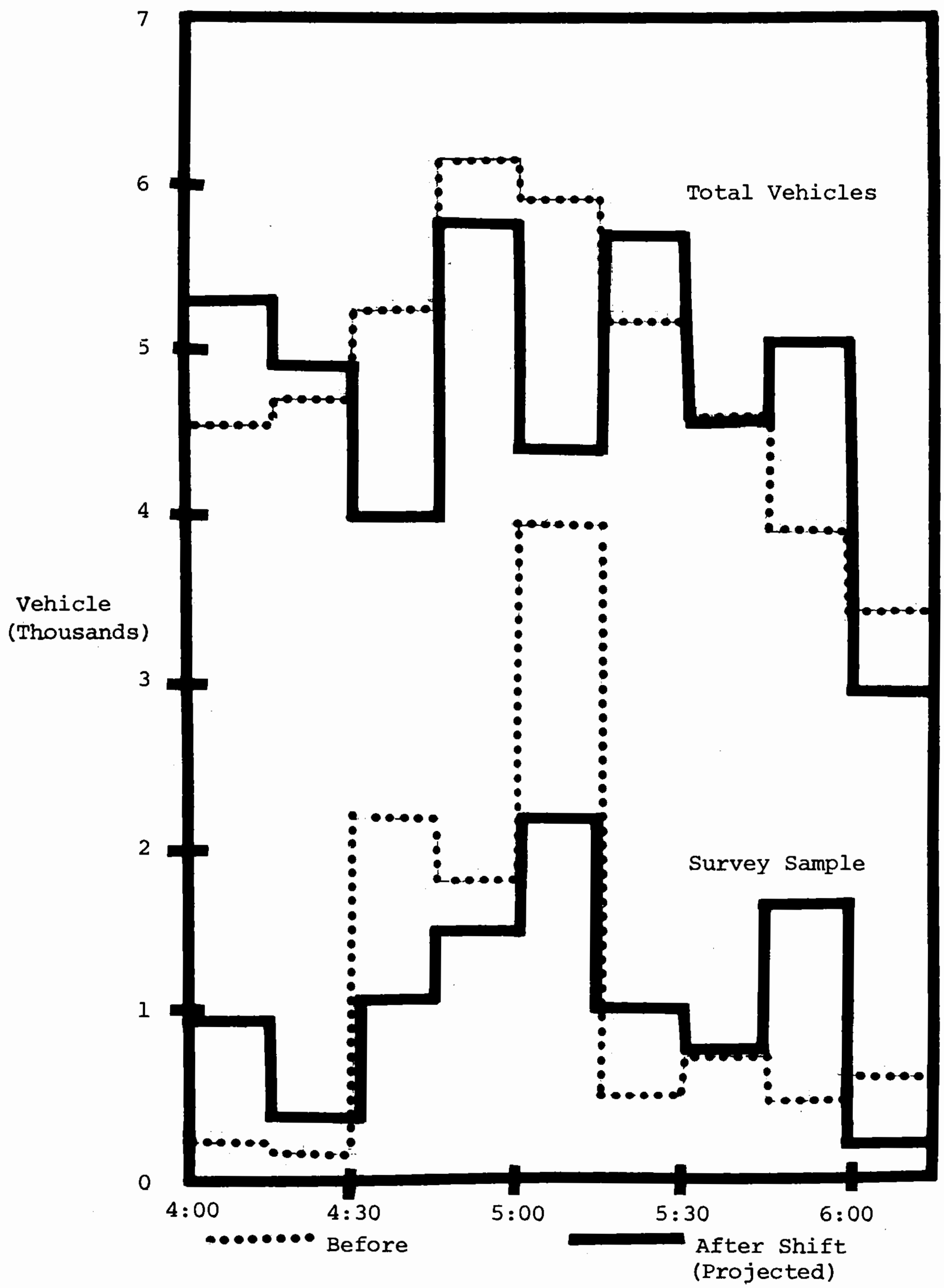

TABLE 7-1: AM Peak Period Los Angeles CBD Cordon Volumes Historic and Possible 4-Day

Year of Cordon Count	Condition	Inbound Volume 7-9 AM (Vehicles)	Percent Volume Reduction[a]
1936	100% on 5-day, 100% working that day	58,000	
1941	100% on 5-day, 100% working that day	62,300	
1957	100% on 5-day, 100% working that day	72,600	
1967	100% on 5-day, 100% working that day	70,000	
1970	100% on 5-day, 100% working that day	72,600[b]	
1970	100% on 4-day, 100% working that day	72,600[b].	
1970	100% on 4-day, 80% working that day	58,000	21
1970	100% on 4-day, 67% working that day	48,400	34
1970	35% on 4-day, 100% working that day	67,400	8
1970	35% on 4-day, 80% working that day	63,400	13
1970	35% on 4-day, 67% working that day	59,800	18

[a] The above data assume that those on a 4-day schedule are working ten hours a day and that some of those working four days receive their third day off in the middle of the work week. These assumptions, however, appear to be questionable as there is strong labor union opposition to a four-day work week in which the work day is longer than eight hours and in which the days off are not consecutive. See: Institutional Background discussion in text.

[b] These figures appear to be inconsistent.

SOURCE: "The Four Day Work Week and Transportation" by Vincent R. Desimone, American Society of Civil Engineers--American Society of Mechanical Engineers, 1971.

the Government Services Administration, for one large employer -- the federal government. Thus, cooperation among employers was not a great problem, and the GSA was very careful to weigh factors considered important by officials at the various government agencies involved who, in turn, were responsive to their employees' needs. The GSA was careful to get the transit operators involved so as to achieve some scheduling changes required to accommodate the proposed revised hours.

- Traveler Response

Reinforcement in the form of large-scale organized efforts to arrange staggered work hours among at least several firms is necessary to produce the desired improvements in processing efficiency that can result from staggering of work hours. Demand for scheduling changes seldom originates with a small firm or among employees (although the four-day work week does get much of its support from these areas). To organize work start and finish times within a specific area so that peaking will be reduced, a large employer (such as the federal government) or an important organization of employers or of employees, must take the initiative. While as of March 1, 1971, there were few United States firms on the four-day plan (90 firms with an average of 185 employees each) there are indications that the trend in the next few years will be toward more participation in the four-day work week. Once initiated, employee/commuter reaction tends to be quite favorable.

III. SUMMARY AND CRITIQUE

The four-day work week and staggered work hours appear to offer substantial reduction in commuter peaking at an extremely low cost. While there is a lack of empirical data on the effects of implementing work scheduling changes on a large scale, the data that does exist suggest that if the institutional barriers are overcome, work hours changes can be implemented successfully with very low implementation cost and at a substantial reduction in peak rush hour volumes with at least some decrease in commuting time. User costs may be reduced with four-day work weeks and remain steady or increase or decrease slightly with staggered work hours. But, particularly with the four-day work week unanswered questions relating to processing efficiency, safety and environmental benefits make further data necessary in evaluating the merits of work schedule changes.

Regarding institutional constraints, any city or area considering work scheduling changes should consider these key questions in evaluating factors working for and against the adoption of the changes in their area:

(1) Is there a single large employer (the federal government usually) or a strong merchants' association within a specific portion of the central business district? (favorable)

(2) Does the proposed plan concentrate on a specific work area or portion of the central business district (favorable) or does it apply instead to the whole city or region? (unfavorable unless the same proportion of participants can be maintained)

(3) Is it likely that public transit will cooperate in making any routing or scheduling additions or changes necessary? (favorable - consequently the plan may work best in areas where transit is fairly solvent or is publicly controlled)

(4) Is the area an involved one which has a concentration of administrative offices (favorable) or an area of offices or stores depending heavily on consumer contact? (unfavorable)

(5) Is the area one in which most offices are to be newly opened, such that employee scheduling and arrangements are disrupted anyway? (favorable)

(6) Is the plan one which union officials will accept? (favorable -- note that unions oppose longer daily hours as well as four-day work weeks in which the three days off are not consecutive)

In any further study of staggered work hours, the most important question that requires clarification is the extent that hours can be changed without interfering with the functions of the affected businesses or public agencies. Without these data, campaigns to persuade reluctant employers and employees would be premature. More investigation into employer, union, and employee feelings on effects of hours changes on contracts, day-to-day transportation arrangements, and office procedures is needed.

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CHAPTER VIII

HIGHWAY TRAFFIC ENGINEERING SYSTEMS IMPROVEMENT

Operating Description and Summary of Findings

A brief review and summary of five types of techniques for improved street system utilization is undertaken to acquaint readers with the documented benefits and results of extensive previous work in this area. The five techniques reviewed are:

1. Traffic Land Use and Directional Control
2. Curb Lane (Parking) Controls
3. Traffic Channelization
4. Signal Control
5. Bus and Large Vehicle Operation

A key observation in almost all traffic engineering studies is that effective law enforcement of traffic regulations is essential to success and will result in maximum gain from any traffic engineering improvement. It has also been observed that poor regulation may negate a traffic improvement program.

In general it can be said that the potential to improve traffic movement through the use of traffic engineering represents achievement of important marginal efficiencies.

PREFACE

The following review is a summary of relevant literature on a variety of possible improvements, as opposed to the more detailed examination of one particular concept or technique such as has characterized most of the other reviews performed in this study. As such, this summary discussion touches on several useful techniques briefly, rather than going into extensive detail on any one.

In the case of Traffic Engineering Improvements, to attempt greater detail in the context of this study would appear to be redundant and/or of questionable relevancy simply because numerous well researched and documented manuals, studies, and textbooks on traffic engineering are already in existince.

It was thought that the most useful contribution of this study would be to identify, for those who need the information, the broad general techniques of traffic engineering which might be usefully applied to local traffic management problems. The assumption is that an interested reader could then refer to the numerous comprehensive studies on these subjects for more detail on implementation, costs, or measures of impact. Many of these are listed in the Bibliography.

One other important guideline used in preparing this review was to direct it at the needs of medium and smaller sized cities. Large cities have their own Traffic Engineering Departments and are thoroughly familiar with most of the features discussed. Traffic Engineering techniques are therefore described and discussed from the point of view of whether their application is reasonable for a smaller community, and the conclusions are not wholly transferrable to large metropolitan areas.

I. INTRODUCTION

The application of good traffic engineering practice may result in substantial gains in the efficiency of street utilization. The traffic engineer relies on a number of techniques involving street-vehicle systems to help realize these efficiencies.

A major area of concern is to increase the traffic handling capabilities of intersections. Increased intersection efficiency may be gained through the combined use of carefully programmed traffic signals, directional controls, markings and signs designed to produce a more orderly and effective traffic flow. The street-vehicle system may be increased in efficiency by increasing the number of effective traffic lanes through parking restrictions, and by channelizing traffic into specific movements. Bus stops and truck loading zones may be relocated to increase street efficiency. In all traffic engineering applications success is dependent upon good design and effective law enforcement.

There are a host of traffic engineering improvements that may be undertaken. They may be generally grouped under the following headings:

1. Traffic Lane Use and Directional Control
2. Curb Lane (Parking) Controls
3. Traffic Channelization
4. Signal Control

Traffic engineering experience indicates that adjustments to the traffic signal controls in a city yields clearly positive and acceptable results under most circumstances. Such adjustments involve a relatively small investment and usually have a large return.

Another means of control that can be accomplished easily, with a minimum of investment and with favorable public reaction, is channelization. Channelization is the placement of traffic separators or simply traffic paint markings to guide traffic flow. Channelization will usually increase the efficiency of a street or intersection by forcing the facility to operate as planned because of the physical constraints on potential traffic violations.

The next area of control that may yield a considerable gain, again at low investment, involves those devices and techniques concerned with directional control and lane use. These controls, particularly one-way street systems, often meet resistance and should in most cases be coordinated with other improvements over a substantial area such as the entire central business district of a small city.

The final method of increasing street utilization is through the restrictive control of parking on all or portions of a street. Opposition is the normal initial public reception given to such regulations but this opposition often subsides if the benefits can be clearly demonstrated, particularly if alternate arrangements for parking can be made. In any case, regulations are well obeyed only where enforcement is vigorous. On very busy streets the location of bus stops is also a factor in the operation of the street but the gains from changing their locations are usually minor.

In general the traffic engineering improvements to be performed first are adjustments to the signal system, lane striping, and other lane control devices. As already noted, these activities are generally well received by the public. Initial reaction is usually negative to regulations that restrict automobile parking and commercial vehicle loading, and thus such regulations should be saved for use where other alternatives have been examined and found wanting.

A key observation in almost all traffic engineering studies is that effective law enforcement of traffic regulations is essential to success and will result in the maximum gain from any traffic engineering improvement. Another important factor is that overkill may negate a traffic improvement program. Excessive installation of traffic signals is a case in point.

II. TECHNICAL EVALUATION

The economic costs and benefits associated with most traffic engineering improvements are usually in themselves quite minor to the individual, but when aggregated over all the trips made during the economic life of the improvement, substantial sums of money may be involved. To simplify comparisons, the automobile operating costs employed in this discussion will be average urban area costs calculated for speeds approaching thirty miles per hour.

. User Price Impacts

The automobile user costs presented here are based on recent studies by Paul Claffey. His studies, as well as prior work, indicate the efficiency of urban travel may be measured by the number of stops that are made during a journey, the delay time associated with each stop, and the average speed of the journey.

The average cost of making a stop is approximately 0.71 cents. The fuel consumed during idling at a stop is 0.58 gallons per hour or 19.72 cents per hour (gasoline at 34 cents/gallon). The relationship between vehicle operating costs and speed in the urban area is shown in Figure 8-1. The curve, drawn employing Claffey's data, includes one stop per mile in the calculations. Cost data serve to emphasize that to minimize vehicle (auto user) operating costs, the best street system operating plan would be one designed to allow steady speeds in the twenty to forty MPH range.

The resulting annual savings may, in the aggregate, be substantial. As an example, the elimination of one stop along a path saves the average individual approximately .07 cents, or 16.6 cents a year (240 days). If 10,000 people daily use the route, the annual savings in operating costs alone is approximately $1,660.

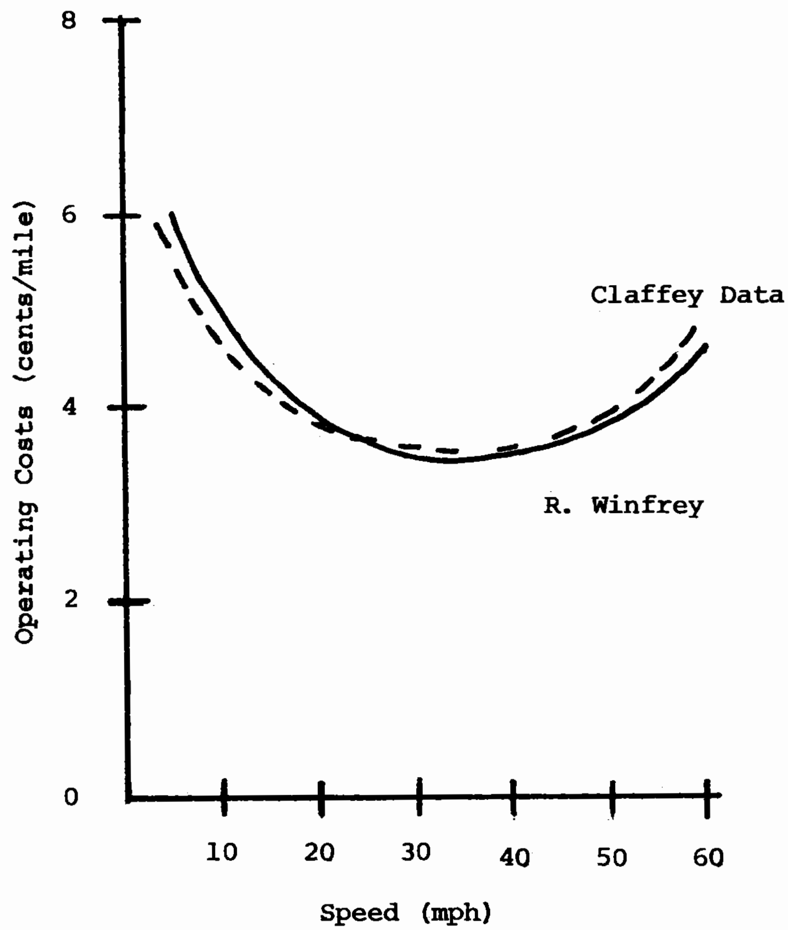
The direct economic benefit of increasing the trip speed through a section of roadway from ten to a steady twenty MPH is an operating cost savings of approximately .08 cents per mile (see Figure 8-1). Thus, the savings over a one mile section of road to 10,000 daily travelers would be $2,120 annually.

Assume that the savings produced by no stop and faster travel are made possible by traffic signal coordination. An annual cost of $3,780 a year would be justified before costs exceeded benefits. Assuming $500 a year maintenance costs, and amortizing over ten years at six percent interest, this equates to a justifiable capital cost expenditure of $24,140.

. Implementation Costs

Installation of new traffic signals is an expensive undertaking ranging from $2,000 per intersection for certain simple fixed cycle systems

Figure 8-1: Estimated Auto Operating Costs for a Typical Passenger Car.



Conditions on Claffey Curve:
level urban area,
2% curvature, 2% grade.

Source: Paul J. Claffey, Running Costs of Motor Vehicles as Affected by Road Design and Traffic, National Cooperative Highway Research Program Report 111, Highway Research Board, Washington, D. C., 1971; R. Winfrey, Economic Analysis for Highways, International Textbooks, Scranton, Pa. (1969).

to $10,000 or even $35,000 for a demand actuated multiphased [1] system. A city that already has its traffic signal system in conformance with safety standards will usually experience low costs in implementing the first group of improvements. The proper timing of traffic signals may be accomplished by a qualified traffic engineer with a minimum of data. Establishment of a pre-timed signal system coordinated for progressive traffic movement is likewise relatively simple, however, full reliability requires installation of relatively expensive interconnection via wires, telephone, or radio. For more complex signal systems, phasing can be developed using computer programs such as SIGOP (Signal Optimization) or analog devices. The hardware for complex systems represents a substantial investment.

Other start-up costs involve painting lane and traffic markings and erecting signs. The equipment to produce these signs and to apply traffic paint may also be needed. Ready made reflective regulatory signs are usually in the $5.00 to $40.00 per sign cost range. Traffic striping equipment ranges from inexpensive applicators, largely manually operated, to machines costing $10,000 or more. The costs of maintaining a crew to do traffic painting ranges from between thirty and eighty cents per capita.*

Improvements employing channelization usually involve new street construction or reconstruction. This can often be expensive and may necessitate outside help in the form of engineering and construction services.

- Operating Costs

The operating costs associated with maintaining a simple signal system are usually reasonable since the equipment is quite robust and repairs may be accomplished by an electrician. The more sophisticated equipment needed for the complex intersections is only somewhat less robust, but maintenance requires specialized training.

- Indirect Economic Effects

The amount of time that may be saved by good traffic engineering is directly proportional to the degree of prior deterioration of the street system. If the entire network of streets is improved the individual may experience a ten to twenty percent improvement in travel time. If the average journey to work in a small city takes fifteen minutes over the road then the time savings is one and one half to three minutes. With a vehicle occupancy of 1.3 to 1.5 persons the total time savings may amount to a low of 2.0 minutes to a high of 4.5 minutes per vehicle trip. Using an average value of time of $2.50/hour to the commuter, approximately one-third the

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[1] More than two separate traffic movements protected by their own signal phase.

* Based on the 1964 Budgets for Detroit, Michigan and Phoenix, Arizona (respectively) as reported in Traffic Engineering Handbook.

annual hourly rate of pay, the amount the commuter can be assumed to be willing to pay for the time savings is 2.7 cents per trip (5.4 cents/day) to 18.0 cents/trip (36.0 cents/day).

In some circumstances there may be opportunities to temporarily alleviate demand for new facilities with traffic engineering improvements. However, traffic engineering improvements alone will in most instances only allow handling of a moderate increase in demand.

- Impact on the Disadvantaged

The groups that gain the maximum benefits from traffic engineering improvements are those who travel in automobiles, particularly during the rush hour. There is also a small but tangible benefit to bus transit users. The benefits to other groups in the urban area are usually minor.

- Environmental Impact

The environmental gains from traffic engineering are in direct proportion to the success in moving traffic at a steady thirty to thirty-five MPH. The automobile moving in this speed range produces a minimum of air pollution. Minimizing the number of stop and start conditions and speed changes will also minimize pollution, since more pollution is given off by an accelerating or decelerating internal combustion engine.

Noise is also minimized when vehicular traffic moves at moderate, steady speeds without accelerating or decelerating at traffic signals or other traffic control devices.

Any traffic engineering improvement such as adjusting the traffic signals, or establishing a set of one-way streets, may result in improvement to traffic speeds and/or the number of stops and thus produce marginal favorable impacts on the environment.

- Safety Impact

The potential gains in the area of safety due to minor traffic engineering improvements is substantial. If traffic is allowed to travel at steady and reasonable speeds, weaving and passing are minimized and the corresponding number of accidents will be reduced.

- Speed or Time

Assuming that the existing traffic signal system of a city center is not set for progression (steady flow at a selected speed), then considerable improvement in the speed and time of traffic movement may be experienced with good traffic engineering. The peak hour improvement may be as much as forty percent increase in average speed and a sixty or seventy percent reduction in the number of delays.

Such improvements in speed and time are subject to the principle of diminishing returns. That is, if the signal system's efficiency is improved by one set of actions, then to obtain a similar improvement with a second set of actions will be much more costly. Efforts at small refinements are further frustrated by the illegal or uncooperative actions of many drivers and/or pedestrians.

The use of a system of paired one-way streets eliminates left turn conflicts. A vehicle turning left across opposing lanes is considered the equal of 1.5 through automobiles, whereas a vehicle turning right is equivalent to approximately 1.2 through automobiles. Under average circumstances a one-way street pair thus provides additional capacity without new construction. Moreover, it is often much more feasible to provide good signal progression on one-way streets than on two-way facilities. The combined result may be an increase in speed of twenty to thirty percent in the peak hour and a reduction of the stops and delays of approximately sixty percent.

The introduction of curb lane controls such as no parking and restrictions on truck loading will not yield full benefits unless enforcement is strict. The time-related benefits include reduction of delays and stops by twenty to forty percent, depending on the amount of traffic.

The use of curb lane parking controls to organize traffic at an intersection may yield substantial improvements in traffic flow. A problem with such controls is the required enforcement; illegal parking or stopping will nullify any potential gains. On the other hand, intersection curb lanes which are well marked and heavily used for traffic generally become self-enforcing over time.

- <u>Volume</u>

The volume of traffic that may be processed through a street network is usually a function of the efficiency of the intersections. The observed maximum capacity of a straight section of urban street having good pavement and a steady flow of cars (equivalent to having a continuous green light) is approximately 2,000 vehicles per hour per lane. If each car is made for some reason to stop and then proceed, the capacity is reduced to approximately 1500 vehicles per hour. Impose on this the typical condition of signalization that the traffic stream receives only fifty percent or less of traffic signal green time, the rest being allocated to cross traffic, and the approximate capacity at the traffic signal becomes 750 vehicles per lane per hour. This volume will be further reduced if left turns and right turns are made from through traffic lanes. If ten percent of the vehicles turn left and ten percent turn right, the effective capacity becomes approximately 700 vehicles per hour.

These generalized figures for signalized conditions, 700 to 750 vehicles per lane per hour, represent the attainable average traffic volumes that may be achieved through proper traffic engineering. Since without improvements each usable lane will still carry a volume approaching these amounts, the additional through put afforded by good traffic engineering is incremental in most instances. In the case of gaining a lane by means of parking restrictions, however, the full lane capacity may be added to the total available.

. State-of-the-Art

Traffic engineering is a technical speciality that has emerged as a result of the wide spread use of the automobile. The principal technical association for traffic engineers was found in 1930, indicating the relative infancy of this speciality.

Traffic engineering practice is a mixture of theory and analytical judgment. The theory of street and intersection capacity has advanced sufficiently that manuals, such as the Highway Capacity Manual, now exist as a basis for engineering calculations. The manuals are based on observed data that allow for relatively consistent conclusions to be drawn in the design of traffic improvements.

. Institutional Background

In regard to ease of implementation traffic engineering improvements may be generally classed into two groups: Those readily accepted by the auto driver and adjacent property owners; and those not readily accepted. The readily acceptable traffic engineering improvements are signal installations, signal timing adjustments, lane striping, and other actions that help the ordering of traffic. The efforts at improvements which often meet opposition and/or non-compliance involve curb lane controls such as no parking and restricted loading zones, and the establishment of one-way street systems. Non-compliance with traffic engineering efforts involving curb use restrictions can negate any potential traffic flow improvement unless the regulations are vigorously enforced.

The funding of traffic engineering improvements may come from federal, State, and local sources. The federal funds are channeled through the TOPICS Program of the Federal Highway Administration. State funds are usually available for routes designated on the State Highway network through some scheme to disburse gasoline tax funds.

III. SUMMARY AND CRITIQUE

Traffic engineering is a vast subject and the potential has been very briefly sketched in the preceeding sections. The potential to improve traffic movement through the use of traffic engineering is significant in most urban areas, most particularly in those not having a traffic engineering department or persons familiar with the principles of traffic engineering. Table 8-1 provides a summary of the general potential of traffic engineering to the typical small urban area.

TABLE 8-1

SUMMARY* OF TRAFFIC ENGINEERING IMPROVEMENTS

ITEM	COST	POTENTIAL IMPROVEMENT			INSTITUTIONAL ACCEPTABILITY
		SPEED	DELAYS	STOPS	
SIGNAL CONTROLS					
Install Where Warranted	HIGH	VARIABLE	GOOD	VARIABLE	GOOD
Time Revisions & Coordination	LOW	GOOD	GOOD	GOOD	GOOD
Peak/Off Peak Hour Signal Timing	LOW	GOOD	GOOD	GOOD	GOOD
DIRECTIONAL CONTROL					
One-Way Streets	LOW	GOOD	GOOD	GOOD	LOW
Turn Restrictions	LOW	FAIR	GOOD	GOOD	LOW
Lane Organization/Channelization	VARIABLE	FAIR	FAIR to GOOD	FAIR to GOOD	GOOD
PARKING REGULATION					
No Parking . Light Traffic	LOW	NONE	LOW	LOW	POOR to IMPOSSIBLE
. Heavy Traffic	LOW	FAIR	GOOD	GOOD	LOW
Truck Loading Restrictions	LOW	FAIR	FAIR	FAIR	POOR to IMPOSSIBLE

* This assumes a medium sized city that has not had a trained traffic engineer on its staff and/or the services of a qualified traffic engineering consultant.

Usually the most important potential improvement is in matching operation of the signal system to the street network and traffic demands. The second important area of potential improvement and easy implementation is the organization of traffic in the immediate vicinity of the intersections. Occasionally the channelization of intersections may prove expensive and hard to change once in place.

An improvement that often meets unfounded criticism and opposition but has great potential is a system of one-way streets. The business community often fears a loss of business. Such has not been the experience in a great many cities that have established one-way street systems.

The potential improvement through the application of traffic engineering varies from city to city. As the traffic engineering improvements become more sophisticated the potential for further improvement usually dimishes.

The two ingredients that appear necessary for the successful implementation of traffic engineering improvements are thorough engineering designs that clearly state the intention of the traffic regulation and enforcement of the traffic regulations. In the few scientific investigations of large scale traffic improvements the need for enforcing traffic regulations stands as being essential in increasing capacity of many street networks.

As stated in the introduction, there are a number of useful texts and handbooks pertaining to traffic flow improvement through use of traffic engineering. A brief bibliography is provided here for reference.

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CHAPTER IX

PAVED RAILROAD RIGHTS-OF-WAY

Operating Description and Summary of Findings

Abandoned or little used railroad rights-of-way may be paved over at moderate cost to provide an exclusive, narrow, roadway for buses. Grade crossings may revert to signalized intersections or continue to operate with railway crossing controls activated well in advance by the bus.

In many cases one lane is adequate to handle directional peak hour flows, although pull-offs for emergencies are advisable.

Major obstacle to extensive usage is the limited number of abandoned or abandonable rail rights-of-way which correspond to areas of high transportation demand. Without good correspondence the paved right-of-way routing may be slower and more congested than direct routes because of the necessity to detour to obtain access and egress.

I. INTRODUCTION

It has been proposed that abandoned or little-used railway rights-of-way be paved for use as an exclusive busway. Under most schemes, the bus would enjoy the same priority over automobiles at grade crossings as railway cars. Costs and investments are kept low through the use of many existing structures such as bridges, tunnels and overpasses as well as some portion of the signal system.

There are several reasons why paving a rail right-of-way would be more desirable than building a new highway facility:

- to avoid costly and time-consuming relocation problems
- to provide an inexpensive, high capacity mass transit facility
- to provide an exclusive facility for buses when none is practical on existing roadways
- to avoid time consuming delays from right-of-way acquisition and the usual engineering planning

Collection and distribution would probably be accomplished both on normal roadways and through the use of station stops along the right-of-way.

II. TECHNICAL EVALUATION

- User Price Impacts

Trip costs for the user would probably not be affected by this technique. Undoubtedly, in some cases, higher fares could and would be justified by the preferential nature of the service. These fares would probably bear the same relationship that express fares bear to regular service on most existing transit systems.

- Implementation Costs

Implementation costs involve removal of existing trackage, paving, provision of adequate drainage, signal and signing facilities, fencing, lighting, landscaping, and intersection improvements. Based on data from two cities, these costs are figured at about $200,000 and $174,000 per lane mile. These figures were gathered, respectively, from a 1968 projected application in Washington, D.C. and a 1971 study for Dayton, Ohio.[1] The difference in cost

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[1]Metropolitan Washington Council of Governments, Improving Express Bus Travel Times in Peak Hours Between Downtown Washington and Fringe Parking Sites. Volume I, "Use of Baltimore and Ohio Georgetown Branch for Public Transportation," October 1968, (Prepared by Simpson & Curtin, Inc., Philadelphia, under U.S.D.O.T. Contract No. FH-11-6870). Also, Dayton Urban Corridor Application, prepared by Vogt, Sage and Pflum Consultants, 1971.

is partly explained by the fact that the Washington, D.C. case was a single twelve foot lane while the paved portion proposed for Dayton would provide for two parallel lanes.

The cost associated with acquiring the right-of-way, usually sizeable, should be included in any analysis. Unlike the rail bus concept, where it may be possible to lease the right-of-way and split costs among its users, paving the right-of-way will normally exclude rail usage and cause termination of railroad ownership.[2] Only motor vehicles would use it with general access by automobiles normally denied. The cost to be borne per transit (or carpool) user would be higher because of the necessity to purchase the land. A range of impacts is tabulated below in Table 9-1 for varying degrees of ridership and land cost. It should be kept in mind that right-of-way costs will vary sharply from application to application.

(Note: It was felt that right-of-way cost should not be annualized under the same terms as for railroad operation, say one hundred year life. This is because the public will be called upon to make a political decision on the wisdom of this capital outlay. This public verdict will be based on whether or not such funds should have been spent on other projects. To reflect the short term loss of opportunity to the community, a more rapid recovery of these funds was felt to be in order. Therefore five year and twenty year life figures were felt to represent the range of lost opportunity costs to other members of the community which should be assigned users.)

- <u>Operating Costs</u>

Operational costs for the buses would not change by virtue of this system except for the marginal improvements due to higher operating speeds on a limited access roadway, thus avoiding costly stop-and-go driving. Costs of maintaining the new right-of-way would undoubtably be justly charged to the transit user. Additional costs also should be expected in connection with maintaining the signal and control system. Since there is no operational experience to date, the existing reports do not address the subject; further quantification of these costs will have to await additional investigation.

- <u>Other Costs</u>

Unlike the rail bus technique, trackage facilities would be lost under most plans. This may affect goods movement plans and costs in the community. It should be noted that most proposals have called for use of abandoned or lightly used tracks. Thus, this loss would be fairly insignificant.

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[2]One version of the Washington scheme called for paving the rail right-of-way much as was done on streets with street car tracks, thus enabling both rubber-tired vehicles and trains to use the right-of-way.

TABLE 9-1: Capital Cost per Mile per Passenger[a]

Amortized Over Five Years

Price Per Sq. Ft.[b]	Headways: 30 Mins.	15 Mins.	10 Mins.	5 Mins.	2 Mins.	1 Min.	30 Secs.	15 Secs.
$0.25	$.1135	$.0567	$.0378	$.0189	$.0075	$.0037	$.0018	$.0009
0.50	.2270	.1134	.0756	.0378	.0150	.0074	.0036	.0018
1.00	.4540	.2268	.1512	.0756	.030	.014	.0072	.0036
1.50	.6810	.3402	.2268	.1134	.045	.0222	.0108	.0054

Amortized Over Twenty Years

Price Per Sq. Ft.[b]	Headways: 30 Mins.	15 Mins.	10 Mins.	5 Mins	2 Mins.	1 Min.	30 Secs.	15 Secs.
$0.25	$.0416	$.0208	$.0138	$.0069	$.0027	$.0013	$.0006	$.0003
0.50	.0832	.0416	.0276	.0138	.0054	.0026	.0012	.0006
1.00	.1664	.0832	.0552	.0276	.0108	.0052	.0024	.0012
1.50	.2496	.1248	.0828	.0414	.0162	.0078	.0036	.0018

[a] Assumes buses have an average load of 53 passengers (some trips have standees) and 6% annual interest is charged. Usage figured over six peak hours, 260 days each year.

[b] Assumes 60 ft. wide right-of-way; costs would be halved if, say, a single lane configuration was developed within a 30 ft. right-of-way.

. <u>Indirect Economic Effects</u>

Some indirect economic benefits may accrue as the result of the value of time saved. In addition, if use of a paved right-of-way makes transit a successful and competitive travel mode, demand may be reduced for new automobile handling facilities such as parking lots and highways. The overall effect is not expected to be significant, however, due to the small number of such facilities which may be successfully converted to paved rail right-of-way uses.

. <u>Impact on the Disadvantaged</u>

Since many rail right-of-ways are convenient to industrial and commercial areas, this concept may present opportunities to provide improved services to employees associated with blue collar and commercial employment. On the other hand, since congestion is more often considered a serious problem on inbound trips in the AM and outbound trips in the PM actual service advantages might be best suited to white collar commuters. Again, improved service for the disadvantaged is likely to be dependent upon the actual application.

. <u>Environmental Impact</u>

Environmental impact would depend upon the number of automobiles removed from the highway. It is difficult to estimate this impact since it is critically related to the extent and character of each application.

. <u>Safety Impact</u>

Safety would probably improve over bus use of public streets due to the absence of competing traffic. Grade crossings may be a safety hazard.

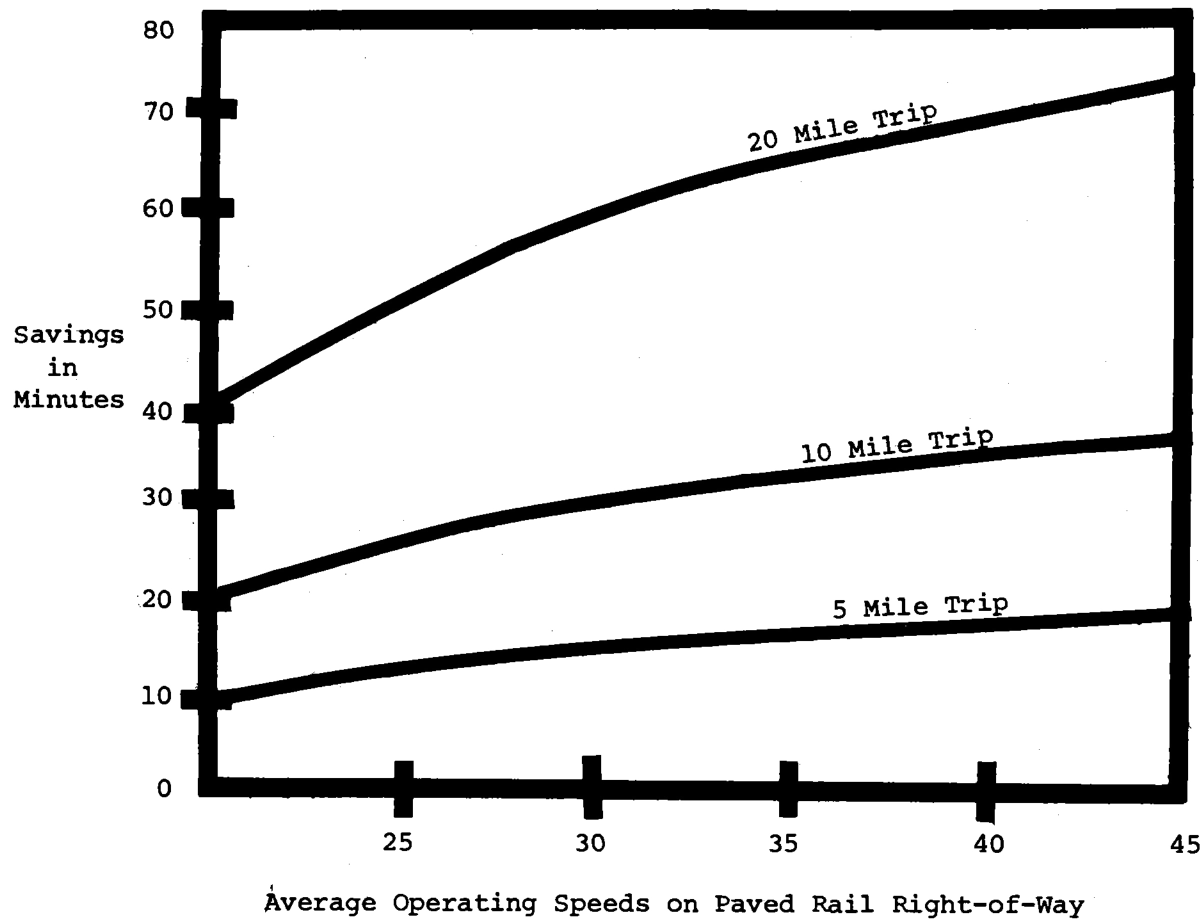
. <u>Speed or Time</u>

The actual speed or time advantage is a function of the average operating speed attainable less the time lost in access and egress to the facility as compared to the average operating speed obtainable in normal operation. As in the case of the rail bus, savings of less than ten minutes are probably not worth considering in view of the capital and right-of-way acquisition costs; thus the application seems limited to longer line haul trips. It is not clear from data available what average speed might be maintained. The Washington, D.C. study by Simpson and Curtin used figures of forty m.p.h. and sixty m.p.h. This may be too optimistic for most applications. Figure 9-1 illustrates the range of time savings attainable with variable distances and operating speeds. Some allowance should be provided for time lost as a result of going "out of the way" to gain access to the rail right-of-way.

. <u>Volume</u>

A major transportation advantage of busways on paved rail rights-of-way is the high corridor capacity. Table 9-2 illustrates this potential.

Figure 9-1: Hypothetical Time Savings Ranges for High Speed Busways (Arterial Average Speed 12 m.p.h. for Same Journey)



$$\text{Savings (minutes)} = 60 \left(\frac{D}{12} - \frac{D}{M} \right)$$

Where D = trip distance in miles
M = trip average speed in m.p.h.

TABLE 9-2: Potential Volumes

Headway Between Buses	Buses per Hour	Passengers Per Lane/Hour
5 secs.	720	38,160
8 secs.	500	25,000
10 secs.	360	19,080
30 secs.	120	6,360
1 min.	60	3,180
5 mins.	12	636

Note: Observation of bus lane operations indicate that buses on exclusive lanes travel at closer than five-second headways.

- State-of-the-Art

There are no new technologies involved with busways. Electronic grade crossing signal activators (to replace rail shunts) may need fabrication but this only requires minor adaptation of existing signal equipment.

- Institutional Background

Institutional constraints for paving a rail right-of-way and using conventional buses are considerably less than for utilization of the rail bus. Rail-related safety and traffic control regulations would not apply. It is also unlikely that there would be any union resistance to such a scheme. Some resistance might be expected from those railroads which desired to retain the rail facility.

- Traveler Response

Demand for vehicles on paved rail rights-of-way is likely to be dependent on the time savings the vehicle provides over driving or more traditional types of bus service. For short distances, use of the paved rail rights-of-way would probably not result in time savings since deviation from the most direct route is needed to reach the rail facility. However, for longer trips involving a long line haul using the rail facility, demand for the paved rail rights-of-way may be substantial. This is dependent on fares being comparable to express bus and auto costs. If a substantial time saving advantage similar to that experienced by users of exclusive busways such as the Shirley Highway can be shown for paved rail applications, then ridership demand would probably be very strong.

III. SUMMARY AND CRITIQUE

It is clear that substantial corridor capacity can be provided by appropriate application of either rail bus operation or by paving over rail rights-of-way for bus operation.

In most cases the capital investment will be greater for applications where right-of-way is purchased for paving over. A hypothetical continuum of applications illustrating places where rail bus or paved right-of-way would be more advantageous is provided in the rail bus discussion.

As in the case of the rail bus, transportation utility would have to be established for the prospective corridor. If the actual population and employment base served by the line is low, or if transit ridership potential is for any other reason low, it would not be appropriate to use the right-of-way for either approach. Widespread use of this technique has been retarded largely because of the inability to find rights-of-way which correspond to areas of high transportation demand.

From the standpoints of vehicle capital and operating costs, technical requirements, safety, and institutional constraints, it seems clearly advantageous to pave rail rights-of-way rather than use a rail bus approach.

CHAPTER X

HIGH CAPACITY TRANSIT BUSES

Operating Description and Summary of Findings

The high capacity transit bus, either an articulated or double-deck model, carries from 50% to 100% more seated passengers than conventional transit vehicles. The increased driver productivity can improve the economics of transit operations by cutting the extra costs associated with serving heavy peak hour demands.

Improved passenger comfort and increased schedule reliability are also likely to be realized from the use of such vehicles.

This technique shows some promise for increasing the efficiency and processing capacity of transit services but the extent is not known. It seems likely that the most effective use would be on routes where headways are short and crowding is severe. It is not known to what extent the high capacity bus could be substituted for other service, nor what union response would be. At present high capacity vehicles are all produced abroad. This concept appears to offer minor advantages with few if any serious drawbacks.

I. INTRODUCTION

The high capacity transit bus refers to a double-decker or articulated bus. The double-decker bus simply provides two levels of seats, one above the other. The articulated bus is essentially an elongated bus which bends in the middle to permit maneuverability in difficult turning situations.

The principle advantage of the high capacity vehicle is that it improves the productivity of the transit labor force. Secondary benefits include greater passenger comfort and increased schedule reliability. The net effect is a reduction in seat mile costs while at the same time permitting comfortable, high volume service to be provided on a more reliable basis.

Both the articulated, single-deck bus and the double-decker bus are in common use in many parts of the world. The articulated bus consists of two elements. The forward element contains most of the mechanical components and the driver. The rear or trailing unit is essentially a passenger compartment joined by an articulation mechanism or hinge to the front element. This hinge permits the vehicle to bend laterally from side to side and vertically, up and down. Typically passengers pass back and forth over the floor in the hinge area with little or no perception of bending. The maneuverability of the articulated bus is not hindered by the extra length and third axle. The engineering of the existing articulated buses actually produces an effective wheel base which is less than the wheel base of the GMC 5300 new-look bus. This is because the third wheel axle, through a simple mechanical device, tracks exactly behind the second or middle axle. On an articulated bus, the middle axle is actually at a shorter distance from the front axle than on the standard new-look bus. The result is the shorter effective wheel base.[1] However, it could be expected that the extra length of the articulated bus will require operators to adjust their habits in heavy traffic situations.

Articulated buses do not carry as many passengers as some double-decker buses. A useful rule of thumb is that an articulated bus would hold approximately fifty percent more seated riders than the GMC fifty-three passenger forty foot bus. For the analysis used in this discussion we will use a seventy-eight passenger capacity figure.

The double-decker bus involves two decks on essentially one chassis. The double-deck configuration permits higher potential capacities than in the case of the articulated bus. A German model, built by Neoplan, is fitted with ninety to one hundred-two seats. The British have recently redesigned their double-decker fleet to combine a short vehicle length (30 feet 10 inches) and sixty-eight seats.[2] This vehicle, which is used as the basis for further discussions in this study, is highly maneuverable in congested traffic. It is assumed that this is sufficiently comfortable to satisfy U.S. standards. Any comfort adjustments necessary would lead to slight modifications of some findings presented here.

Traditional objections to double-decker buses have resulted from the requirement for two-man operation. The second man was a conductor whose duties were to collect fares, since passengers could enter from more than one point and

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[1] Bond and Solomon, <u>The Promise and Problems of High Capacity Buses in the United States</u>, National Transportation Center, Pittsburgh, 1971, pp. 61-62.

[2] <u>Ibid.</u>, p. 52.

would not necessarily pass the driver, and to supervise passengers on the upper deck. With the advent of modern fare collection equipment and monitoring techniques (periscopes and TV cameras) it has been possible to remove the conductor from the double-decker vehicles.

The double-decker bus is handicapped by the fact that it requires approximately 13 feet 6 inches of vertical height for passage.[3] This would prohibit use of many important tunnels and some bridges on key transportation arteries. However, the problem seems far from insoluble as many old cities in Europe operate large fleets of double-deckers.

II. TECHNICAL EVALUATION

- User Price Impacts

User prices are not expected to change with the introduction of high capacity vehicles. Theoretically it would be possible under certain circumstances to reduce fares because of the increased productivity of the operating unit and the lower costs of passenger processing. In reality, due to the unprofitable nature of most bus services, any extra revenue would probably be devoted to some other use rather than resulting in a user charge reduction.

- Implementation Costs

According to Bond and Solomon, "A high capacity bus for American service might cost perhaps $75,000.00."[4] This figure represents about twice the cost of a new forty foot air-conditioned GMC 5300 bus. This vehicle is estimated to have a twelve year, 750,000 mile life. Thus the incremental capital cost per mile at eight percent interest would be about seven cents. Since capital grant funds are available from the Urban Mass Transportation Administration to purchase such vehicles, the actual local cost would probably be close to one-third of this charge.

- Operating Costs

No data are available to quantify the difference in operating charges including vehicle maintenance costs associated with high capacity vehicles. Informal conversations and "estimates" suggest that this figure does not run substantially more than for conventional vehicles. However, in any plan to introduce high capacity vehicles to the United States, there would undoubtedly be higher additional costs associated with the first operation of these vehicles. Since six cents a mile represents an average maintenance cost per mile charge on conventional vehicles, a useful estimate of maintenance charges would probably

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[3] Ibid., p. 55.

[4] Ibid., p. 67.

be about nine cents a mile.[5] This cost per mile combined with an incremental depreciation/capitalization charge of approximately seven cents a mile (see above) means that the vehicle portion of operating costs would increase approximately sixteen cents a mile for a fifty percent minimum increase in capacity. In the case of federal capital funding this additional cost per mile would be about fourteen cents per mile. Using a range of typical operating costs of $0.75 to $1.10 a mile, means that operating costs would increase incrementally between twenty-one percent and fourteen percent without federal capital assistance and eighteen and twelve percent with federal assistance.

The major economic advantage that would be associated with high capacity vehicles is the increased productivity of the vehicle itself. This would mean that the vehicle would generate more revenue for every dollar of operating costs. In actuality, the operator may not be able to utilize this excessive capacity at all times and, therefore, would only generate additional revenue at certain periods of the day.

A principal concern of transit operators is the so called peak to base operating ratio. This ratio describes the relative amounts of service required in the peak and off-peak periods. If the amount of service required in the peak periods is substantially greater than that required in the off-peak period, it introduces diseconomies into transit operation because of the necessity to schedule extra vehicles and extra drivers for only a few hours each day. The company is usually economically penalized in some ways when a driver does not work a straight eight hour shift and amortization of vehicles used as peak hour relief only is very costly. With the use of high capacity vehicles, increased capacity would be available during peak hours.

Bus operators from seven major metropolitan areas representing twenty-five percent of the nation's bus operations were sufficiently interested in the economic potential of the high capacity bus to put up $15,000 each for a total of $105,000 (to be matched by $210,000 in federal funds) for demonstration of a high capacity vehicle in service.

Careful analysis of each application situation would be needed before it could be said that the use of high capacity vehicles would result in a net positive income flow. It is also possible, but unlikely, that some of these economic benefits could be passed off to users in the form of fare reductions.

. Other Costs

High capacity buses may prove difficult to supervise if adequate techniques are not developed to deal with the increased space in each vehicle.

. Indirect Economic Effects

Indirect economic benefits associated with high capacity vehicles are somewhat difficult to assess. Where schedules are not trimmed to the point of exactly matching prior seat-miles of service, the capacity would improve passenger comfort and decrease crowding on buses. As a result there might be some decrease in the demand for private transportation facilities. Some traffic

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[5] Alan M. Voorhees & Associates, "A Short Range Program for Transit," Franklin County Regional Planning Commission, Columbus, Ohio, 1969, p. 41.

capacity would be made available by virtue of the smaller number of transit vehicles involved.

An important effect of using high capacity vehicles with indirect economic benefit is improved schedule reliability. A complex set of relationships described by Bond and Solomon and based on other empirical research indicates that the primary cause of schedule delay is excessive boarding time. If buses are maintaining close headways, less than four minutes, actual observation shows that there is not enough time between buses for wayward vehicles to correct for headway digressions. Consequently, buses bunch and serious headway deterioration occurs. When headways deteriorate, variance from schedule can become extreme and wait times will vary widely. Mode split empirically derived equations indicate that wait time is consistently two to three times more important than bus trip time to potential patrons able to choose between modes. Thus, eliminating variance in schedule adherence is considered to be an important component in attracting more riders to transit with the resulting indirect economic benefits. Super buses are ideal for dense routes, permitting substitution of one vehicle for two, and would increase headways such that adequate recovery time would be available from delays in loading.

. Impact on Disadvantaged

Since many low income residents are heavily dependent upon public transportation, increased seating capacity would mean greater comfort for lower income workers, assuming that low income routes are well served by the improved service.

. Environmental Impact

It would appear that super buses would reduce vehicle emissions because of higher capacity and less than proportional increases in horse power. This effect is expected to be minimal, however. If any automobile drivers are diverted to public transit there may be a decrease in total vehicle emission levels. There are no data to substantiate that these effects would be other than minor.

. Safety Impact

While there are no data to substantiate the safety record of high capacity vehicles, it is possible to speculate that the awkwardness of the large vehicles may increase accident rates in difficult traffic situations. Further investigation is needed.

. Speed or Time

The high capacity vehicle will operate under normal circumstances at the same speed as existing vehicles. However, it should be noted that smaller capacity vehicles in periods of intense demand often experience serious delay in loading and unloading because of congested passageways on these vehicles. High capacity vehicles generally have at least two standard entrances. In some cases there are three entrances or double entrance passages in the front. It has been noted that on some vehicles in European use the large entryway at the front of the bus acts as a holding area so that the bus can pull away from the curb before all passengers have paid their fare. It is not known to what extent this would improve travel time.

- Volume

The substitution of large buses for lower capacity vehicles provides a minimum increase in seating capacity of fifty percent. This can be used either to increase seating or decrease vehicles required. Of course, this increased volume is only useable, and therefore, of economic value when demand is such that conventional vehicles frequently have standees, turn away passengers, or operate at headways so close that a fifty percent less frequent service would not significantly lengthen the wait time. On some routings, present demand is not sufficient to even fill standard vehicles at acceptable service frequencies.

One interesting benefit in congested terminal areas would be, in the case of double-decker buses, that there would be less queuing on streets as fewer vehicles would need to be employed to board waiting passengers. Ancillary benefits would include less general traffic congestion, and less deviation from schedules occasioned by busses being "out of place" or having to wait for earlier arriving buses to dissipate.

- State-of-the-Art

High capacity vehicles of both the double-decker and articulated style are currently being manufactured in a variety of foreign countries. It does not seem that this technology requires substantial adaptation to meet American operating standards. Negotiations have been underway between bus manufacturers and other groups in this country with their European counterparts to obtain patents and rights to the necessary technology. However, it is expected that certain developmental costs must be incurred before production of these vehicles could begin in this country.

- Institutional Background

Principal institutional barriers are Federal, state and local regulations concerning size and weight of vehicles. Currently there is restrictive legislation for vehicles involved in interstate commerce. Local metropolitan areas may set their own standards and have done so in the past. For example, they have permitted the 102 inch wide bus to operate within metropolitan regions. Undoubtedly regulations will differ from community to community along with the capacity of the transit operator to alter these regulations.

Another institutional problem that needs to be analyzed is union wage requirements as a result of the operation of a higher capacity vehicle. It may be that unions will feel justified in asking for increased operator pay for increased productivity. If so, this would substantially offset the benefits associated with the higher productivity of the super bus.

- Traveler Response

The increased space and comfort of the large bus during crowded peak hour trips is likely to be appreciated. However, one would not expect a sudden increase in commuters using transit since comfort appears not to be a critical factor in choice of mode.

III. SUMMARY AND CRITIQUE

The major advantage of the high capacity vehicle is that it increases the productivity of the transit fleet and labor force. The potential advantage of improved productivity is to allow transit operators to realize increased revenue (and thus make transit service more economically viable) and/or to distribute the increased productivity in the form of community service improvements. For example, savings in peak periods may be so substantial as to offset money losing service in ghetto neighborhoods or outlying low density communities.

A further advantage that should not be understated is the reduction of crowding normally associated with peak period bus traveling and increased schedule reliability.

The full extent of both economic and non-economic benefits associated with the high capacity vehicle is not known. It appears that European experience has been reasonably favorable as double-deckers and articulateds continue to be produced. In fact, after abandoning the double-decker in the early 60's, London Transport recently revised their vehicle purchase program to once again emphasize production of double-decker vehicles.

Any further investigation should concentrate on these topics:

- Given the operating characteristics of a typical U.S. bus operation, would a high capacity vehicle's productivity be of sufficient value to offset higher capital and related costs? Included in such an analysis would be a definitive quantification of expected increased productivity.

- What would be the nature of union demands concerning driver operation of such vehicles?

- Are there sufficient differences between U.S. and European behavior patterns such that increased vandalism and rowdiness might be expected in the U.S. with one man operation and supervision of these vehicles?

Technical issues seem sufficiently resolvable so as to require little additional attention.

Production issues should be further investigated. A small production facility for such vehicles may not exist in this country and the existing bus manufacturers may not be easily persuaded to retool for the production of high capacity vehicles.

A cautionary note should be sounded about one potential abuse of the high capacity vehicle. If operators substitute high capacity vehicles freely for standard units on routes where headways are in excess of eight to ten minutes, the result can only be a further serious deterioration of transit service since headways would be as much as doubled. The resulting inconvenience from the decrease in frequency is well established as a factor in discouraging transit patronage. Thus, it should not be construed that high capacity vehicles should be substituted for existing fleets in toto. Rather, high capacity vehicles belong on heavily populated routes where patronage is high. (Such vehicles might be put to use as special charter or tourist sight-seeing vehicles in off-peak periods.)

Potentially, the high capacity vehicle is an attractive technique for more efficiently utilizing the nation's mass transportation systems.

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CHAPTER XI

ORGANIZED COMMUTER CAR AND BUS POOLS

Operating Description and Summary of Findings

Organizing commuters into bus and car pools as a substitute for individual modes would, theoretically, remove large numbers of automobiles from the highway and thus increase the carrying capacity of existing facilities.

Subscription bus service refers to a concept of organizing the bus riders of a neighborhood so that each has a guaranteed transit seat and each receives close to door-to-door service as a result of previous knowledge of demand by the bus operator.

"Pooling" has substantial theoretical and real benefits. At this time there is little evidence to indicate that these benefits can be achieved through voluntary efforts. A substantial organized effort is needed to coordinate "pools" and to provide effective incentives for their use.

I. INTRODUCTION

Most existing patterns of automobile travel and bus service in metropolitan areas can be said to be patterned around an unorganized but definite demand. Automobiles proceed from individual origins along personally acceptable travel corridors to particular destinations. At the same time, many other automobiles are proceeding from roughly the same origins along roughly the same travel corridors to roughly the same destinations. In the case of automobile travel, the vehicle occupancy rate is very low. This can be considered wasteful as excessive numbers of vehicles are on the highways in relationship to those needed to process the actual demand. Similarly, buses operate along fixed routes at fixed time intervals providing often the same trip function as the individual automobile. However, very often the schedule of bus service, the location of the service or route, and the needs of the individual traveler are not well matched. Decentralized residential patterns have led to the gradual degeneration and reduction in bus service, in turn, requiring commuters to depend more and more on the personal automobile.

Carpools, as usually conceived, involve an informal association of either friends or neighbors who ride together to work. In theory carpools would reduce highway space requirements and save the individual rider substantial amounts of money. For various reasons, however, individuals continue to drive to work alone rather than form carpools. Informal carpooling remains relatively ineffective since only a small percent of those who might benefit actually participate. And, of course, total numbers of carpools appear to be too insignificant to have actually improved utilization of existing facilities.

The organized carpool and/or buspool attempts to resolve most of the inefficiencies normally associated with carpooling while preserving the advantages. This is accomplished by organizing travel demand so that riders with similar origins, destinations, and time requirements are matched. In this way, the usual frustrations, delays, and diseconomies are avoided.

The concept of buspool should be separated from the concept of a carpool. A carpool, organized or unorganized, essentially involves using a small capacity vehicle, such as an automobile to carry its full complement of passengers to and from their destinations. The buspool involves leasing or chartering of a full-sized, regular transit vehicle to carry a larger number of patrons who share the same travel characteristics and trip needs. In both cases an attempt is made to organize the demand. Subscription bus service as described here is a version of the buspool. Under a plan of subscription bus service the rider reserves, usually on a long term basis, a place on the bus. The vehicle is routed so as to collect all of the daily reservations and then proceeds on a line haul basis to the destination served. Two notable experiments have been performed; the original work was carried out in Decatur and Peoria, Illinois. The second experiment was in Flint, Michigan. The first was a conditional success; the latter, a qualified failure.

- User Price Impacts

For the carpool user, costs would be as follows using the standard automobile charge of twelve cents (12¢) a mile.

No. In Pool	Cost Per Mile
2 members	6¢ mile
3 members	4¢ mile
4 members	3¢ mile
5 members	2.4¢ mile

The cost of parking would be extremely variable but several examples are shown in Table 11-1.

The individual commuter who participates in pooling will often realize substantial savings. Table 11-2 provides figures on a number of hypothetical carpool situations. Clearly, as the distance increases the savings to the individual commuter also increases. In general, we can say that the average carpool (composed of four members) saves the user about seventy-five percent of his normal automobile commuting expense. If the commuter still maintains a second car, he will save somewhat less due to the fact that he will still incur depreciation and maintenance charges on the second car. Parking costs, if added, would be reduced by the same proportions. Table 11-2 provides examples of savings which may amount to $1,000 or more each year, exclusive of parking costs.

A study of carpooling showed that for mode choice predictions, a twenty-eight minute penalty associated with the entire range of undesirable aspects of carpooling was reasonably accurate in predicting behavior. If an average man's commuting time is worth $1.80 an hour, this would mean the traveler would need to save at least eighty-four cents a trip before carpooling would become at least as attractive as driving alone.[1]

In some situations, the carpool may enjoy a preferential parking rate, absence of tolls over congested facilities, or other economic incentives. This would reduce the per capita charge even more.

Buspool fares are a function of charter rates or some similar fee representing all or a portion of the cost of reserving the vehicle. Occasionally the bus operator is in a position to make a profit with this fee. This can result in slightly higher user charges. The Reston Commuter Bus charges $1.20 per twenty-two mile, one-way trip (ten tickets for $12.00) - 5.6¢/mile, which is still a very reasonable charge.

A similar proposed arrangement whereby a bus from Fredericksburg, Virginia is commuter chartered into Washington, D.C. would cost the user about five cents a mile. Unfortunately, this service is not yet operating and the reality of that figure would be heavily influenced by actual average patronage. Con-

[1]Alan M. Voorhees & Associates, Inc., "Feasibility and Evaluation Study of Reserved Freeway Lanes for Buses and Carpools." Prepared for U.S. Department of Transportation. Washington, D.C., 1971.

TABLE 11-1: Parking Cost per Mile Under Various Automobile Occupancy Plans

No. Members In Pool	Roundtrip Distance Traveled (Miles)	Parking Charge Per Day	Cost per Mile per Member
3	10	$0.50	$.016
3	10	1.00	.033
3	10	2.50	.083
3	20	0.50	.008
3	20	1.00	.016
3	20	2.50	.042
5	10	0.50	.01
5	10	1.00	.02
5	10	2.50	.05
5	20	0.50	.005
5	20	1.00	.01
5	20	2.50	.025

Note: Volunteer labor for small group carpooling is not counted as a cost here since an individual probably does not consider this as an economic cost when making a decision between modes.

TABLE 11-2: Annual Cost Savings of Car Pool Riders

Formula: X Miles $\cdot \frac{12¢}{\text{Mile}} \cdot$ 260 Work Days = Cost

Occupancy Level	Round Trip Distance in Miles						
	5	10	15	20	30	40	60
Total Cost (i.e. No Savings, 1 Person per Car)	$156	$312	$468	$624	$936	$1,248	$1,872
2 Riders Save 50%	78	156	234	312	468	624	936
3 Riders Save 67%	104	208	312	416	624	836	1,248
4 Riders Save 75%	117	234	351	468	702	936	1,404
5 Riders Save 80%	125	250	374	499	749	998	1,498

(Figures shown are estimated annual savings to each user for each occupancy level shown. Actual commuting costs may be determined by subtracting the dollar savings for a particular level of occupancy from the total cost row.)

tinental Trailways offers parallel service which is costed out at about nine cents a mile. Undoubtedly, costs would change as a function of distances traveled and/or average operating speed increased or decreased.

Subscription bus service fares have been set on a basis similar to buspools. In Decatur and Peoria, cost per user averaged 2.5¢/mile. These cost figures are very low when compared to the Flint subscription service which costed out at about fifteen cents to twenty-five cents a mile.

- Implementation Costs

Establishing an organized carpool (as opposed to informal carpools) and operating it on a daily basis would require a certain amount of investment in facilities and probably capital equipment. Administration-related implementation costs would include central offices and probably a data processing facility to handle the large amounts of data that would be generated. Some plans for organized carpools have included purchase of the actual vehicles, and therefore it would be necessary to plan not only for this capital expenditure, but also for the maintenance and service facilities which would be associated with equipment ownership. It is difficult to estimate actual costs of these facilities because of the tremendous variations possible; however, one firm has made a proposal to the DOT asking for $310,000 to administer and operate such a service for one year. No capital costs were included in this estimate. A breakdown of these costs was not furnished.

Capital costs may or may not be relevant. In many instances, plans have called for purchase of ten to twelve passenger vehicles, the cost of which is passed on to the individual user. Table 11-3 gives a cost breakdown on these vehicles and equipment.

With twelve paying riders, costs per month, per rider for amortization of the capital cost over three years at eight percent interest would range between sixty-six cents and seventy cents a day, or based on a thirty mile round trip journey, between $0.021 and $0.023 a mile.[2] This cost is high due to the fact that salvage value is assumed to be zero at the end of three years.

- Operating Costs

Vehicle operating costs for automobiles are about twelve cents a mile, twelve to fifteen cents a mile for vans, and seventy-five to $1.10 a mile for bus operation. In the case of leased buses (and drivers), the nature of union rules, bus operator cost, accounting, and scheduling procedures make it unlikely that substantial economies can be achieved over existing operating costs. In fact, in outlying areas the withdrawal of the bus from close-in operations may make it difficult to schedule other transit service at either end of the commuter trip. As a result, the commuter group would have to pay for the unproductive time of driver and bus which is incidental to providing the chartered service.

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[2]Based on 260 days use each year.

TABLE 11-3: Cost of Vehicles for Organized Car Pool

12-Passenger Vans	Ford	Chev.[a]	Dodge
Base Price Including V8 Freight	$4,363.82	$4,104.25	$4,378.40
Automatic Transmission	242.50	242.25	242.90
Air Conditioning	692.55[b]	521.35	507.85
Radio	70.00	68.50	71.95
Power Brakes	49.70	Standard	45.95
Power Steering	134.20	140.10	134.45
West Coast Mirrors	30.20	30.30	30.70
Gauges	12.10	12.65	6.40 (oil)
High-Output Heater	17.40	N.A.	N.A.
W/Hd Suspension Package	87.20	Included	Included
Total	$5,700.02	$5,110.40	$5,418.60

[a] GMC Division manufactures the same vehicle for approximately the same price

[b] Air ducts throughout the vehicle

SOURCE: Minnesota Department of Highways--unpublished letter report

Administrative costs associated with organizing carpools are hard to pin down because of differences related to the extent of application, and the absence of large scale operating experiments. Bus operators report that administrative expenses account for from five percent (smaller properties) to fourteen percent of total operating costs.[3]

This range would seem to encompass possible administrative costs associated with all the various schemes discussed including subscription bus service. A superficial summary of costs is given in Table 11-4. These are operating costs, which in the case of carpool and van pool are about the same as user costs. For the buspool, the stated bus system average operating costs are much lower than user costs (fares) because fares are set to cover profit and the previously mentioned additional costs incidental to providing the chartered service.

- Other Costs

The primary non-economic costs associated with carpooling are loss of privacy and the individual convenience normally associated with one's personal automobile.

- Indirect Economic Effects

The indirect economic benefits which would be associated with buspooling and carpooling are primarily those resulting from savings in capital investment in parking garages and highway laneage. In theory, if average automobile occupancy increased, less capital intensive facilities would be needed.

With widespread implementation, it would be possible to bring dramatic reductions in volumes carried on existing highways. These resulting efficiencies may even be sufficient to absorb growth in demand for a substantial period of time (see Volume discussion). Even small-scale implementations may result in important efficiencies. For example, if 10% of peak period users of an overcrowded highway corridor were induced into carpools with average occupancy of 4 and were evenly dispersed during the peak period, a 7 1/2% reduction in vehicles would result. This may be sufficient to change operating conditions from unstable to stable, with a resulting increase in operating speeds. This in turn may alleviate pressures for more facilities needed to handle excessive demand.

- Impact on Disadvantaged

In theory, the organization of buspools and carpools would provide low income commuters with a better access system to remote job locations. While low income workers tend to live in the central business district where transit service is generally good, increasingly more job opportunities for low income workers are now located in the suburbs where transit is usually very poor. For captive riders this has meant curtailment of many job opportunities.

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[3]American Transit Association, "Transit Operating Reports - 1969, Part II - Motor Bus Operations." Bulletin No. 930, July 1970, Washington, D.C.

TABLE 11-4: Operating Cost Comparisons

	Car Pool (5 pass. max.)	Van Pool (12 pass. max.)	Commuter Bus (53 pass. max.)
Operating Cost	12¢ mile[(a)]	12¢-15¢ mile	75¢-$1.10 mile[(a)]
Organization & Administration	4¢[(b)]	4¢ mile[(b)]	In above
Total	16¢ mile[(b)]	16¢-19¢ mile	75¢-$1.10 mile
Total Per Passenger[(c)]	.032 mile	.013-.0158 mile	.014-.0207 mile

[(a)] Includes allowance for maintenance and depreciation

[(b)] A purely speculative figure for administrative expense--4¢ per mile X average 30-mile trip per day X 100 vehicles nets $31,200 per year

[(c)] Estimated net cost per passenger; in the case of some observed van pools, per capita cost is as indicated but frequently to compensate the driver all the other passengers pay slightly more so the driver travels gratis in return for his services

Provision of buspools and carpools would work to alleviate this situation. Data from the so-called "poverty transportation" projects report a high incidence of carpool association and use in preference to the bus service provided to suburban job locations. This has actually undermined public transit in these instances.[4]

- <u>Environmental Impact</u>

The environmental impact of buspooling and carpooling would be in direct proportion to the number of vehicles that are replaced by the buspool/carpool arrangement. Until more sophisticated analysis is undertaken, it would be difficult to estimate the net impact on the environment.

- <u>Safety Impact</u>

Monarch Inc., a New Jersey carpool organizing firm (now defunct), reported that insurance rates dropped reflecting the safety of volunteer driver carpools. Two elements seem to be at work here to improve safety:

- Familiar routes and traffic patterns which reduce unknowns.
- Greater sense of responsibility as a function of traveling with neighbors or co-workers.

- <u>Speed or Time</u>

Buspools and carpools are slower than individual automobile transportation. This time disadvantage is primarily due to the collection and distribution delays associated with each mode. For example, carpools must pick up all the members in the morning before they can proceed to the line haul portion of the trip. Similarly, they must wait in the evening until all members have reported to their vehicle. Buspools usually pick up passengers along a fixed route before proceeding to the line haul portion of the trip. This collection trip will lengthen in time and distance as rider dispersal increases. On the average, it is probably longer than a carpool's. The only slower conventional transportation mode is probably fixed route bus service.

- <u>Volume</u>

The additional volume available through buspooling and carpooling is significant. With the average volume of an individual car figured at 1.3 passengers per vehicle, an increase to five passengers would represent about a 380 percent increase in vehicle capacity. While this relationship cannot be directly translated into a 5-fold increase in capacity of existing highways, it does suggest that widespread implementation would provide dramatic improvements in the capacity of existing highways. Increased capacity associated with

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[4]John Crain, "The Reverse Commuter Experiment, A $7 Million Demonstration Project." Prepared for UMTA, December 1970.

buspools would be even greater. Of course, the actual decrease in congestion or the change in capacity that existing highway facilities might exhibit is a function of the degree of substitutability of car and bus pools for different transportation arrangements. More detailed study is necessary to provide both estimates for the maximum feasible number of such associations that can be formed, and practical expected number that might be formed. Of particular interest is the proportion of current bus riders who might be attracted to carpools as this would act against improved volume/vehicle.

- State-of-the-Art

This concept in any of its versions could be put into effect with few technical reservations. Appropriate computer software for organizing bus and car-pools is not known to be available, but sufficient analogous applications exist to assure that this particular requirement could be met.

- Institutional Background

The primary reasons why many additional carpools are not functioning are as follows:

- There is no federal program which could support either the demonstration or operation of such mixed mode experiments.
- Spontaneous organization is not efficient in organizing carpools.
- Statistically, people prefer traveling in their own vehicle whatever the reason (status, comfort, time savings, independence, etc.).
- Carpooling is convenient in direct proportion to the amount of carpools available. The more carpools available the higher the probability that a person can travel with people who live close to home (shorter collection inconvenience) and the higher the probability the destinations are close. Generally, there are not enough available to prevent imposition of definite convenience penalties on users.

A program of organized carpooling could probably only offer the user immediate cost savings. Being able to travel to work faster or even riding with people who both live and work close by (thus minimizing collection and distribution penalties) would remain a remote objective to be achieved when a great many more people are organized into pools.

- Traveler Response

Apparently, demand for these modes would have to be organized. This purpose is served by centralizing and computerizing the formation and possibly the operation of such pools. Data from the Monarch experience indicate that this service itself stimulates demand.

While costs would be reduced quite a bit by having each member of the pool drive only once a week, rather than every day, other incentives might also be needed to maximize carpooling: reserving parking spaces for carpools at little or no cost, and/or letting carpools use bus-exclusive lanes, etc. The above would probably increase demand for carpools. The San Francisco-Oakland Bay Bridge exclusive lane - toll free arrangement for carpools seems to bear this out, since carpool vehicles doubled in the first few weeks of operation.

III. SUMMARY AND CRITIQUE

Carpooling, buspooling and related service improvements have a tremendous potential value both to the individual utilizing the service and the total urban environment. The individual user benefits are realized under the most limited application; however, for a larger social benefit to occur requires carpooling and buspooling sufficient to remove a large number of automobiles from existing facilities. To date, no such effort is available for analysis. However, prima-facie evidence from years of experience in informal carpooling suggests that this cannot be accomplished on a volunteer basis.[5] Therefore, this study would conclude that an organized buspool or carpool program for an entire metropolitan area or perhaps for a small congested sector of an urban area is necessary before this technique might prove a viable alternative to constructing new facilities. Further investigation is needed before final conclusions are rendered. Several of the more important of these issues are listed below.

- Data are needed on the wait time associated with collection and distribution under group riding schemes which can be tolerated by individual members who are used to door-to-door service.

- Some estimate should be made of the administrative structure and facilities necessary to sustain wide scale urban area carpooling and buspooling programs.

- The exact proportion of the population that would have to participate in buspooling and carpooling before substantial system-wide efficiencies are introduced should be better pinpointed.

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[5]This appears to be equally true for buspools. Contrasted with the success of the Reston service have been the difficulties associated with serving Hagerstown, Maryland and Fredericksburg, Virginia, the reluctance to expand service from Columbia, etc. All these reflect personal, political, institutional and other concerns that are not easily resolved by small groups working informally.

- A review and investigation of transit operator planning and accounting practices is needed to improve our understanding of how arrangements such as buspools can become economically viable components in overall bus operations and, perhaps, reduce costs to buspool users.[6]

- Some data should be collected on the trade-off relationship between the convenience, privacy, and other amenities normally associated with private transportation and the savings and other advantages attributable to carpooling. An important factor in the success of future buspooling apparently, is the degree of sociability achieved within the group of riders. This would suggest that privacy amenities can be traded for social amenities possible only through a multi-passenger vehicle environment.

- The role of information services needs to be better defined. Presumably, if commuters had more access to carpool information, it would be easier to form pools, change pools, etc. The extent of value associated with such information services needs to be better defined.

- Some investigation should be made concerning the flexibility of schedules. Many workers are unable to leave at normal quitting time. Conceivably if the demand was great enough, regrouping of overtimers might be accomplished through a central information service.

- Estimates need to be made on whether bus riders will be diverted to carpooling in greater numbers than auto passengers. If so, the net effect could be substantial increases in vehicle-caused congestion.

To make carpooling an attractive alternative to auto driving may require certain negative incentives to automobile drivers. For example, provision of reserved lanes for carpools may increase time savings to the passengers. Provision of parking space on a preferential basis would probably also divert commuters from their own individual automobile. The Oakland Bay Bridge experiment, which has just gotten underway, reports an estimated 100 percent jump in carpools as a result of provision of special uncongested access lanes to the bridge as well as no tolls.

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[6] A formula for estimating potential ridership on subscription bus service was an important part of the research project carried out in Peoria and Decatur, Illinois. According to the authors of this work, application of this formula to routes suggested in Flint, Michigan would have identified the most unprofitable and unsuccessful of these. Application of such formulas or at least understanding of those factors represented by the formulas are essential if serious failures are to be avoided.

Buspooling and carpooling is a promising enough concept that attempts should be made to implement an experiment with potential to affect congested urban areas. A major program using municipal computers is just getting underway in Honolulu and may provide valuable data at a later date.

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CHAPTER XII

FREEWAY METERING, MONITORING, AND CONTROL SYSTEMS

Operating Description and Summary of Findings

In order to avoid unstable freeway traffic flows with attendant delay and congestion, methods have been proposed for regulating the volume of vehicles attempting to utilize a freeway. Metering techniques are designed to regulate the number of vehicles entering the freeway through an electronic assessment of the available capacity. Monitoring and control techniques are designed to warn controllers of accidents or other conditions which may warrant restrictions on vehicle admittance and may also facilitate the quick removal of the impedance.

A successful metering, monitoring and control system requires a nearby parallel route to absorb unwanted traffic. Few freeways operate under these conditions. Metering does not increase theoretical capacity or speed; rather it permits highways to operate at design levels by preventing overloading. As a result only minor impact on growth in demand for new facilities can be expected.

I. INTRODUCTION

The nation's freeway system is intended to process a substantial amount of transportation demand at high speeds by virtue of design and operating characteristics. However, when demand exceeds capacity, which often occurs in urban areas during the peak periods, the effect is severe congestion. This congestion, in turn, reduces the actual carrying capacity of the freeway. The theoretical maximum capacity of a freeway operating under ideal uninterrupted flow conditions is usually figured at about 2,000 cars per hour per lane of freeway.[1] In order to realize this capacity, average operating speed must not exceed or drop below the 30-35 m.p.h. figure.

When demand exceeds capacity (defined in a number of ways, but essentially meaning that more cars are attempting to enter or are already on the freeway than can operate on the freeway at the optimum 30-35 m.p.h. speed level) then operating speeds decline with a corresponding decrease in the vehicles carried per hour. If speeds decline to 20 m.p.h. approximately 1,700 vehicles per lane per hour are carried; and at 10 m.p.h. the figure is approximately 1,000 vehicles per hour per lane. The two principle cases of demand exceeding capacity are: (1) when a lane is suddenly blocked, reducing capacity, with excess demand in effect piling up behind and (2) when vehicles in excess of capacity are trying to gain access through one of the inlet facilities. Freeway monitoring, control, and metering techniques are designed to permit control over the demand and insure that it does not exceed immediate capacity with the resulting degeneration of the entire highway flow. Three techniques which have been advanced to regulate freeway traffic are:

(1) Flow Monitoring - This technique involves regulating, by means of overhead dynamic signing, the rate of flow (speed) of the vehicles actually utilizing the highway. Most observers have found this technique to be ineffective and it is not further considered.

(2) Blockage of Ramps - It has been reasoned that blocking a ramp or two or more might divert cars that would normally use freeways to other routes. The difficulty with this technique is that it provides extremely crude controls and no guarantee that capacity will be effectively regulated. However, in certain obvious cases it may be a valuable technique, particularly where the individual ramp involved has deficiencies in design that in and of themselves adversely affect freeway operation. This technique is not considered here however.

(3) Ramp Metering - In full scale applications of this technique, the actual ramp is controlled so as to only allow vehicles to enter the stream of traffic when a space exists to accommodate them. Under optimal conditions the space available in the freeway is coordinated with

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[1]Highway Capacity Manual, 1965. Highway Research Board Special Report 87, p. 62.

the car desiring access to the freeway so that both arrive at the point where the ramp meets the freeway at the same time. The obvious advantage of this technique is that it keeps freeway lanes filled without exceeding capacity. Also, if an unexpected stoppage or delay occurs, regulation of the ramp permits vehicles to be shut out so that whatever lanes are available are not over-subscribed.

"Basically the components in the freeway control system consist of one traffic signal per entrance ramp, one merge detector, one ramp speed detector on the outside lane of the freeway, and a regulating controller. These are the minimum requirements for controlling a single entrance ramp. For controlling the entire freeway, one checking detector, one vehicle classification detector, and one queue detector can be added per entrance ramp; one detector per ramp; one detector per freeway lane between entrance ramps; and preferably a real-time central computer controller."[2]

Ideally, new freeways should be designed for control with detection and transmission systems built in. In this way, surveillance using these centers would begin the day the freeway is open to traffic and freeway control would be implemented as needed - - certainly before the demand builds up to the point where it has exceeded the capacity.[3]

A simplified version of ramp metering has been applied using pre-timed ramp signals designed solely to space out entering vehicles as they approach the point of merging with through traffic.

Sophisticated monitoring techniques usually use TV cameras to detect any breakdowns. The primary value of a TV monitoring system is that it speeds emergency vehicles to the scene.

It has been proposed that metering schemes provide priority access for buses in an attempt to expedite the movement of people rather than vehicles. These schemes require that the bus be able to bypass the queue of automobiles at any given ramp. This usually necessitates a separate ramp approach for buses or a means of getting to the "head of the line" bypassing the auto queue.

Buses generate different demands on the traffic stream than do automobiles:

- they require large gaps to fit into traffic.
- They require different signal timing due to the different acceleration and deceleration characteristics of buses.

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[2]Donald R. Drew, Kenneth A. Brewer, Joe J. Buhr, and Robert H. Whitson, "Multi-Level Approach to the Design of a Freeway Control System." Texas Transportation Institute. Highway Research Record No. 279, Freeway Traffic Characteristics and Control, Nineteen Reports, Washington, D.C., 1969.

[3]Ibid.

No bus preference metering scheme is now in operation, although Minneapolis is currently planning to implement one in their urban corridor program. Their plans are too general at this point to analyze its feasibility.

It should be clearly emphasized that the primary value of freeway metering and similar control techniques is to permit the capital facility to operate at its optimal level. Except where breakdown of freeway operation would otherwise occur, it does not provide additional capacity without sacrificing speed. Likewise, it does not allow greater average speeds over those which are maximally efficient. (If speed is deliberately reduced and controlled, in theory, additional capacity could be accommodated; conversely, if higher speeds are desired, volume constraints would have to be revised downward.)

II. TECHNICAL EVALUATION

- <u>User Price Impacts</u>

Overall user costs should not be adversely affected by this improvement. Any additional costs that are assumed by the user would occur in the additional time necessary to reach his destination should he be prohibited from using the freeway by delays at ramps or other barriers. The user that is permitted to enter the freeway would achieve some time benefits.

- <u>Implementation Costs</u>

Estimates have been prepared for installing metering equipment by the Texas Transportation Institute.[4] They are, on a unit basis, as follows:

1.	Counting Detector	$ 600.00
2.	Ramp Metering Signal and Advance Flasher	2,000.00
3.	TV Camera and Monitor	12,000.00
4.	Central Control Equipment & Furniture	30,000.00
5.	Bus Two-Way Radio System	
	. Base Station	5,000.00
	. Bus Radio	1,000.00

These figures were based on recent experience in Detroit and Houston. The cost of these major hardware components includes the cost of all the necessary support hardware and the cost of installation for that component.[5]

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[4]John C. Glennon, et al., "A System to Facilitate Bus Rapid Transit on Urban Freeways." Texas Transportation Institute, December 1968. Clearinghouse for Federal Scientific and Technical Information, (PD 183 390), p. 45.

[5]<u>Ibid.</u>

An estimate of costs associated with each ramp, in toto, is shown in the following tabulation also prepared by the Texas Transportation Institute.[6]

SUBSYSTEM UNIT COSTS FOR SURVEILLANCE AND CONTROL

Subsystem Unit	Components	Cost
Auto Entrance Ramp	signal installation, gap detector, merge detector, input detector, demand detector, queue detector	$5,000.00
Bus Entrance Ramp	signal installation, gap detector, input detector, demand detector	3,800.00
Combination Entrance Ramp	2 signal installations, gap detector, merge detector, 2 input detectors, 2 demand detectors, queue detector	8,200.00
Exit Ramp	output detector	600.00
Main-line Detection Stations		
a. 2 lane	2 main-line detectors	600.00
b. 3 lane	3 main-line detectors	1,200.00
c. 4 lane	4 main-line detectors	1,800.00

- Operating Costs

Operating, maintenance, and associated lease costs are shown in the Texas Transportation Institute figures reproduced below.[7]

ANNUAL LEASE COSTS

1.	Office Rental	$ 6,000.00
2.	Computer (IBM 1800 or CDC 1700 with 32K core)	54,000.00

ANNUAL MAINTENANCE COSTS

1.	Counting Detector	50.00
2.	Ramp Metering Signal	150.00
3.	TV Camera and Monitor	500.00
4.	Central Control Equipment	500.00

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[6] Ibid., Table 4.2

[7] Ibid. Unfortunately the base system for these operating cost estimates is not known. We would expect that as the scale of operations of the metered freeway service increases or decreases, unit operating costs would change slightly.

5. Bus Two-Way Radio System
   a. Base Station 100.00
   b. Bus Radio 100.00

ANNUAL TRANSMISSION COSTS

1. Control Functions - based on $50 per year per function	
a. Counting Detector - requires 1 function	50.00
b. Ramp Metering Signal - requires 4 functions	200.00
c. TV Camera Control - requires 10 functions	500.00
2. Video Transmission - closed circuit	Variable

ANNUAL PERSONNEL COSTS (SYSTEM OPERATION ONLY)

1. Managing Engineer	18,000.00
2. Operating Engineer	12,000.00
3. Two Operating Technicians (14 hours/day, 250 days/year, $3.00/hour)	10,500.00
4. Electrical Engineer	15,000.00
5. Two Maintenance Technicians (Electrical)	18,000.00
6. Two Draftsmen-Technicians	12,000.00
7. Secretary	6,000.00

. Other Costs

While studies to date indicate that traffic as a whole will flow faster and more efficiently with use of metering and control systems, individual autos may suffer heavy time penalties. Lack of adequate alternate routes would also penalize these drivers whose access to the freeway is delayed. If traffic increases on the various routes through the corridor, including the freeway, one expects penalties to deferred drivers will be greater.

. Indirect Economic Effects

The primary economic savings attributed to this technique is the value of user time saved. The validity of these attributed savings depends on whether those who are not permitted access to the freeway have an alternative which is at least as fast as a congested, unmetered freeway. However, it should be remembered that frequently people are attempting to use freeways for trips that could be served with equal swiftness through the use of non-freeway facilities. Under these conditions, diversion of this demand from the freeway will effect a net travel time reduction for all parties attempting trips.

It has been stated by authorities in this field that metering will not reduce the demand for new highways.[8] At best, by permitting maximum volume to be processed, there may be a definite feasible increase in capacity for the particular facility which in turn may permit the highway to handle what appeared to be over-crowding but what in reality was inefficient use of existing capacity. As total demand increases, the necessary capacity can only be achieved through new facilities. Metering will not reduce the amount of highway facility required to fully service a given traffic demand.

- Impact on Disadvantaged

Slight, if any.

- Environmental Impact

The reduction in stop and start traffic movement and in overall vehicle operating time will result in a reduction in the total quantity of emissions. To date, quantification of this benefit has not been obtained.

- Safety Impact

One of the most important non-economic benefits is that the accident rate declines. "Traffic accident data compiled by the Chicago Area Transportation Study indicates a 14.4 percent reduction (444 to 380) in outbound expressway (and ramp) peak-period accidents in the eighteen months following commencement of the entrance ramp control system. All other Eisenhower Expressway accidents for the same length of roadway (including inbound peak period accidents) increased 2.9 percent (2240 to 2306) during the same eighteen month period. Assuming that outbound peak period accidents might have increased at this same rate without the ramp control system, the net prorated accident reduction amounts to 16.8 percent (457 to 380).

"It is most probable that the reduced outbound peak period traffic congestion accomplished through the ramp control system is responsible for the decreasing accidents reports...Moreover, the favorable decrease in congestion and accidents suggests that other expressway operational benefits, such as the reduction of disabled vehicles and reduced air pollution, are also produced by effective ramp controls."[9]

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[8] Leonard Newman, Alex Dunnet, and Gerald J. Meis, "Freeway Ramp Control -- What It Can and Cannot Do." Traffic Engineering, June 1969, pp. 14-21.

[9] Joseph M. McDermott, "Operational Effects of Automatic Ramp Control on Network Traffic." Highway Research Record Number 157, Freeway Traffic Characteristics and Control.

- Speed or Time

The principle advantage of metering is that it prevents freeway conditions from degrading when demand exceeds capacity. Under ideal circumstances an under-utilized street system paralleling the freeway can be used as an alternative to the freeway. It is assumed that cars not permitted to enter the freeway can travel on these alternative routes with little or no time penalty. (In this sense, metering provides a better way to utilize existing facilities by providing an information service).

In the study of a six mile section of metered freeway in Houston, Texas it was found that total travel, as measured in vehicle miles, increased eleven percent. Total travel time, as measured in vehicle hours, decreased 48 percent. One can conclude from this that more cars are passing through at faster speeds.[10] The average speed in miles per hour increased from 14 m.p.h. to 30 m.p.h., an increase of 114%. This study also performed an analysis of the effects upon adjacent arterials. Their conclusion was "no large increase in travel times were recorded at any time during the study on the city streets, indicating that the increased travel did not effect traffic operations."[11]

- Volume

Metering does not provide for increases in capacity to handle vehicular volume; it merely permits the highway system to operate at this volume. This figure is estimated at 2,000 cars per lane per hour.

- State-of-the-Art

It appears that nearly everything required in software and hardware is presently available. The primary area where further development might be necessary is in development of more sophisticated algorithms to handle the differing gap requirements for buses in bus preference systems utilizing gap acceptance theory techniques. Refinement of integration and monitoring techniques would appear to offer promise to increase the efficiency of freeway metering systems.

- Institutional Background

While the advantages of metering and control systems are obvious and the costs are not particularly onerous, these improvements may have limited appeal to planners. Two reasons are advanced for this:

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[10] Charles Pinnell, Donald R. Drew, William R. McCasland, and Joseph A. Wattleworth, "Evaluation of Entrance Ramp Control on a Six-Mile Freeway Section." Highway Research Record Number 157, Freeway Traffic Characteristics and Control, pp. 22-71.

[11] Ibid.

(1) The nature of the system requires justification of denial of travel opportunity, although to date this has not been a real problem as evidenced by the low rate of citizen complaints.

(2) The highway agencies have to operate a system as opposed to simply setting the system up and letting it run itself.

These problems are not judged to be severe.

- Traveler Response

Implementation of metering and control systems is not expected to change overall demand characteristics, although some increase in use of arterials as a result of avoiding ramp queues should be noticeable.

III. SUMMARY AND CRITIQUE

Metering and control systems are primarily designed to permit existing facilities to operate at levels for which they were designed. To the extent that there are substantial numbers of freeways which are crowded during peak hours and the capacity of these freeways is, therefore, restricted and there are demands for more capital facilities as a result of inefficient, unregulated utilization, then metering represents a useful way of more efficiently utilizing existing resources and investment. No data are available to predict how many highways could expand feasible capacity through controls. In any event, the increased efficiency can be categorized as marginal. It seems likely that overall growth in demand for new facilities would only be checked momentarily.

For metering to be fully effective, however, under-utilized capacity must exist on the adjacent arterial street network. Otherwise, cars discouraged from entering the metered freeway may be subject to time penalties at least as severe as if they entered an unregulated highway.

Bus preference systems may be useful adaptations of metering technology. To date, absence of substantial real experience in bus metering preference schemes has hindered evaluation of this concept.

Further data need to be gathered in order to determine the number of urban environments where metering could be effectively applied and in order to quantify the actual value of application.

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CHAPTER XIII

FREE OR HEAVILY SUBSIDIZED TRANSIT

Operating Description and Summary of Findings

Proponents of "free" or heavily subsidized transit contend that lowering the price will divert commuters from inefficient auto modes to more desirable transit modes. As a result congestion on existing facilities will be allieviated and demand for new facilities abated.

Unfortunately there is little reliable data at this point to substantiate these claims. What little theoretical and empirical data available suggests that mode choice is only moderately sensitive to the single factor of price. It is observed, however, that more transit trips are made when the price goes down, perhaps reflecting the increased attractiveness of transit for short trips or marginally necessary travel.

I. INTRODUCTION

Free or heavily subsidized transit has received considerable attention in recent years as a technique for relieving urban transportation crises. Proponents contend that one of the best known and perhaps most fundamental devices for influencing individual decisions is the price mechanism. The argument is made that if the price of public transportation were reduced, substantially more people would opt for public transit as their mode of travel. Opponents of subsidized transit, on the other hand, contend that people do not make transportation decisions on the basis of cost of service. Instead tangible service characteristics such as trip time, availability of service to destination, etc., along with such intangible factors as privacy and comfort are held more important in determining transportation behavior.

The central and critical issue is whether or not, and to what extent, people will switch from congestion-producing auto trips to transit when transit fares are lowered. Opponents point out that while there will be increases in ridership on transit systems, these may be attributed to increases in the number of trips made by persons already using transit as their principle travel mode. In other words, it is contended that people would ride short distances or make unnecessary trips more than they would divert from auto usage. Unfortunately, little data is available to definitely support either position.

Some relevant empirical data on this subject is derived from studies on fare increases and their impact on transit ridership. The most well known are the observations of Simpson & Curtin that each one percent rise in fares will result in approximately a one-third of one percent decrease in ridership - an elasticity of -.33 (see Figure 13-1).

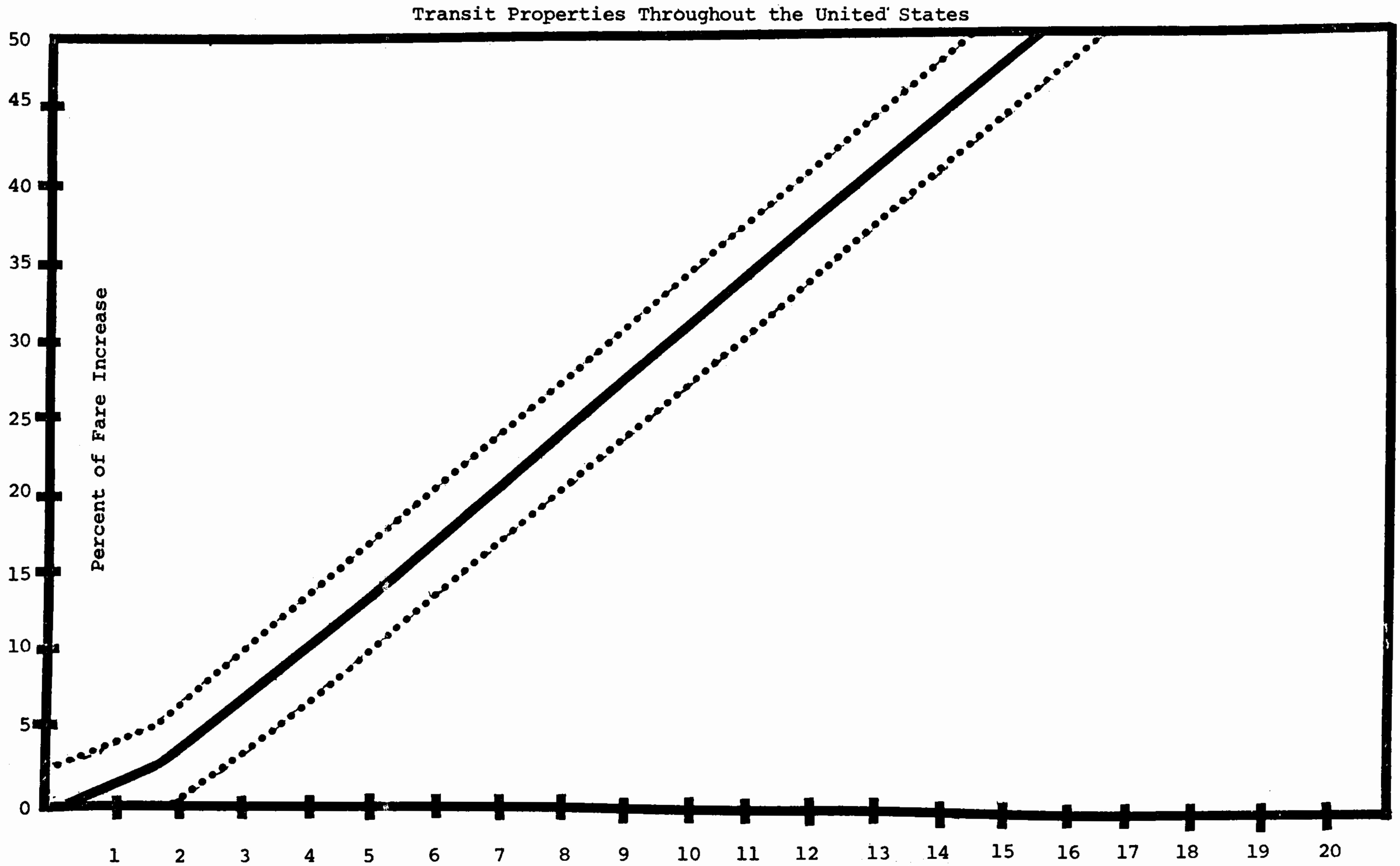
It is not known whether the same elasticity would apply to the impact of lowering fares.

Another important source of empirical data is Atlanta, where the fare was reduced from 40¢ to 15¢ on March 1, 1972. Very preliminary data indicates something of the nature of ridership changes.[1]

Time Period	Percent Increase	Charles River Study predicted increase as result of direct elasticity (see text)
Week Day		
AM Rush	12.5%	+10.6%
Midday	31%	+20%
PM Rush	12.5%	+10.6%
Saturday	29%	
Sunday	31%	

[1]Metropolitan Atlanta Rapid Transit Authority, "Atlanta's Reduced Transit Fare Experience, March 1 - June 30, 1972." Prepared for Presentation at the UMTA UTPS USER SYMPOSIUM, July 27-28, 1972. (unpublished)

Figure 13-1: Shrinkage in Passenger Traffic Due to Fare Increase



Source: Coordinated Transit for the San Francisco Bay Area--Now to 1975, prepared by Simpson & Curtin, San Francisco, October 1967, p. 152.

This data indicates that those periods where service was least utilized showed the highest percentage gain. It could be imputed from this that increased use of the service by transit captives is a definite factor, although there are other possible explanations as well. Complicating findings is the fact that additional service has been added in Atlanta since the March 1, 1972 fare decrease.

There is evidence that Atlanta ridership is continuing to rise over time, as indicated in the following tabulation:

Month	Percent Increase
March	13.98%
April	18.63%
May	15.74%
June	20.8%

Additional time and study is needed before a complete appreciation of the significance of these changes is possible.

A major but theoretical source of information on this topic is the 1969 study by the Charles River Associates on the effects of free transit. Their study developed a model for predicting the impact of free transit based on existing travel characteristics data from the Boston Area.

Their model indicated that transit demand is very inelastic with respect to changes in fares. "For shopping trips the fare elasticity is about -.32 while for work trips it is about -.17"[2]

More important than direct elasticities were the findings concerning the cross elasticities between auto and transit travel. "...most of the cross elasticities are very low or negligible."[3] If true, this would indicate that congestion would not be affected by lowering the price of transit. Table 13-1provides more detail on the Charles River Data.

These figures on elasticity, if directly applicable to the 62 1/2% reduction in Atlanta fares, would indicate that off-peak ridership should increase 20% while peak ridership should increase 10.6%. As can be seen, these data would underestimate the Atlanta ridership changes slightly in respect to the peak period and by a larger amount in the off-peak.

Some of the increases in Atlanta ridership may be traceable in part to cross elasticities but the extent is not known. Until a thorough study of ridership is made, it is impossible to further clarify the nature of the Atlanta ridership increases.

Discussed below are some of the specific instances of free or subsidized transit which, while poorly documented, provide some additional insight into actual behavior.

Commerce, California, for example, has had a completely free bus service for many years. Unfortunately, no evidence has been presented on the extent to which Commerce is or is not free of auto congestion or on what proportion of work trips are made by bus as compared to normal.

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[2] Charles River Associates, Inc., An Evaluation of Free Transit Service. Cambridge, Massachusetts, August 1968, p. 8.

[3] Charles River Associates, Inc., Loc. Cit.

TABLE 13-1: Elasticities of Passenger Travel Demand with Respect to the Components of Travel Cost

Auto Trips

Trip Purpose	Direct Elasticities: Auto Line-Haul	Direct Elasticities: Auto Out-of-Pocket	Cross Elasticities[a]: Transit Line-Haul	Cross Elasticities[a]: Transit Access	R^2
Work	-.494	-.071	.138	0	.41
Shopping	-.878	-1.65	0	0	.55

Transit Trips

Trip Purpose	Direct Elasticities: Transit Line-Haul	Direct Elasticities: Transit Access	Cross Elasticities[a]: Auto Line-Haul	Cross Elasticities[a]: Auto Out-of-Pocket	R^2
Work	-.09	-.100	0	0	.35
Shopping	-.323[b]		0	0	.63

[a] The zero cross-elasticities shown in the table occurred because constrained regression analysis was used in estimating the parameters of the model and the constraints were binding for the variables for which zero cross-elasticities are shown. They were not estimated to be zero.

[b] The available shopping transit trip sample was unsuitable for estimating elasticities for the disaggregated cost components.

SOURCE: Reproduced from: An Evaluation of Free Transit, Charles River Associates, Inc., Cambridge, Massachusetts, 1968, p.48.

The Florida Department of Transportation initiated in October of 1970 a one-year demonstration project in Clearwater, Florida to provide minibus service in outlying areas not served by the regular transit system.[4] The project had artifically low ten cent fares at the beginning which were later raised to twenty-five cents. This experiment was reasonably well documented with before-and-after ridership surveys as well as dwelling unit surveys. Certain findings were particularly interesting:

- Very few trips were work trips (about ten percent) with a very high percentage of trips for social-recreational and shopping purposes (about seventy-five percent). These are the kinds of trips which are more optional, and hence more likely to be susceptible to price.

- The largest single group of trips (thirty-five percent) were made by people who had not previously made the same trips, with the second largest group (thirty-three percent) involved persons who previously used an auto to make the same trip. No other previous mode was reported of any significance.

- An analysis of the forty percent decrease in ridership after the fare increase from ten cents to twenty-five cents shows that about half of this decrease was due to people who stopped riding the bus altogether and half due to a reduction in number of trips by riders. (It was not known what happened to those who stopped riding altogether.)

- There was little indication of cross elasticity between transit and auto usage. Indeed a follow up survey showed that after the fare increase had been put into effect there was an increase in the absolute number of users who reported that their previous mode was auto, while other categories of previous modes showed declines. (In some cases it is alleged that prior auto mode meant they paid someone to drive them to their destinations.)

The results of this study generally support the contention that there is a group of citizens who want and will use transit, in some cases in preference to auto. Price apparently does determine whether people make as many trips as they want. Since so few of these trips were work trips, these data are really only marginally applicable to peak period travel behavior - - the period when congestion is usually a problem.

Rome, Italy experimented with free transit over the Christmas holidays. The UPI (Washington Post, January 13, 1972) reported a forty-eight percent increase in ridership and "Current Transit Trends" (January 1972) reports a seventy-three percent increase in riders. The latter article commented that most of the increase was in children or those who would normally have

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[4] Alan M. Voorhees & Associates, Inc., Clearwater Demonstration Bus Project - First Interim Report, June 1971.

walked a short distance. The study of the Rome experiment appears to be too casual to draw any but general conclusions from these reports.

Thus in conclusion, data, such as there are, do not offer any clear support to the general thesis that given lower transit fares a great many more people will use transit and abandon their auto. These conclusions should not be regarded as final until more data and experience are available for analysis.

The balance of this paper examines subsidized or free transit according to standard criteria of this study.

II. TECHNICAL EVALUATION

- User Price Impacts

The obvious advantage to the user is lower travel costs. Figure 13-2 sketches out a continuum of savings which are possible under various assumptions concerning travel arrangements for daily work trips.

In the case of free transit, for example, assuming a twenty-five mile round trip daily, the commuter could save about $800 yearly over private automobile operation. In the case of subsidized transit service (ten cent fare) the savings would still be substantial at about $750 yearly. Naturally, the level of savings is greater the longer the commuting distances involved. The ability to use transit for other non-work trips would add to these savings.[5]

- Implementation Costs

Minimal, if any. The primary initial implementation effort needed would be to advertise the new fare structure. However, should patronage rise or areas not well served become vocal about wanting adequate transit service then new service would have to be implemented. This might well require additional capital investment from outside sources.

- Operating Costs

There are two aspects of operating costs which are worth noting:

> First, in the event of free transit, operating economies might be achieved when it was no longer necessary to collect fares, store fares, process cash and manage the accounts. The Charles River Associates' report noted that

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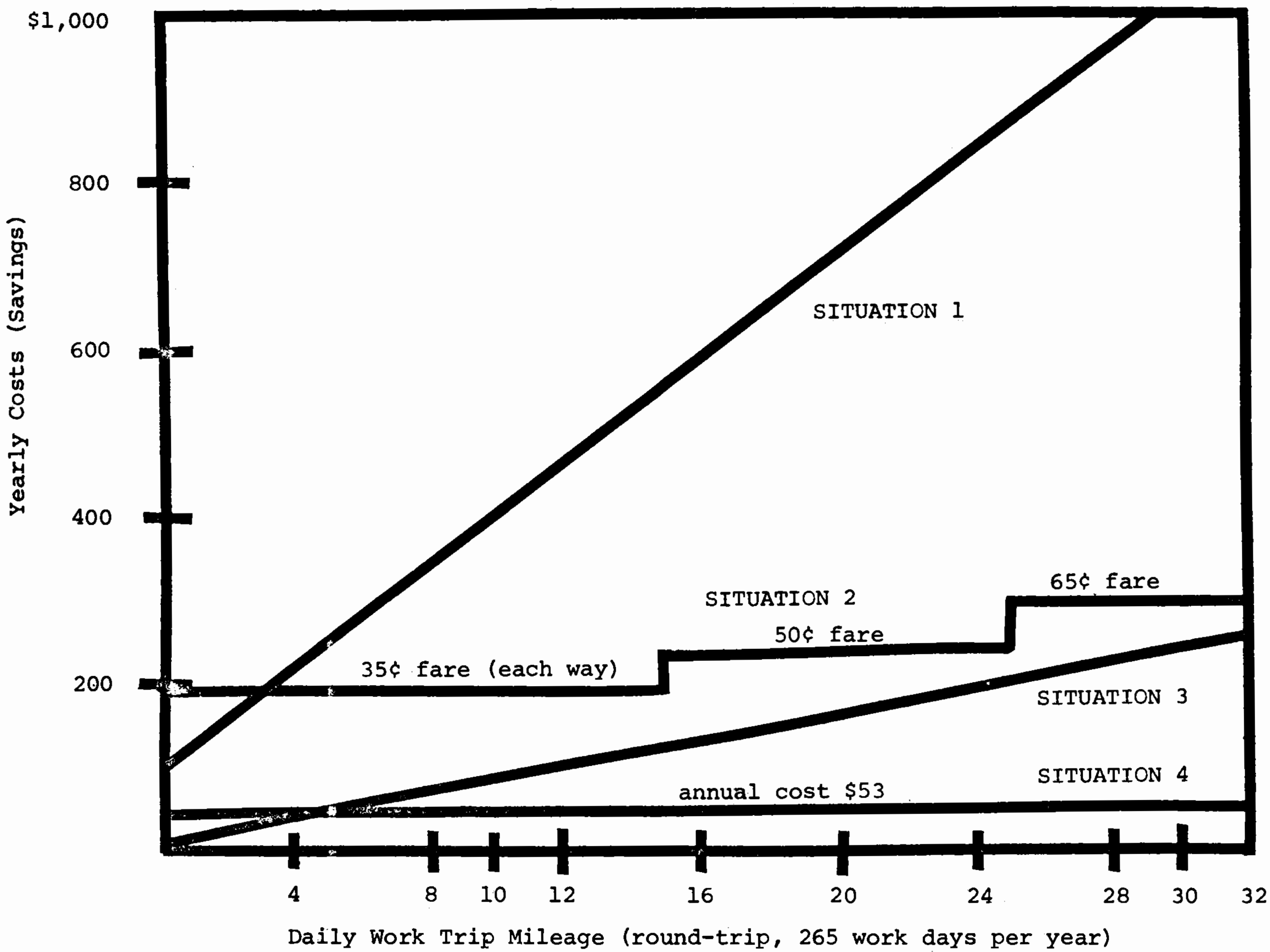
[5]These savings would not necessarily be realized completely. If the traveler opted for retaining ownership of a car he would still incur certain fixed costs (mainly depreciation) which may be completely or only slightly rationalized by other usage.

Figure 13-2: Yearly Personal Travel Costs



Situation 1: Auto, no passengers; costs: 12¢ mile, 25¢ each way for tolls

Situation 2: Unsubsidized transit, average fare: 35¢ each way, up to 15 miles (round trip),
50¢ each way, round trip distance 15-35 miles,
65¢ each way, over 25 miles round trip

Situation 3: Car pool, 3 passengers and driver; costs: 12¢ a mile, 25¢ a day in tolls

Situation 4: Subsidized transit, average fare: 10¢ each way while on large rapid transit systems the need for ticket sellers would be eliminated, the need for "officials" or "information dispensers" would not decline and therefore there would be few opportunities for savings.[6] For bus systems, there is a minor financial commitment to fare collection equipment and its maintenance as well as cash processing. These companies may achieve some worthwhile savings. Data on bus operator expenses in regard to fare collection are not generally available, but there are reports that adoption of exact fare alone has allowed tightening of schedules with minor savings in bus trips. (Of course, these savings would only materialize under completely free transit plans.)

The second aspect of operating costs would be the overall expense associated with maintaining the subsidy of the transit operation. Several typical examples of operating costs associated with various sized bus fleets and cities are shown in Table 13-2. As noted, unit operating costs are likely to be less in smaller communities.

In any plan of subsidized transit, some decision must be made as to what portion of costs will be borne by the public. As an illustration of these costs, see Figure 13-3 For example, if City "D" decided to drop fares from forty cents to ten cents, the community would have to generate approximately 3.5 million dollars of support.

These costs are broken down on a per capita basis in Figure 13-4. It is interesting to note that while the annual per capita burden for each city varies substantially it is in all cases eminently reasonable, ranging from six to eleven dollars per capita per year.

- Other Costs

There are several possible effects which may materialize in the event of heavily subsidized transit. First, charges of discrimination may be warranted since in most cases communities do not have adequate public transportation systems. Thus, large numbers of users would be unable to take advantage of lower fares.

Second, it has been observed that persons age twenty and younger use low priced transit service in much greater numbers than when the fare is higher. This was observed in Rome's Christmas 1971 holiday free transit experiment and documented in the Clearwater experiment. In the latter case, based on a surveyed response to raising fares from ten cents, it was predicted that age twenty and under trips would decline thirty-three percent. They actually declined 44.3 percent, the greatest decline registered by any age group.[7]

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[6] Charles River Associates, Op. Cit., p. 11.

[7] Voorhees, Op. Cit., p. 154.

TABLE 13-2: 1970 Operating Cost and Revenue Statistics[a]
Selected Cities

City	Geographic Area Of Country	Population Served (000)	Number Buses In Fleet	Base Fare	Annual Revenue (000)	Total Operating Expenses (000)	Surplus or (Deficit) (000)	Operating Cost per Bus Mile
City "A"	N.E.	73	58	$.25	$ 710	$ 680	$ 30	$ .77
City "B"	Mid-Atlantic	210	104	.35	1,540	1,465	75	.77
City "C"	East	300	194	.35	4,150	4,250	(100)	.96
City "D"	West	700	228	.40	4,960	6,760	(1,800)	.89
City "E"	Mid-West	1,300	708	.50[b]	8,700	9,215	(515)	.91

[a] All-bus fleets only

[b] Fare has since been rolled back to forty cents

SOURCE: "1970 Transit Operating Report: Revenues, Expenses, Operating Statistics," American Transit Association, Washington, D. C., 1971

Figure 13-3: Range of Annual Incremental Costs to Subsidize Transit Given Existing Profits, Costs, and Ridership Patterns.

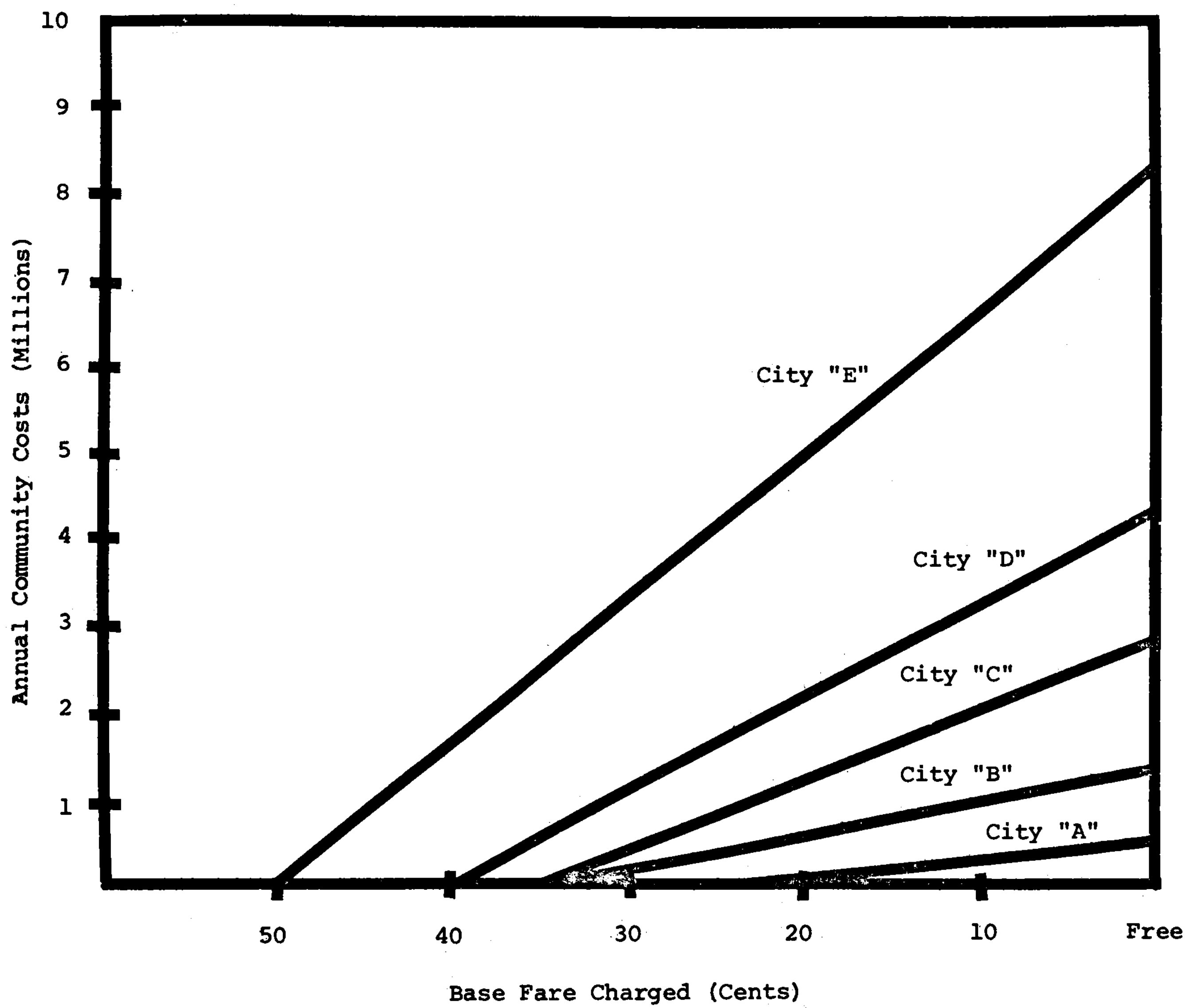
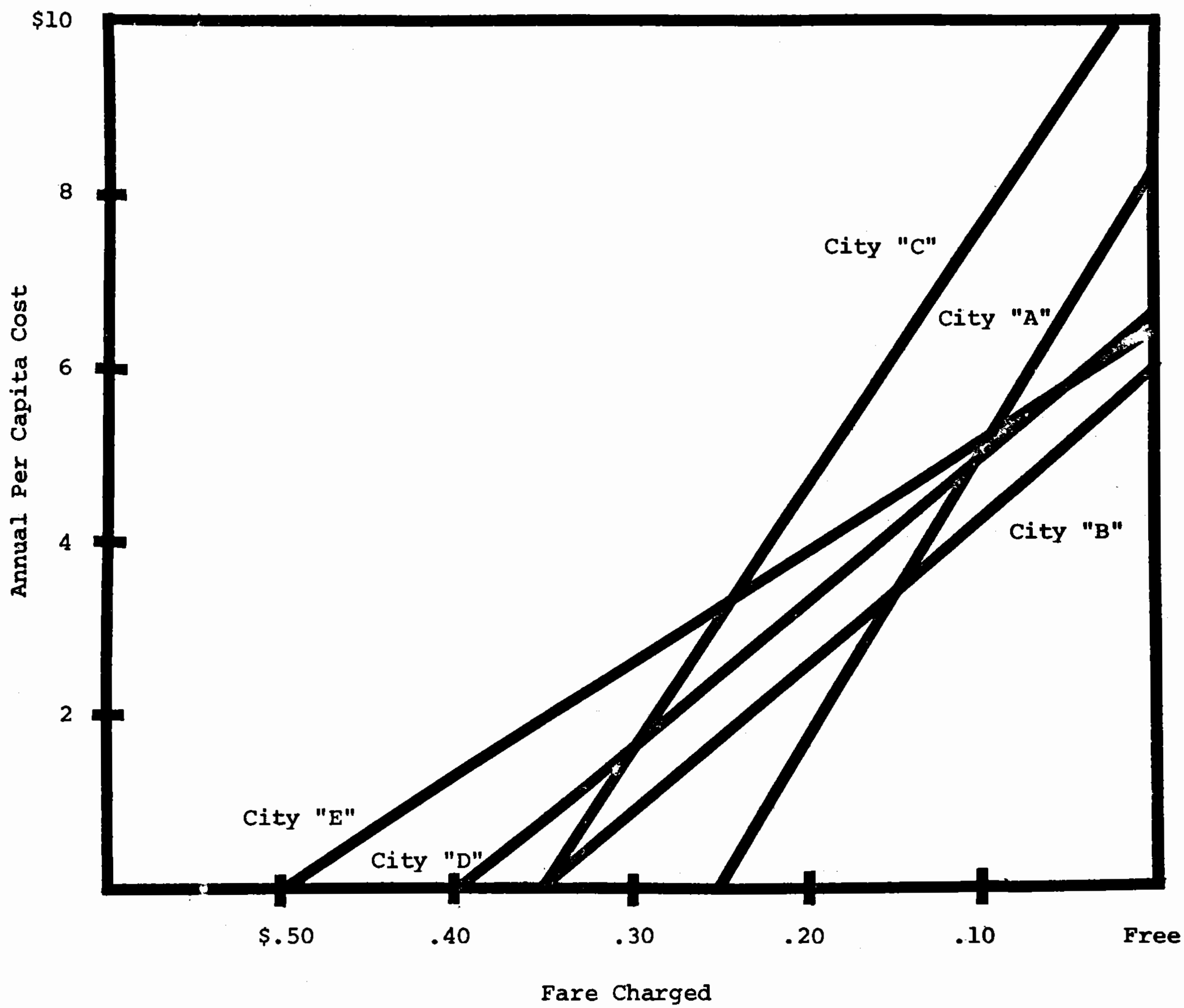


Figure 13-4: Per Capita Cost to Replace Fare Revenue with Public Subsidy



The greater use of transit by younger travelers may be unobjectionable in many cases, and may indeed represent a decrease in "chauffeuring" by adult auto drivers. In other cases it may simply provide an inexpensive diversion for younger persons, which could be easily abused.

A third important non-economic impact with economic side effects would be related to travel patterns. For example, more low income shoppers may use transit to go downtown or to large regional shopping centers and bypass other shopping areas not well served by transit. Thus, the nature of transit trips possible will to some extent shape the travel of community residents, especially those transit dependents having small incomes.

- Indirect Economic Effects

Indirect economic benefits are the main justifications for subsidized transit. These benefits are related to the assumption that if fares are low people will forsake more costly and space-consuming private vehicles and hence, demand for highways will decrease. Unfortunately, there is limited substantive evidence at this time, either theoretical or actual, to support the belief that this would indeed happen. As was mentioned earlier, the Charles River study model indicated almost no cross elasticity between free transit and auto.

The Charles River model was constrained by present service characteristics; given improved service it could be expected that more origins and destinations would be served, and therefore, that a meaningful alternative to private auto would be presented to more citizens.

Further support of the better service theory is provided from mode choice research data assembled by the ITT Research Institute. Table 13-3 shows that for work trips, where a car is available as an alternative, the most important factor reported in Chicago as influencing choice is "time" followed by "comfort" and "car necessary".[8] "Cost" as the main factor influencing choice, among those using car, is reported in only six instances of 1,165 persons interviewed (0.5 percent). However, for those using transit where a car is available as an alternative, thirty-two percent reported cost as the main factor for their choice, by far the most significant single factor explaining why people preferred using transit when a car was also available.

The ITT data is difficult to interpret since the "Main Factor Influencing Choice" will differ whenever any of several other important factors such as cost, time and convenience (Parking-walking variables) are essentially equal in quality or cost regardless of mode.

However, a large proportion of transit users with options give cost reasons (cost, parking too costly) as the major reason for using transit. Either all the cost-sensitive travelers with options are now using transit or substantially greater cost advantages must be provided to induce more mode choice changes. It is not clear in the latter case, what proportion of those who give non-cost reasons as being responsible for choice of auto

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[8]Mode choice models suggest that time, convenience, and cost explain at least 90% of transportation ridership decisions. People may think comfort is important; concrete evidence that they respond greatly in practice to any actual comfort discrepancies between modes is lacking.

TABLE 13-3: Persons for Whom a Car Was Either the Actual or the Best Alternative Mode of Travel for Work Trips Classified by the Actual and Alternative Modes and by the Main Factor Influencing Choice between Them

Principal Travel Mode		Main Factor in Choice of Travel Mode								
Actual	Alter-native	Time	Cost	Comfort	Walking	Parking Not Available	Parking Too Costly	Car Necessary	Other Factors	Total
Car	Rail-road	14	0	17	4	0	0	31	5	71
Car	Rapid Transit	41	1	29	8	0	0	40	9	128
Car	Bus	423	5	250	18	0	0	223	47	966
Rail-road	Car	17	19	9	1	6	7	0	9	68
Rapid Transit	Car	2	22	0	0	10	16	0	12	62
Bus	Car	2	54	3	1	18	8	0	86	172
Total		499	101	308	32	34	31	294	168	1,467

SOURCE: Table 4 from Factors Influencing Model Trip Assignment, Interim Report, IIT Research Institute, Chicago, Illinois, 1965, p. 47.

trips could be diverted by greater reductions in cost. It is clear from other mode choice studies that remedying other factors besides cost is the only sure way of obtaining large mode choice changes. (Time + car necessary are factors which might be remedied through better service, for example.)

- Impact on Disadvantaged

There would be clear and definite social advantages for low income and other disadvantaged workers if transit fares were subsidized or eliminated. This would mean greater opportunities for access to a wide variety of social services, employment opportunities and other activities. The Charles River study showed some elasticity for shopping trips (little for work trips) among present transit users, implying that price influences the number of such optional trips by existing users.[9] Clearwater showed similar results when fares were raised; about half the decline in ridership could be attributed to transit riders reducing the number of trips made. The high proportion of ITT Research Institute's transit-using respondents reporting cost as the main factor in choosing transit (thirty-one percent) also indicates that existing riders tend to be more price sensitive. These studies suggest that low income people do not often travel when trips are optional, and thus we would expect low income and other disadvantaged individuals to increase the frequency of optional trips for medical checkups, job interviews, etc., if transportation costs were lowered. Preliminary findings showing much greater increases in ridership in off-peak periods and on weekends in Atlanta would support this interpretation.

- Environmental Impact

To the extent that transit trips are substituted for individual car trips, then decreases in pollution and environmental impact might be expected.

- Safety Impact

Substitutions of transit trips for auto trips should decrease accidents caused by congestion. Based on existing information on mode choice behavior, a slight but positive safety impact might be expected.

- Speed or Time

No measurable change. If streets are cleared of congestion it may make it possible for the remaining vehicles (including transit) to move more quickly. However persons switching from auto to transit would on the whole face longer travel times.

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[9]Charles River Associates, Inc., Op. Cit., p. 47.

- Volume

Changes in system capacity would of course occur to the extent transit rides were substituted for private automobile trips on a one-to-one basis. Such diversion would result in an increase in system capacity. To realize the full potential of this capacity, it may be necessary to add transit service.

- State-of-the-Art

Providing free or subsidized transit *per se* will involve no esoteric technology. An appropriate mechanism to screen out non-essential trips may be the most difficult operating system component.

- Institutional Background

Unlike most innovations, transit unions have fully supported subsidized transit and are actively lobbying for it within Congress and the Executive Branch. Therefore, little transit in-house resistance is expected. The principal opponents to free or subsidized transit are the public agencies who would have responsibility for finding the funds to support the subsidy. With the possible advent of the Federal funding of operating costs (such a provision had been included in the Highway Act of 1972, but this bill was not enacted by the 92nd Congress), there would be Federal funds to assist in supporting such efforts and local resistance would probably weaken. Certain citizen opposition might be expected since it would involve paying the costs of transportation for "other" citizens, and the usual arguments against such welfare state schemes would be raised.

- Traveler Response

Generally speaking, the response can be expected to be fairly positive. Data reported from Atlanta, Rome and Clearwater indicate that people will take advantage of a low priced good.

III. SUMMARY AND CRITIQUE

The concept of free or heavily subsidized transit is aimed at diverting motorists from their private vehicles and thereby reducing congestion associated with urban areas which are heavily auto dependent. Unfortunately, what little data is available suggests that mode switching might not be as substantial as proponents anticipate.

This review appears negative in its overall findings and conclusions. The study staff, however, feels that this conclusion may be premature. There is simply too little data from which to draw meaningful conclusions and certain of the data is contradictory. Hopefully more thorough investigations can be launched which will provide more definitive counsel.

Charles River Associates, Inc. An Evaluation of Free Transit Service. Cambridge, Massachusetts, Aug. 1968.

Factors Influencing Modal Trip Assignment. Interim Report, IIT Research Institute, Chicago, Illinois, 1965.

Metropolitan Atlanta Rapid Transit Authority. Atlanta's Reduced Transit Fare Experience, March 1 - June 30, 1972. Prepare for Presentation at the UMTA UTPS User Symposium, July 27-28, 1972.

Simpson and Curtin. Coordinated Transit for the San Francisco Bay Area -- Now to 1975, October 1967.

1970 Transit Operating Report: Revenues, Expenses, Operating Statistics. American Transit Association, Washington, D. C., 1971.

Voorhees, Alan M. and Associates, Inc. Clearwater Demonstration Bus Project-First Interim Report, June 1971.

CHAPTER XIV

LINE HAUL FEEDER SYSTEMS

Operating Description and Summary of Findings

Systematic efforts at organizing the collection and distribution of demand around fast line haul transit facilities are designed to (a) replace automobiles carrying out this function and (b) improve the convenience of the line haul facility itself. The resulting increase in use of mass transit may be expected to alleviate certain demand for highway facilities.

The study found that a properly integrated feeder bus or similar service could be expected to improve the use of line haul faciiities and thus alleviate demand for new auto related facilities. Costs associated with use of feeder bus appear to be less than for conventional transit operation.

Certain problems exist in (a) developing an intergrated service system especially on a regional basis and (b) in persuading auto oriented travelers to use feeder bus services.

I. INTRODUCTION

Rail rapid transit lines, commuter railroads, and exclusive busways represent the bulk of the existing or anticipated fixed facility line haul transit service facilities. In most cases the line haul facilities have unused capacity. Better utilization of this capacity may be generated through improved public transportation at either end of this line haul facility.

The principal advantages that might be associated with improved transportation access and egress are as follows:

(1) Reduction in commuter parking requirements at line haul stations and in the CBD.

(2) Reduction in excess vehicle traffic involved in kiss and ride activity at stations.

(3) Enhancement of rail line patronage, resulting in better use of fixed transit facilities, and a corresponding reduction in vehicular traffic and traffic facility needs.

To the extent that public transportation access to line haul facilities can also be made to serve local public transportation needs, i.e. dual purpose feeder and local service bus routes, the following advantages might be added:

(1) Maximization of transit service to all rider groups.

(2) Provision of additional revenue to offset losses associated with under-utilized general neighborhood bus service, to the extent that the local service routes would have sufficient excess peak capacity.

II. TECHNICAL EVALUATION

- <u>User Price Impacts</u>

In most configurations of service, the user is expected to pay more for using feeder service than if he merely used the line haul facility. Under some circumstances special free or low cost transfers are provided. Below are some examples of actual fares associated with use of rapid transit service and feeder bus (the only widespread example to date).

Line Haul and Feeder Bus Fares[1]

System	Line Haul Fare	Bus Fare	Transfer	Combined Fare
New York City-local (N.Y.C.T.A.)	30¢	30¢	none provided	60¢
Chicago-Local (CTA)	45¢	45¢	5¢	50¢
Chicago-Evanston (CTA-EBC)	60¢	35¢	none provided	85¢
Philadelphia-Local (SEPTA)	30¢	30¢	5¢	35¢
Philadelphia-Red Arrow (SEPTA)	30¢	35¢	none provided	65¢
Boston-Local (M.B.T.A.)	25¢	20¢	none provided	45¢
Cleveland-Local (CTS)	50¢	45¢	5¢	50¢
Toronto-Local (TTC)	30¢	30¢	free	30¢

While the combined fares do not appear to represent an onerous burden, the feeder bus patron does essentially have to pay twice for combined service on about half of the existing rapid transit line haul operations and on almost all commuter railroad lines. The burden, of course, is heavier for line haul passengers who must use a feeder-distributor bus at both ends of the trip. Under some proposals, feeder bus service would be very low cost or free. Proponents of these proposals suggest that total system revenues would rise as users became more dependent on the basic service.

- Implementation Costs

It is not useful here to talk about implementation costs except in relation to costs associated with setting up or expanding feeder bus service.
One major element of cost is the purchase of buses. Three types of buses that might be purchased are summarized below.

	Type	Capacity	Cost Ranges
(1)	Mini-buses	17-21 passenger	$15-21,000
(2)	Midi-buses	25-31 passenger	20-27,000
(3)	Regular transit buses	45-53 passenger	36-40,000

Other major cost elements are the construction of storage and maintenance facilities and the one-time element of subsidy costs that are associated with running any new service while ridership is low.

[1] American Transit Association, Fare Reports (periodic circular).

In many communities, providing efficient feeder bus service for access to line haul facilities may not so much involve purchasing and installing new equipment as reorganizing existing service to better serve the objective of feeder operation.

Some judgments about the extent of total capital costs may be gained from independent studies of feeder and local bus service needs in the North and South Suburbs of Chicago, respectively. These studies and the cost estimates presented cover provision of multi-purpose bus service keyed to providing both rail line access and local public transit service. Both studies involve areas where partial service already exists.

The Chicago North Suburbs[2] study area covered approximately 200 sq. miles and a 1970 population of 476,000 persons. Existing and proposed bus lines would serve about one-half of the land area with most of the population served by medium-density feeder and local bus service. Estimated first year capital and start-up costs are given below:

NORTH SUBURBS BUS SERVICE CAPITAL AND START-UP COST SUMMARY

Item	Completely New Facilities and Equipment	Completely New Facilities, Equipment Purchases Incremental to 1966-70 Buses	All Purchases Incremental to Existing Usable Facilities and Equipment
Revenue Build-Up Allowance	$ 654,800	$ 654,800	$ 654,800
Buses	6,698,000	5,712,000	3,366,000
Miscellaneous Start-up Costs	500,000	500,000	500,000
Garage Facilities	1,970,000	1,970,000	1,000,000
Total	$9,822,800	$8,836,800	$5,520,800

The Chicago South Suburbs study area[3] covers about 1,250 sq. miles and a population of 2.1 million people. About half the study area is urbanized, with the urban area including the southerly one-third of the city of Chicago. The summary of capital improvements recommendations includes the following sums for first year bus purchases and garage modifications:

Buses	$23,870,000.00
Garage Modifications	$ 1,025,000.00

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[2] Richard H. Pratt and Howard W. Bevis, "An Initial Chicago North Suburban Transit Improvement Program," prepared for the North Suburban Transportation Council, May, 1971.

[3] W.C. Gillman and Co., Inc., "Southward Transit Area Coordination Study," prepared for the Illinois Department of Public Works and Buildings in Cooperation with the Southward Transit Area Coordination Committee.

. Operating Costs

Fixed route feeder bus operating costs would be comparable to those experienced in any conventional bus operation, with per mile costs ranging between 75¢ and $1.10. Most of the variance would be a function of different labor cost figures. Since feeder service is more likely to be needed in a large metropolitan area with higher labor rates, the higher figures would normally pertain.

The principal issue of interest to community decision-makers is the net out-of-pocket cost (or profit) to the agency sponsoring such service. This would again depend on the specific applications; the more patrons per hour of service, the lower net costs would be.

Data from the Chicago South Suburbs study projected a twelve hour operating cost per feeder bus of $150 per day, Chicago being an area of high labor cost. The Southward Transit Area Coordination Study concluded that "within the STAC area, it does not appear economically feasible to operate a bus service that exclusively feeds commuter rail stations. Bus feeder service is being provided economically, however, on routes where there are three to four other patrons for each feeder patron. Thus feeder service should be continued and expanded on routes where sufficient non-feeder ridership can be generated." The report also concluded that, considering only construction and operating costs and not other costs or indirect benefits, it is cheaper to provide commuter rail station parking than to operate an exclusively feeder oriented bus service.

Using the operating cost figure of $150 per day, per bus, some useful if limited comparisons can be drawn between hypothetical feeder bus operations and equivalent trunk line bus line operations. This is done in Tables 14-1 and 14-2, which assume running times, fares, and a set of possible passenger loadings for the purpose of calculating net profit or loss. For the assumptions used, including a longer peak for the trunk service, the feeder service would sustain less net loss at either one-half or three-quarters the trunk line fare. The assumptions are highly simplified and omit such possibilities as higher passenger turnover on a trunk service. Nevertheless, the comparison serves to demonstrate that there are significant bus operating economies produced simply by the inherent shortness of the typical feeder routes.

In the Chicago North Suburbs study, operating costs and net revenues were estimated in detail for a suburban feeder and local service system covering 228 miles of streets with peak service of 20 minutes or better and mid-day service of 30 minutes or better. To encourage multiple passenger use, each route with few exceptions was designed to have at least one end at a major shopping area and to make contact with at least one rail transfer point. At a 35¢ fare and 1969 costs, the required annual subsidy for the second and subsequent years was estimated to be $104,700.00 plus a bus-rail transfer rebate subsidy of $219,900. The total estimated subsidy was thus $324,600 per year not counting extra subsidies required during the initial year of operation. This equates to just under $3.00 per year, per family in the bus service area.

No information is available on the costs of providing better access to trunk line facilities by means other than feeder bus.

TABLE 14-1 Feeder Service:

Performance Of Each Bus Given An Assumed 1/2 Hour Round Trip[a]
And Various Passenger Loadings

Passengers Carried Per Bus Day			Total Revenue Per Bus			-Daily- Net Profit (Loss)	
Peak 4 Hours (8 Trips)	Off Peak 8 Hours (16 Trips)	Total 12 Hours	Fare @ $.30 Per Passenger	Fare @ $.20 Per Passenger	Operating Cost [b]	Fare @ $.30/ Passenger	Fare @ $.20/ Passenger
80 (10 per trip)	32 (2 per trip)	112	$ 33.60	$ 22.40	$150.00	($116.40)	($127.60)
160 (20 per trip)	64 (4 per trip)	224	67.20	44.80	150.00	(82.80)	(105.20)
240 (30 per trip)	128 (8 per trip)	368	110.46	73.60	150.00	(39.60)	(76.40)
320 (40 per trip)	192 (12 per trip)	512	153.60	102.40	150.00	3.60	(37.60)
480 (60 per trip)	240 (15 per trip)	720	216.00	144.00	150.00	60.00	(6.00)

[a] Including layover.

[b] Per bus operating cost of $150.00 per day, a high wage scale figure obtained from the Chicago Metropolitan area (see text for more detail).

Table 14-2 Trunk Service:

Performance of Each Bus Given an Assumed 1-1/2 Hour Round Trip [a]
and Various Passenger Loadings

Passengers Carried Per Bus Day			Total Revenue Per Bus		
Peak 6 Hours (4 Trips)	Off Peak 6 Hours (4 Trips)	Total 12 Hours	Fare @ $.40 Per Passenger	Operating Cost [b]	- Daily - Net Profit (Loss)
40 (10 per trip)	8 (2 per trip)	48	$ 19.20	$150.00	($130.80)
80 (20 per trip)	16 (4 per trip)	96	38.40	150.00	(111.60)
120 (30 per trip)	32 (8 per trip)	152	60.80	150.00	(89.20)
160 (40 per trip)	48 (12 per trip)	208	83.20	150.00	(66.80)
240 (60 per trip)	60 (15 per trip)	300	120.00	150.00	(30.00)

(a) Including layover.

(b) Per bus operating cost of $150.00 per day, a high wage scale figure obtained from the Chicago Metropolitan area (see text for more detail).

Further investigation of this concept should include giving attention to establishing the range of required subsidy or profit found or estimated for actual applications. Even with better establishment of this range, each individual application of the concept will obviously require its own unique set of cost and revenue estimates.

If ridership is at all responsive to improvement of line haul access, these operating revenue improvements would accrue:

(1) Increased line haul revenue
(2) Increased revenues from other bus services

The Chicago North Suburbs Study is one instance where specific estimates have been made of "before-and-after" patronage such that some inferences can be drawn regarding revenues. In respect to effects on line haul ridership, it was estimated that expanded suburban bus service would increase transit usage in and out of Chicago by some 3,000 trips. Most of these would be relatively short trips and use connecting line haul buses; some would be rail trips. The approximate annual gross revenue gain implied by these figures, using the CTA central zone fare of 45¢, is $378,000 annually. This gain is of the same order of magnitude as the total subsidy requirement anticipated for the expanded suburban operation.

Estimates from the Chicago North Suburbs Study also indicate an increase in gross revenues for the suburban bus services themselves. However, the indication is that net revenues would be in the same range before and after. The forecast increase in suburban bus ridership is from 10,337,000 passengers per year to 17,415,000 per year, up 62%. Gross revenues would follow accordingly. The operating ratio of expenses to gross revenue is projected at 1.02 if the cost rail-bus transfer is subsidized or 1.05 if carriers absorb that subsidy. The present limited operation, as reported in 1968, produced a slightly profitable .97 operating ratio for one operator; the other two operators showed ratios of 1.07 and 1.29.

- <u>Other Costs</u>

Most feeder service concepts are relatively innocuous. However, some complaints from neighborhoods where new service is initiated, especially if any facilities are involved, may be made.

- <u>Indirect Economic Effects</u>

Likely indirect economic effects include reduced congestion, reduced parking demand at line haul stations, and reduced demand for new road facilities. Quantitative observations or estimates of these effects are again not available for a broad spectrum of applications.

Estimates are available for the combined local and feeder bus system proposed for the Chicago North Suburbs. An estimated 6,000 daily vehicular trips would be removed from the streets in the intra-suburbs travel category by expanded bus service. These trips are spread throughout the day and throughout the area and thus represent no particular traffic concentration. It was forecast that 1,200 daily vehicle trips would be removed from the suburbs to Chicago category. The study notes that when translated to peak period traffic, this might represent only 100 vehicles removed from the peak direction of traffic flow during the peak hour on the major corridor freeway facility. However, it was further noted that this would represent some 5-7% of freeway lane capacity and could have noticeable beneficial effects if freeway volumes are in the vicinity of unstable traffic flow.

The estimated effect on commuter access was that 2,100 peak period vehicular trips would not be made to or from stations because of expanded suburban bus service. Some 450 vehicles would not occupy commuter parking space, equivalent to an 18 percent increase in space. The report does note one important aspect of the estimates presented, namely that they cover only first order effects of improved feeder bus service. The freeing of commuter parking spaces and reduction in congestion around terminals might in turn attract more trunk line transit users but in amounts not thought feasible to forecast.

Clearly, the available data is too limited for reliable generalizations. This is underscored by the recent findings from Contra Costa County, California, a lower density area to be served by the San Francisco Bay Area Rapid Transit District (BART).[4] The draft report concludes that the total capital and operating costs for each of nine Contra Costa County bus systems evaluated would exceed the total benefits to users and other sectors of the total community by a substantial margin. Contra Costa County development patterns, it should be noted, present very limited opportunity for attracting non-feeder passengers.

- <u>Impact on Disadvantaged</u>

The principal social benefit of feeder bus service is that low income and other disadvantaged users will have improved access to employment and other activities when collection and distribution coverage of the metropolitan area is bettered. Where the improved access to trunk line service is in the suburbs, benefits will include the specific element of added lower income group access to suburban employment. The degree of improvement will, of course, be a function of the system size and configuration.

- <u>Environmental Impact</u>

The degree of environmental impact will be directly related to the amount of private vehicle use which is eliminated. No definitive data are available on environmental effects, but the net impact is not expected to be large.

- <u>Safety Impact</u>

Safety benefits will be directly related to the number of persons attracted from auto use to transit use, transit being a safer travel mode. Again, no definitive data are available, but a negligible impact is expected.

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[4]DeLeuw, Cather and Company, <u>Draft Report</u>, Contra Costa County Transportation Needs Study, December, 1971.

. <u>Speed or Time</u>

It is obvious that the mean time associated with the collection and distribution of line haul passengers by feeder bus will be greater than with the use of the private automobile for access. Partially compensating will be the "chauffeuring" time saved where kiss-n-ride activities are reduced, and any general time savings attributable to congestion reduction at stations.

. <u>Volume</u>

There are two principal aspects concerning volume. First, feeder service enables the line haul terminal facility to handle more passengers than the land area of the terminal might otherwise support, as in the case where all-day parking and kiss-n-ride parking space constraints exist. Secondly, feeder service is a potentially high capacity carrier, substituting 18 to 53 passenger vehicles for private automobiles, and which can thus serve a variety of growing local transportation needs without straining capacity of the local street system.

. <u>State-of-the-Art</u>

Improvement of line haul facility access through use of the conventional feeder bus involves little more than a variation of standard bus operating procedures. The major area where further research needs to be performed is in establishing data on economic characteristics of the service such as might influence the design and feasibility of feeder bus systems.

Other types of improved access to stations could be considered. Most forms of demand actuated transit service are applicable. Many-to-one "Dial-A-Bus" service concept is currently in use for feeding the Toronto, Ontario "GO" commuter railroad service. The state-of-the-art for demand actuated transit has been described in the literature discussion pertaining to that concept.

There is a possibility of even more unconventional line haul collection and distribution systems in the form of pedestrian movement devices. Certain types of pedestrian movement systems could essentially expand the walking distance range of line haul facility stations. No such systems exist as line haul transit service connectors, although one is under study for interconnection of the Philadelphia to New Jersey Lindenwold Rapid Transit Line with the suburban Cherry Hill complex. Pedestrian movement system technology of the "horizontal elevator" classification is relatively well developed in design but unproven in application except for a few quite limited installations.

. <u>Institutional Background</u>

As with any transit service development proposal, projects for line haul collection and distribution service improvements involve significant political and administrative tasks which must be accomplished. If transit operation is private, improvement of feeder and local service may involve as a first step the setting up of transit operating or coordinating agencies with regulatory and/or taxing powers.

Some of the other institutional problems that will be encountered in the process include: providing a mechanism to plan service improvements, obtaining funds, establishing the requisite operating authorities, possible coordination of independent operating companies and unions, and possible fears about infringement on franchised transit operating rights. Some of these institutional problems may be avoided where all regional transit operations are under a common authority. However, this commonality pertains in less than half the cities where major trunk line transit facilities are in operation or are authorized. Complex problems have impeded coordination of bus operations with existing line haul facilities to the extent that some rapid transit lines are not yet serving in a fully productive relationship with pre-existing carriers, even where obvious potential exists for improving line haul station access.[5]

- <u>Traveler Response</u>

Too little is known about the relative acceptance of feeder bus vis-a-vis other modes. The broad mode choice studies referred to earlier indicate that the attractiveness of the transit trunk mode can be improved by the provision of feeder service. The extension of local service concomitant with establishment of feeder service also will attract some riders. It would seem that definitive answers on traveler response are also heavily dependent upon the utility of the trunk service.

III. SUMMARY AND CRITIQUE

Feeder bus service is aimed at and most beneficial to three groups of commuters:

(1) Low income commuters (i.e. transit captives), mostly from the inner city, who could use line haul transit to travel to far away locations, then transfer to feeder service to reach individual job sites.

(2) Line haul patrons now delivered by car (Park-n-Ride, Kiss -n-Ride) where such car use is not desired.

(3) People who would use local feeder routes as a mode of transit (i.e., transit captives who use feeder bus for local trips).

Whether the revenues gained from feeder bus service would exceed the costs is based on many factors. An important point to remember, however, is that

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[5]Richard H. Pratt, "Impact of Rail Transit on Bus Operations," <u>Transportation Engineering Journal of A.S.C.E.</u>, Vol. 97, No. Tel, Proc. Paper 7881, February, 1971, pp. 31-42.

the shortness of the typical feeder routes means more economical operation as compared with other bus routes.

A forecast cited in this concept report indicates that feeder service would increase line haul ridership while cutting down on daily vehicular trips. If this could be achieved, then it appears that feeder bus service is a viable concept well worth additional development.

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CHAPTER XV

AIRPORT ACCESS IMPROVEMENTS

Operating Description and Summary of Findings

Improved airport access techniques are needed as substitutes for extensive highway and parking facilities serving airports. Four possible approaches were summarized in this analysis: (1) organized limousine or bus service (2) demand bus service (3) minibus shuttles from close in lots (4) satellite parking facilities in remote locations.

The four techniques surveyed could reduce demand for land adjacent to airports. However, faster access is more likely to result from improvements in general traffic flow.

There are likely to be institutional barriers to implementation of several of the reviewed techniques.

I. INTRODUCTION

From a transportation viewpoint, airports are a large traffic generator similar to office parks, shopping centers, and central business districts. Superficially, the airport access problem differs little from difficulties associated with other major traffic generators. However, there are several important characteristics which are unique to airport access transportation needs. Five of the most important of these are discussed below:

(1) Extremely high traffic generation - Air travel at present is the largest public carrier of inter-city trips, and projections show that trips by air will continue to rise. In addition to travelers, most airports have large numbers of employees, both working at the airport proper and for business firms located near-by. It would appear that employment will continue to grow near airports, particularly in auxiliary office complexes. Finally, airports appear to attract a large number of sightseers, a category rather unique to a major generator.

(2) Rigid adherence to schedules - For the air traveler, adherence to schedules is vital. To arrive at the airport a few minutes after the airplane has left can be an individual disaster. Obviously the need for rigid adherence to access schedules is only critical to the air travel portion of the traffic destined for the airport, but this portion of the traffic is often mixed in and inseparable from other traffic.

(3) Mixed peaking - Because of the mix of travel purposes, the peaking of traffic traveling to an airport may differ considerably from other facilities. Employee commuting will tend to peak during normal rush hours, and will be heavily directional. The casual visitor (sight-seer) tends to be concentrated in the weekend. The Cleveland Survey found that 77.4 percent of the casual trips were made on Saturday or Sunday. Air travel *per se* produces the least peaks; the Cleveland Study found that the highest hour (5-6 PM) produced a peak of only 12.5 percent (both directions) while 9-10 PM was the fourth highest hour with 7.4 percent.

(4) Lack of highway infrastructure - Most modern airports are located to avoid disturbing residential neighborhoods, often resulting in the airport being in an undeveloped section of the urban area. Unfortunately, this also usually means that local roads (arterials and collectors) are at a minimum unlike most office parks, shopping centers, and central business districts. Excess demand may place abnormal loads on the principal roadway to the airport, especially during peak periods or when accidents occur.

In many cases access is primarily dependent on one roadway.

The terminal as a transportation destination also appears to have some unique problems. The air terminal represents a single destination point for all air travelers. Congestion at the terminal (such as where the passenger is dropped off or picked up), combined with the long distances between the terminal and parking facilities and the large demand which may be generated, produces several delays in the final portion of the access trip. In addition, the air traveler, if he is an auto driver, will consume a large number of parking space hours per trip, thus increasing the parking requirements with respect to trip generation over what we would consider normal for office parks or shopping centers. The Cleveland Study found that approximately 93 percent of the air travelers did not return in the same day and that 65 percent stayed away three or more nights. The air travelers also have the problem of handling baggage.

The balance of this paper is a summary discussion and evaluation of four techniques which are representative of the low capital or non-capital approaches toward meeting airport access needs.

(1) Bus or limousine service from areas of dense employment and residence to the airport-- a conventional service already operating in most cities.

(2) Modified many-to-one Dial-A-Bus service to the airport - a proposal whereby the customer phones in his request for a bus at a specific time, with pick up at a particular place. His request is coordinated with other similar requests for service, and from this coordination the specific route for that run is determined. A simple version of this system is in use in a number of smaller cities where limousines or small buses are used to pick up people at almost any location. The driver attempts to pick up as many people as possible and still reach the airport in time for the passenger with the earliest flight.

(3) Mini-bus shuttle from the airport parking lot to the terminal - a small bus shuttles air passengers from distant long-term parking lots to the terminal. This is operational in such airports as National Airport, Washington, D.C. Its prime advantage is that it reduces the inconvenience of the long walk from the parking lot to the terminal.

(4) Satellite parking lots-- here the lot is located even farther from the terminal than in (3) above-- the parking lots could be scattered throughout the city, with service to the airport and terminal provided by limousine or bus service. Satellite parking lots are proposed as a means of reserving high-priced airport land for uses other than parking. The satellite lots might be located in suburban shopping centers, but would definitely not be located in the CBD, where land is also very valuable.

Satellite parking lot systems have been highly recommended for intermediate solutions in certain cases where fixed capital airport access investments may be justified at a later date.

Some of these outlying terminals would lie on the line haul route to the airport and be an integral part of such service systems.

II. TECHNICAL EVALUATION

. User Price Impacts

Comparative costs to users for the various airport access facilities are discussed in Table 15-1 and Table 15-2 presented on the following pages. For more information on Dial-A-Bus costs, see Appendix B. Regular transit service which extends to an airport is probably the least expensive of the concepts discussed. Limousine is next least expensive. Dial-A-Bus, satellite parking,and remote airport lot shuttling have mixed economic impacts, depending on how they might be used.

. Implementation and Operating Costs

Table 15-1 includes a listing of operation and implementation costs for the four airport access modes being discussed.

. Other Costs

Other cost factors do not appear to be significant; however, several minor non-economic costs should be mentioned:

- User inconvenience and lack of private comforts usually associated with private auto or taxi service.
- Parking lots in portions of the Metropolitan Area may be unwanted intrusions with incidences of higher traffic, noise and exhaust pollution.

. Indirect Economic Effects

Avoiding commitments to expensive parking lot development near airports represents the primary indirect economic benefit. Additionally, various services described may ease pressures for more capital intensive facilities especially designed to serve airports.

TABLE 15-1: Airport Access Mode Costs

Mode of Transportation	Passenger Cost per Mile	Implementation Costs	Operating Costs
Conventional Bus & Limousine Operation	Fares average 30¢/mile for a limousine (based on informal survey). For conventional bus a flat fare similar to other city transit service is charged. Due to the long mileage to and from airports, this means that costs per mile would not be very high.	Buses are normally available from the existing transit operator. Limousines cost about \$7,000-\$11,000 each. Administrative costs would be dependent on the particular application.	Bus \$.75--\$1.10/mi.; limousine estimated at 8-10¢/mile plus labor (limousine labor costs are typically low since most are not unionized.[a]*
Dial-a-Bus Operation[b]	19¢ per mile.[b]	Administrative set-up may be more costly because of sophisticated dispatching arrangements that are possible. Otherwise, merely involves purchasing of vehicles which may cost from \$4,500 to \$30,000 depending on size.	85.7¢/mile operating costs similar to normal bus operation with some savings due to smallness of the vehicle & "straight shifts, for the bus driver--no split shifts caused by extreme peaking.[a]
Satellite Parking Lots	No figures are available on possible parking fees for the satellite lots; if commuters took limousines from the lot to the airport, fares might be about 30¢/mile.	The company operating the system has to pay for land and paving costs, plus construct security facilities. However, existing shopping center lots might be used in which case the cost would probably be slight. In many cases no charge would be involved. Administration should be low cost and uncomplicated.	In general, attendants are required along with standard paving maintenance costs. Specific figures are not available.[a]
Minibus Parking Shuttle	Usually free--but passengers pay for parking space. Parking costs:[c] National Airport \$2.00/day; Balto./Friendship \$1.00/day; Dulles \$1.50/day.	An approximate average cost figure for a small bus is \$22,500. There would be almost no administrative cost.	Costs should be at the lower range of typical bus operating cost (\$.75-\$1.10/mi.) in the absence of union labor.

*For footnotes, see next page

TABLE 15-1, continued

Footnotes

[(a)] The operating cost should include in some cases a concession fee paid to the airport for each passenger arriving or departing the airport

[(b)] See Appendix B

[(c)] From "Airport Access in the Baltimore/Washington Region: Immediate Action Improvement Program and Planning Guide," Peat, Marwick, Mitchell & Co., Washington, D. C., March 1971, p.97

TABLE 15-2: Aspects of Airport Access Modes: A Summary

Mode of Trans-portation	Description	System It Replaces	User Costs as Compared to Other Access Modes	Speed or Time As Compared to Other Access Modes	Savings to Public
Conven-tional Bus & Limousine Operation	Already operational in major U.S. cities; the bus or limousine runs between the air-port and CBD offices and hotels.	Taxis, chauf-feuring in private ve-hicles, use of private car.	Conventional bus fare is less costly than driving when stand-ard fares are charg-ed. Limousine costs $2-4/trip, for service from National Airport to various suburban Md. locations, which is lower than compar-able taxi costs or auto, where parking must be paid as well.	Slightly slower than a private vehicle.	Reduction of congestion; no capital facili-ties involved. An effective system would reduce pressure for more air-port parking.
Dial-a-Bus Opera-tion	Intermediate between taxi and bus; rider calls in his location and destination, a bus is routed to pick up the caller and other passengers who have also called in. Pri-mitive versions are operational in a few cities.	Taxis, chauf-feuring in private ve-hicles, use of private car, regular mass transit or limousine.	Difficult to pinpoint costs, but probably on the order of limou-sine costs. More fa-vorable than private auto if parking is involved, but higher than conventional bus.	A bit longer trip than private vehicle or taxi, since it's less direct; however, since airports are often quite far from the rest of the city, there should be long line haul portion of trip with speeds similar to taxi.	Reduction of congestion--holds more than taxis, no capi-tal facilities needed, would reduce pres-sures on air-port land.
Satellite Parking Lots	Lots to be located in various sites through-out the city—probab-ly where parking space already exists and where densities are fairly low such as suburban shopping center lots, etc. Us-er would then be bus-ed into terminal. Not yet properly imple-mented. Study exists for Washington, D.C.-Baltimore.	Air passen-gers driving autos and parking them in lots at the airport.	Cost: normal limou-sine fare plus a park-ing charge or airport users could be drop-ped off at the lot by their families, thus just pay limou-sine fare and allow their family use of the auto.	Probably longer trip time; in some cases the lot may be out of the way and increase travel time to the airport slightly. Wait for mass transit vehicle to airport may consume more time.	Reduction of congestion, re-duced need for land near air-ports.

TABLE 15-2, continued

Mode of Transportation	Description	System It Replaces	User Costs as Compared to Other Access Modes	Speed or Time As Compared to Other Access Modes	Savings to Public
Minibus Parking Shuttle	Minibuses pick up airline passengers who have parked their cars in adjacent lots distant from the terminal building--now operational in Washington, D.C. and a number of other airports with large parking lots distant from the terminal.	Walking from the long-term parking lot to the terminal.	Usually no cost, except for parking; on occasion tips are solicited. Thus more expensive than bus or limousine if parking fee is high or parking charge accumulates. Probably parking charge at airport would be higher than for satellite lots.	Faster than walking from very distant lots; a great assistance when heavy luggage is involved.	Could operate to alleviate terminal road congestion associated with loading and unloading passengers and luggage from autos at terminal entrance.

. Impact on Disadvantaged

These facilities appear directed at businessmen, middle and upper income individuals who make frequent use of airport facilities. Over 50% of air travel involves a business trip; therefore ground arrangements are set up to meet this demand: service to midtown and suburban hotels and offices. Satellite parking lots would serve air passengers living in the suburbs, including businessmen, most of whose trips originate from home, rather than the office. The minibus parking shuttle also would serve middle income groups who drive to the airport and leave a car while on the air trip. Only Dial-A-Bus and conventional bus service would potentially aid the transportation disadvantaged. This assistance would occur principally as the result of providing airport employees with access to their jobs, assuming that a number of them are low income employees and that the service would penetrate low income residential neighborhoods. The low marginal cost of either service might make it possible to charge a lower fare to low income airport workers.

. Environmental Impact

Dial-A-Bus and conventional bus and limousine operations carry greater volumes of passengers per vehicle than individual autos and single-passenger taxis, which are the other much-used modes for reaching airports. Satellite parking lots would lead to some increase in passengers per vehicle, since a bus or limousine would be used for the long, line-haul portion of the trip. Thus some minor but positive impact on environmental pollution would result from a net decrease in vehicle miles of travel.

. Safety Impact

Bus operators have much better driving records per vehicle mile than the average automobile driver. As auto drivers are diverted to buses and limousines for their airport transportation, safety records on airport-bound trips will improve. This safety advantage is probably very minor.

. Speed or Time

No claims of reduced trip time or increased speed are given. In certain instances-- satellite lots, Dial-A-Bus, minibus shuttle and the like-- trip time will probably be slightly longer when compared to door-to-door taxi or private auto trip times.

. Volume

All these systems, with the exception of the minibus parking shuttle, would increase the number of passengers carried per vehicle when compared with the other principal modes used to reach the airports-- taxis and private automobiles. This increase in volume carried could result in reduced congestion on the airport access road (the freeway or other highway leading from areas of concentrated population to the airport), and the roads within the airport itself that lead to the terminals and parking facilities. This reduction of congestion might be considerable. At Logan Airport in Boston, for example, approximately 25% of all persons arriving by automobile were delivered by taxi.

Diverting some portion of these trips into more space-efficient modes may have some effect on the capacity of existing facilities. For example, a Dial-A-Bus or limousine could carry about 4-9 times as many passengers as the taxi or automobile carrying one passenger. A bus could carry between 45 and 53 passengers.

In general, the greater increases in capacity or volume would be directly proportional to the incidence of airport-bound traffic on a particular facility. A road such as the Dulles access, devoted exclusively to airport access, would be expected to show marked increases in capacity when certain of these techniques were adopted. Roads used for general traffic (Bayshore Freeway in San Francisco) would not show much change since general traffic would remain unchanged. Similarly, the impact on the entire region would be minimal since such a small number of total trips are going to the airport.

A second aspect of volume would be parking capacity. The facilities for parking cars adjacent to busy airports are more and more severely taxed. Use of satellite facilities would provide an almost unlimited expansion of parking capacity.

It should be noted in concluding that the ability of airports to better organize arriving and departing travelers will improve the efficiency of any of the adopted techniques. Such organization might include special lanes for buses and limousines, checking luggage on board vehicles, special loading area, etc.

Conclusions regarding volume are all, of course, subject to the restraint that travelers must be attracted to alternative means of access if the alternatives are to be effective. This is discussed further in Section VII.

- State-of-the-Art

None of the systems mentioned, except Dial-A-Bus, seem to have technical problems that need further development. Certain questions remain about the technical practicality associated with sophisticated dispatching, routing, and scheduling (see Dial-A-Bus Analysis - Appendix B). Feasibility studies to analyze the economics of the system and the potential market are necessary for individual applications.

- Institutional Background

Occasionally in the past, taxi, limousine, and conventional bus operators have collided over who should receive franchises and rights associated with airport travel. New techniques and modes or service patterns would undoubtedly be subject to similar conflicts. In some cases, service beneficial to the public may be blocked.

Satellite parking may divert revenues from profitable airport parking lots which may cause some concern and resistance. However, airport land is quite valuable; there should be significant potential for converting this land to other revenue-producing functions.

. Traveler Response

It seems fairly safe to say that a large majority of airport patrons will continue to prefer the convenience, relative time advantage (even if slight), and privacy of the auto as compared to using public modes of transit to the airport. This is the major limiting factor in the usefulness of the access alternatives discussed.

Some parking lot shuttle services and limousine services that are in operation today are fairly well patronized, others are not. As with other applications of public transit service, the circumstances of the particular case must be subject to feasibility analysis or trial operation to determine the potential. The proposed access mode with the largest untried potential-- because of its door-to-door convenience-- may be the many-to-one Dial-A-Bus.

III. SUMMARY AND CRITIQUE

The four concepts discussed above are representative of non-capital intensive alternatives for providing transportation to and from airports. Most are relatively low cost (major exception purchase and paving of satellite parking lots), and offer reasonable service systems. In some cases user costs would drop (satellite parking, limousine, bus, etc.) from that normally associated with private auto plus airport parking or taxi.

It would be expected that travel time would stay the same, at best, and in many cases actually increase over private auto or taxi.

Metropolitan-wide decrease in congestion is unlikely to be effected by introduction of these techniques, but capacity of the airport to absorb and distribute passengers, workers, and visitors would be increased.

In general, airport access improvements such as discussed here are reasonable, if probably unpopular, alternatives to continued high cost airport access solutions such as expanded parking lots and new roadways.

It goes without saying that any effort to improve the movement of people and vehicles throughout the metropolitan region can have a positive impact on the movement of airport-bound traffic.

CHAPTER XVI

AUTOMATION OF BUS SCHEDULING

Operating Description and Summary of Findings:

Current manual bus scheduling procedures are extremely slow and inefficient. As a result of this archaic technology, it is almost impossible to make major route and schedule changes in the medium sized and larger bus systems. Assignment of men and vehicles is accomplished in an inefficient manner and route patterns are not easily changed in response to changes in the patterns of origins and destination.

It is thought that automation of this procedure, chiefly through computerization, would improve the frequency and thoroughness of schedule revision.

Major obstacles remain in the way of implementation of this technology. First, the computer programs and related techniques have not been perfected although current research promises near term results. Second, inertia within the transit industry and active resistance from unions means that implementation will not easily be achieved. While the implementation of this technique is moderately costly, if successful it could generate definite savings to transit operators. Its major advantages however, are more likely to accrue as the result of facilitating widespread reorganization of transit service necessary in any plan of providing faster and more convenient transit service to urban residents. This technique may well be essential to the success of any plan of reorganization or extension of transit service as alternatives to present pattern of private transportation.

I. INTRODUCTION

Scheduling of the nation's bus fleet and the men who operate it remains a difficult, time-consuming, archaic practice. In most instances it is carried out by manual procedures which have not changed in operation for half a century. As a result, most cities operate essentially the same pattern of transit routes and schedules as they did many years ago. Minor adjustments, dropping a run, adding a run, or extending a line are handled through timeless manual procedures, but the process is usually slow and inefficient.

A more efficient technique for scheduling would serve to reduce the operating costs of transit systems and permit more efficient reassignment of vehicles and men to meet changes in demand brought about by changes in the urban environment, including shifts in the pattern of employment and residency. It is thought, therefore, that improved scheduling procedures would lead to improved levels of transit service without exaggerating existing costs or requiring expansion of existing investment in capital facilities.

Scheduling, as used in this paper, refers to three distinct processes:

(1) Data Collection
(2) Vehicle Scheduling
(3) Manpower Scheduling

Data collection is essential in order to know when and at what time people desire to travel by transit. Generally speaking, there are two ways to obtain this information. First, long-range projections are developed for expected future travel patterns of citizens. In this way changes in patterns of origins and destinations can be detected and theoretically transit schedules are modified accordingly. The other technique of data collection, more frequently used and oriented towards short term schedule changes, is on-board data collection. Information is gathered on where passengers are boarding, the number of passengers boarding, the time of day and occasionally miscellaneous other data.

Vehicle scheduling is simply assigning buses to cover routes which will coincide with the patterns of travel of citizens identified above.

Manpower scheduling involves assigning drivers to vehicles so that all routes and schedules are covered. Manpower scheduling is by far the most difficult element in scheduling because of the objective of having as many drivers as possible working straight eight-hour shifts. In that way there are no penalties, economic or other, for the transit operator when drivers are unable to work the full shift or are transferred to several different buses during the day. Naturally, there are union regulations which govern manpower assignments.

Work now underway sponsored by the Urban Mass Transportation Administration and being carried out by the MITRE Corporation may provide efficient computerized procedures to handle all three of these tasks. If such techniques can be wisely utilized in all possible ranges of schedule revision -- from minor adjustments to major system overhauls -- transit service can be rescheduled frequently to meet the changing demands of the metropolitan area that it serves. The end result of such flexibility is to provide a responsive transit system which may reduce needs for more undesirable or costly transportation modes.

- <u>User Price Impacts</u>

There is little likelihood that bus riders will benefit through improved fare structures as the result of improved scheduling. The provision of service more nearly tailored to the needs of the population served can help only to make transit service more attractive and may in this sense postpone fare increases which are necessitated by climbing transit operating deficits. However, this may be only a remote possibility.

- <u>Implementation Costs</u>

It is difficult at this time to estimate the actual cost of implementation of advanced computerized scheduling. Developmental costs are being assumed at the present time by the federal government. Cost of installing the eventual system on an individual operating property will depend on a number of factors. The principal cost element will be adapting software to meet the needs of a particular transit operator's scheduling department, and these costs will vary with the size of the property and with the extent of existent in-house software capabilities. In addition to the basic software, it will be necessary to provide the appropriate system hardware. It may be possible to use in-house equipment or remote data processing facilities by means of a variety of techniques. Costs for such hardware will again depend on the size of the transit operation and the extent to which existing hardware systems can be utilized. Such costs could run into the hundreds of thousands of dollars.

Data collection devices are available which will count people and indicate heavy loading points. The output of such devices are usually compatible with the computer facility used in scheduling. These devices based on conversations with those familiar with their manufacture, are estimated to cost several hundred dollars each. In many operating configurations only a small number of such devices are needed since they are switched about from bus to bus during the course of an evaluation period and need not be installed on all vehicles at all times.

In most cases the use of computer technology to handle scheduling will require extensive training or re-training of existing schedule departments. Costs associated with this should not be minimized.

- <u>Operating Costs</u>

Costs associated with operating computer scheduling are difficult to estimate at this point since no actual facility is currently in operation. It can be stated, however, that given an equal degree of output efficiency, the computer system would have these cost characteristics:

(1) Costs of using the system should be equal to or lower than present normal scheduling costs on the larger transit properties.

(2) Given the same amount of data collection and assuming full use of mechanical passenger counters, data collection costs should be considerably reduced for those systems that do a reasonable amount of passenger counting.

(3) For smaller systems, particularly where there is no existing computer facility, and where, for all intents and purposes, there are no data collection efforts, costs of using computer systems could well be higher than with manual techniques.

(4) It may be necessary to adjust union contracts as a consequence of introduction of advanced scheduling procedures.

Significant total transit system operating efficiencies result from consolidation of schedules and operating manpower. It is estimated that industry as a whole could save about three precent of its annual operating costs through provision of automatic scheduling and increased efficiencies.

Building block component programs in the computerized scheduling system have been tested at various times on properties in Chicago, Baltimore, and Washington, D.C. Indications are that savings from such limited applications run between one half of one percent and 1.5 percent in actual operation. It is expected that when complete operation of these scheduling techniques are tested, the savings will be even greater as a result of compounding.[1]

- Other Costs

It appears at this time that there are no significant non-economic costs associated with the implementation of computerized scheduling.

- Indirect Economic Effects

Perhaps more critical to the community will be the indirect economic benefits associated with greater flexibility in schedule making. Swift reaction to changing conditions, such as economic circumstances, new industry, changes in residential development patterns, etc., call for adjustments by transit operators. In many cases, rapid rerouting of the system cannot be accomplished. The provision of computerized scheduling procedures should make this a reality. The better service expected should be able to provide potentially greater mobility to many disadvantaged and ordinary commuters alike. As a result of this, one could expect a greater convenience factor for transit, and this has been shown to be a primary motivator in choice of transit as the commuting mode.

A second important indirect economic benefit is the opportunity for transit operators to keep existing ridership and possibly develop new revenue. Too often the inability to quickly change routes and schedules to meet new needs means that travelers are denied the opportunity to use transit.

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[1] Vehicle Scheduling and Driver Run Cutting, Rucus Package Overview, MITRE Corp., September, 1971.

Delay in adjusting to such situations permits the automobile too often to become the predominant mode in a particular area.

- Impact on Disadvantaged

A major complaint of the disadvantaged has been that transit service does not serve those destinations most relevant to their needs. In particular, in recent years, the shift in employment opportunities for low income workers to the outlying suburban areas, while the poor and other disadvantaged workers tend to live in the central city, may have prevented some work opportunities from being realized by the disadvantaged. In theory, better scheduling techniques would allow transit service to efficiently meet certain of these needs.

- Environmental Impact

Automated bus scheduling is not expected to produce any environmental impacts of consequence.

- Safety Impact

Little or no impact on safety is expected from improved scheduling.

- Speed or Time

It is not likely that average travel speeds will be improved. However, routes which are more responsive to travel demand may be more direct and thus provide an improvement in passenger processing efficiency.

- Volume

Some increases in volume could be expected if the efficiencies generated from computerized scheduling are used to extend service. The effective increase in capacity may be somewhat greater in specific instances. That is, shifting excess capacity which cannot be utilized from unproductive routes to areas where demand cannot be adequately served (i.e. frequent crowding) may improve the actual capacity substantially for those routes.

- State-of-the-Art

Techniques for automating scheduling are still in the developmental stage. Several specific test runs have been made on properties in Chicago, Baltimore, and Washington, D.C. However, no complete integrated system test has been made. Until such tests have been made, the complete technical feasibility of such a system remains open to question. It is anticipated that one to two years more developmental work will be undertaken in the present program carried out at the federal level before it can be said that such a system might be operational. However, despite many false alarms in the past about solving scheduling problems through the use of a computer, it appears that the present effort has definite near-term implementation potential.

- Institutional Background

Two sources of institutional resistance appear likely. First, the transit industry as a whole is heavily inertia-oriented. Convincing demonstrations and substantial motivation will need to be provided before transit operators will adopt the technique.

A second resistance area is associated with labor unions. Tendencies to decrease costs are generally seriously questioned by labor union representatives. Frequently, such attempts are also greeted skeptically by regulatory agencies and other public officials.

- Traveler Response

It is likely that demand characteristics will not change with the introduction of advanced scheduling techniques. Demand would only be indirectly effected by the implementation of computerized scheduling in that as service levels are generally improved transit will prove more attractive to users or potential users, and some additional growth in demand would be expected.

III. SUMMARY AND CRITIQUE

At this time the long-sought revolution in the expensive and time-consuming activity of transit scheduling may be near at hand. Unfortunately, results from limited tests are very skimpy and details on costs almost unknown. In reviewing the recent data on the system, it was noted that the package is designed to operate on large scale equipment. Since very few transit systems have general access to large scale processing equipment, it may not be feasible to extend the complete system to any but the largest systems, although some component programs can be operated on smaller equipment. Aside from the hardware problem, very few properties have personnel with sufficient technical expertise to operate the system, process the data, and interact between management and labor.

It is likely that a certain amount of system efficiencies can be realized through automation of scheduling. This, in turn, may result in various marginal benefits for transit operators and the community as a whole. Major efficiencies or widespread improvements in the rate of utilization of existing facilities are not likely to accrue from automation of transit scheduling per se. However, in order to accommodate the operation of other system improvements, including many discussed in other papers in this series, radical adjustment of existing bus service may be required. This radical adjustment will be difficult to accomplish without some technique such as computerized scheduling.

CHAPTER XVII

ECONOMIC PENALTIES AND/OR INCENTIVES

Operating Description and Summary of Findings

Regulation of demand for transportation facilities through policies of charging users different fees for road useage and/or parking is one suggested technique for reducing congestion and promoting use of more efficient transportation modes such as mass transit. Two techniques were reviewed here: Road pricing (both electro-mechanical and a license approach) and parking charge schemes.

Policies of establishing actual prices reflect differing philosophies. Some contend that prices should reflect actual costs including the costs associated with delay and congestion. Others contend that pricing should reflect traffic management objectives and would be raised or lowered according to the achievement of traffic management goals.

It is clear that incentives and penalties could be effective in reducing vehicle miles traveled and thus the attendant urban evils.

There are substantive reasons why immediate implementation is not likely. First, the technology of administration, operation, and enforcement has not been satisfactorily described or demonstrated. And serious questions about implementation techniques remain to be resolved. Second, for those "priced out" there must be a satisfactory transportation alternative. In few if any cities does the transit system meet this criteria. Third, public resistance, including charges of discrimination against low income and inner city residents has been severe to date. Finally, there is a real danger that hard pressed urban decision-makers may look upon pricing as a technique for revenue generation rather than traffic regulation.

I. INTRODUCTION

The concept of road or transportation pricing is based on the principle of assessing a vehicle user the true cost for his use of the public transportation investment, chiefly roads. The purpose for levying these fees, which would vary with the user's route and time of journey, may include

- Controlling the number of cars entering the central business areas
- Increasing trip speeds to a level acceptable to an optimal number of road users who will pay a premium for the privilege of using the road while other cars are excluded
- Encouraging public transit ridership
- Maximizing the usefulness of existing roadways
- Shifting some demand to off peak hours
- Encouraging car pooling
- Encouraging relocation of residences and/or employment

Reducing the number of automobile trips made during currently congested periods is a central theme of all of these objectives. However, some persons studying road pricing also hope that it can be set up to satisfy the additional goal of what they term equity: Whereby the road user and/or parker is charged an amount exactly equivalent to the costs to drive and park his vehicle. In this case rather than imposing a uniform parking surcharge or a peak hour road use fee, the automobile user would be charged for <u>any</u> use he made of the road. Determining what constitutes true costs is not, however, a straightforward problem.

The various elements which comprise true economic costs are described more fully later.

At this point it is useful to note that apportionment of costs can be done according to various formulas which will have differing impacts. For example, if total costs are apportioned on an hourly basis, the greater numbers of peak hour drivers will pay less, thus encouraging peak hour travel. If costs are apportioned on a time of use basis, then perhaps peak period users would pay more and would thus be discouraged.

Numerous other methods of allocating costs exist. The above examples show the complexity of the system and suggest that no matter which system is adopted, charges of inequity and unfairness might well be raised by the "injured" party.

Certainly road costs now are paid for on an "unfair" basis, but this is the status quo. A new system entailing publicity and requiring action for passage is more likely to be objected to.

Various pricing schemes, which may or may not satisfy the goal of equity, have been suggested as ways of meeting the urban goals mentioned at the beginning of this paper. Two basic types of pricing techniques have been proposed: road use pricing and parking changes. They are further discussed below.

A. Road Use Pricing

Under a road pricing scheme people would be charged for using all or certain sections of the street system. Fees could be based on the location of the road used and/or the time it is used. It is usually advocated that charges should be levied individually on each vehicle (with larger vehicles charged somewhat higher) so that carpooling and use of public transit would clearly lower per person out-of-pocket travel costs.

Cost, technology, and enforcement needs for road use pricing depend on the type of system used. Elements of several proposed road use pricing systems include:

1. Vehicle On-Board Systems - A meter which registers fees is attached to the vehicle; travel costs for the user of this system may be assessed through:

   a. Point Pricing - Costs are based on the number of impulses counted by the meter with these impulses received from electrical cables placed in or adjacent to the roadbed at various pricing points.[1]

   b. Continuous Pricing - Authorities would establish differential zones with vehicles being charged for the time or distance traveled in a zone and with zone changes registered by on-board meters. Again, road sensors would be required at all points on the roadway system to indicate zone changes.

2. Off-Vehicle Systems - Vehicles would be equipped with automatic identification devices which relay information on vehicle movements to a central computing station. Thus, actual calculating

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[1] G. J. Roth, "Paying for Roads: The Economics of Traffic Congestion," Second International Symposium on the Theory of Traffic Flow, OECD, London, 1963, p. 47

of vehicle fees is done off the vehicle. The cheapest way of transmitting the data on car movements appears to be by storing the data at pricing points and sending it to the computing center at convenient times rather than transmitting it there directly. The first method would save money because it eliminates the tremendous influx of data that would occur during peak hours if information was transmitted directly to computers. Thus, the need for expanded computer facilities to handle peak hour data is eliminated.[2] "Point pricing," "continuous pricing" or other techniques could be used with off-vehicle systems as a basis for determining prices charged.

3. Differential Licenses - Licenses, valid on a yearly or daily basis, allow a vehicle access to congested roads or zones. While cheaper and simpler to use than metering systems, they are not as comprehensive or precise. For example, under this system vehicles making short journeys through congested areas would be charged as much as vehicles making longer journeys in these areas.[3]

4. Present Road Use Pricing Systems - In addition to charges for vehicle licenses (a fixed charge) there are, and have been for many years, variable fees dependent on the amount the car is used which provide a current form of road pricing. These fees include taxes on gasoline, tolls on toll roads, and parking fees (see below). More widespread application is frequently mentioned as a means of implementing and achieving road pricing.

B. Parking Pricing Changes

Two forms of parking changes have been suggested:

1. Removal of all Parking Subsidies - municipally constructed lots and meters provide parking at costs below the going rates due to municipal savings on land taxes, maintenance costs, etc. Roth[4] contends that certain local authorities require that parking spaces be provided for planned buildings, even if the developer does not view the spaces as economically desirable. Thus, Roth points out, the user of the parking space is subsidized at the expense of those who have made the site available to the developer.

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[2] Ibid, p. 50

[3] Ibid, p. 54

[4] Ibid, pp. 131-2

2. Imposition of a Parking Surcharge - this method has the aim of discouraging those auto users who park in the city center from using automobiles. A surcharge has been proposed for cars parked all day in downtown Washington, D.C. and is currently in effect in San Francisco, California

Parking pricing changes are easier to implement than on or off-board vehicle pricing. But, as with differential licensing, the relative ease of operation is coupled with inequities. Such techniques as the parking surcharge do not reflect the true economic costs imposed by commuters driving to the CBD. Arbitrary fees, as have been proposed or implemented, do not reflect the true costs imposed by each commuter on society and may be oriented towards maximizing revenue to the city which, of course, is directly at odds with attempts to reduce congestion. Three examples of the inequity of usual parking surcharge schemes are listed here:

1. No matter how far the commuter drives to reach the CBD he pays the same surcharge. Thus, commuters who use more facilities or drive on particularly congested routes are charged no more than other drivers.

2. Parking charges apply to those vehicles which park in the CBD. However, vehicles which travel through the CBD without parking contribute to congestion but would escape being charged. In some cities through traffic may constitute a majority of vehicle miles of travel.

3. A parking surcharge would be difficult to apply to all parking areas in the CBD. For example, proposed parking fees may not be easily administered in government parking facilities or to private parking provided by building owners for tenant cars.

There are ways to improve the effectiveness of parking surcharges, but they are likely to increase the complexity and cost of administration substantially. And, any technique to charge through traffic would probably also be more efficient at charging non-through traffic than a separate parking charge system.

Issues associated with both road pricing and parking surcharge schemes will be discussed further in the section on processing efficiency.

In summary, pricing is designed to ration expensive capital facilities by diverting marginally valuable trips to other modes or times. Pricing may also provide a means of promoting use of other modes of travel such as transit or carpooling.

II. TECHNICAL EVALUATION

Since the concept of incentives and penalties is basically an economic one, the cost discussion will be lengthy. By way of beginning, this section will treat the problem of deciding how much to charge as set forth by the economists who have done research in the area or have written road pricing proposals.

Most of the research on road pricing has been done in England. A prime objective of these pricing inquiries was to determine how road pricing could be applied to decrease highway congestion.[5]

To decide what to charge, some idea of how much traffic would best be allowed on a road must be developed. Roth, a transportation economist, has set down a standard for optimal road capacity:[6]

- "The optimal economic capacity of a road network, at a given composition of traffic, is the level of traffic flow in it at which those who find it least worthwhile to use the network receive net benefits equal to the costs imposed by them on the rest of the traffic."

According to the above, the monetary value of each trip can be determined by the economic value of each trip and the value of the individual's time, (all other things being equal).

The cost imposed by each trip can next be computed. (For the purposes of this discussion, each trip taker has identical cost characteristics, i.e., same route, vehicle type, and is alone.)

Therefore, each trip imposes equal (except for the value of the driver's time) total costs on the system and on the driver. This total cost is the sum of:

a. The cost to the driver of making the trip:

1. fuel costs
2. wear and tear on the vehicle
3. value of his time

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[5] R. J. Smeed, Road Pricing: The Economic and Technical Possibilities, Great Britain Ministry of Transport, H.M.S.O., London, 1964, p. 1.a
Cost data listed in this reference paper are then given in British values (the data was derived from British studies), along with the U.S. equivalents. In order to better facilitate monetary comparison between the two countries, 1965 per capita GNP is listed here: U.S. - $3240; United Kingdom-$1550 (in U.S. Dollars).

[6] G.J. Roth, "An Economic Approach to Traffic Congestion", Second International Symposium on the Theory of Traffic Flow, OEDD, London, 1963, p. 309.

and b. the cost to other people (society) of the trip being made:

1. cost of providing the road itself
2. wear and tear on the road
3. extra cost to other individuals if congestion occurs:

    a. higher fuel costs (lower mileage per gallon)
    b. Loss of peoples' time, as translated into monetary terms

4. noise, dirt, fumes, and other environmental costs

These cost calculations presented from various studies tend to reflect simple models and do not take into account such costs as accidents and more minute user charges related to such effects as tire wear, etc.

The prevailing pattern currently is for each person to think of trip costs only in terms of section "a" costs. Those advocating road pricing, however, believe that both sets of costs must be considered. As Smeed admits, some of the cost figures can often only be estimated,[7] and calculating the value of drivers' time is especially difficult. Policy makers would determine, perhaps arbitrarily, those hard-to-quantify social costs of driving.

When both the value of the trip to the driver and the total trip cost are computed, the two can be compared. The only trips being made would be those in which the economic value of the trip is greater than or equal to total trip cost. Actual road prices, then, would be established at such a level as to assure that the economists' "rational man" would not take a trip if its benefits were less than its total costs, nor would he be restrained from making any trip with greater benefits than costs. (If some trips with greater benefits than costs were restrained, a waste of resources would probably result.)[8] Accordingly, trips for entertainment with a relatively low economic benefit might be postponed to time periods when road costs are lower (the off-peak). Of course, if such pricing policies were adopted and congestion reduced then road costs would decline somewhat during the usual congested time periods. When road costs decline, for some the lower costs would prove attractive and lower benefit trips would become once again more economically justified. Thus, presumably a balancing would take place so that at any given time only economically justified trips would be made. In this way individuals would constantly be assessed a price reflecting all private and public costs incurred in his use of the roadway. It seems likely that policy makers would interfere in the fluctuating market mechanism and set fixed, fairly permanent peak

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[7] Smeed, op. cit., p. 3

[8] Ibid, p. 2

hour prices to achieve desired traffic management objectives and to achieve manageable administration of the system rather than to satisfy the principle of charging users only actual costs at any given moment.

User Price Impacts

Roth [9] has calculated a tentative price for vehicles traveling in what are now congested areas. The price is specifically set to equal the costs of congestion "under the condition prevailing after the imposition of the new price."[10] Thus, congestion pricing would initially be a trial-and-error process since reaction of traffic to price variation is not currently known.

Vehicle user costs under road pricing might well remain the same as current vehicle user costs, Smeed contends. Vehicle license costs, fuel taxes, and parking charges might be adjusted downward to mesh with revenues collected from road pricing "so that the motoring population as a whole would pay no more than it would otherwise have done".[11] This is an interesting possibility. However, it may be difficult to achieve since it involves a delicate balancing of the fixed charges and congestion costs over population which is constantly fluctuating in time and space due to diversion obtained by road pricing. Such a flexible road pricing policy would have to divert trips in the peak hour and attract trips in the off-peak so that total collected revenue would remain the same and desirable levels of vehicle travel would be maintained. Pricing to divert users away from the peak hour can probably be accomplished but difficulty would likely be experienced in attempting to attract the requisite number of users in the off-peak. Thus caution must be exercised, as in the work done by Smeed, in drawing definite conclusions on the ultimate effect of road pricing on user costs.

To estimate costs that a road user might be expected to pay under road pricing systems, one has to know the valuation of the costs that the vehicle user imposes on other people when he makes a trip. This cost imposed on others can be broken down into:

1. Physical Roadway Costs:

   These costs vary according to the cost of the roadway and the number of vehicles using a facility per unit of time. One English source is quoted as saying these costs are about one half cent a mile in towns.[12] This source was not available for reference so it

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[9] Roth, Paying for Roads, p. 138 (Appendix 1).

[10] Ibid, p. 41.

[11] Smeed, op. cit., p. iii.

[12] Ibid, p. 3.

was not known how this conclusion was reached. Nonetheless, it does not appear that a single cost figure can be used since costs and traffic level are strikingly dissimilar from application to application. Urban freeway costs per route mile can range from under one million dollars to over one hundred million. However, for purposes of this study, construction costs between $2 million and $25 million per route mile will be considered, this being an acceptable range found in other sources.[13] Traffic levels were measured by using twenty-four hour volumes of between 9,000 and 60,000 vehicles. While the lower figure may well be too extreme for U.S. urban freeways, the higher figure is exceeded by documented figures.

Table 17-1 shows a range of user fixed costs determined by roadway construction costs and roadway volumes as cited above. It must be stressed that the vehicle charge per mile as shown in this table includes fixed costs only, thus omitting the congestion costs which would be assessed certain users.

2. Congestion Costs:

   These are the costs associated with delays due to the presence of too many vehicles on the road to allow optimal speed and density levels to be reached. Empirical data on congestion costs generated by heavy traffic conditions in London have been gathered by the Road Research Laboratory. Congestion costs include higher labor costs, loss of peoples' time, higher fuel and running costs, and reduced efficiency of utilization of vehicles and their loads.[14] Tables 17-2, 3, and 4, a set of three related tables, show estimates of fuel consumption at various levels of congestion as measured by average speeds, by starts and stops, and by slow-downs. These tables indicate the extra gasoline consumed by speed changes and the reduction in miles per gallon at low speeds.

3. Environmental Costs:

   A third category of costs are those associated with environmental pollution from noise, dirt, and fumes. It must be noted that this cost category is related to congestion costs since emission of pollutants increases with decreased speeds. Figure 17-1 shows

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[13] Wilbur Smith and Associates, Transportation and Parking for Tomorrow's Cities, 1966, New Haven, p. 108.

[14] Pennsylvania Department of Highways, Bureau of Planning Statistics, traffic count data (24 hour total on one major route - 72,513 for weekday non-holiday, 1969 data).

TABLE 17-1: User Fixed Costs Per Vehicle, Per Mile, According To Freeway Volume and Freeway Construction Costs (24 hours vehicle volume)

Gross Cost ($1,000,000)	Annual Cost 20 Year Amortization 8% compound interest	Volumes						
	24 hour (000)	9	20	25	30	40	50	60
	Annual (000)	3,285	7,300	9,125	10,950	14,600	18,250	21,900
$ 2	203,700	.06	.03	.02	.02	.01	.01	.01
$ 6	611,110	.18	.08	.07	.06	.04	.03	.03
$10	1,018,500	.31	.14	.11	.09	.07	.06	.05
$12	1,222,200	.37	.17	.13	.11	.08	.07	.06
$14	1,425,900	.43	.19	.16	.13	.10	.08	.07
$16	1,629,600	.49	.22	.18	.14	.11	.09	.07
$18	1,833,300	.56	.25	.20	.16	.12	.10	.08
$21	2,138,850	.65	.29	.23	.19	.14	.11	.10
$25	2,546,250	.77	.35	.28	.23	.17	.13	.11

TABLE 17-2

Automobile Fuel Consumption as Affected by Speed and Gradient - Straight High-Type Pavement and Free-Flowing Traffic [1]

Uniform Speed (MPH)	Gasoline Consumption (GPM) on Grades of:										
	Level	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
(a) Plus Grades											
10	0.072	0.080	0.087	0.096	0.103	0.112	0.121	0.132	0.143	0.160	0.179
20	0.050	0.058	0.070	0.076	0.086	0.094	0.104	0.116	0.128	0.144	0.160
30	0.044	0.051	0.060	0.068	0.078	0.087	0.096	0.110	0.124	0.138	0.154
40	0.046	0.054	0.062	0.070	0.078	0.087	0.096	0.111	0.124	0.140	0.156
50	0.052	0.059	0.070	0.076	0.083	0.093	0.104	0.118	0.130	0.145	0.162
60	0.058	0.067	0.076	0.084	0.093	0.102	0.112	0.126	0.138	0.152	0.170
70	0.067	0.075	0.084	0.093	0.102	0.111	0.122	0.135	0.148	0.162	0.180
(b) Minus Grades											
10	0.072	0.060	0.045	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
20	0.050	0.040	0.027	0.022	0.021	0.021	0.021	0.021	0.021	0.021	0.021
30	0.044	0.033	0.022	0.016	0.014	0.013	0.013	0.013	0.013	0.013	0.013
40	0.046	0.035	0.025	0.018	0.014	0.012	0.012	0.012	0.012	0.012	0.012
50	0.052	0.041	0.030	0.025	0.021	0.018	0.013	0.013	0.010	0.010	0.008
60	0.058	0.048	0.036	0.037	0.030	0.027	0.018	0.018	0.014	0.011	0.008
70	0.067	0.058	0.048	0.043	0.039	0.036	0.027	0.027	0.022	0.016	0.013

[1] The composite passenger car represented here reflects the following vehicle distribution: Large cars, 20 percent; standard cars, 65 percent; compact cars, 10 percent; small cars, 5 percent

SOURCE: P.J. Claffey and Assoc., Running Costs of Motor Vehicles As Affected by Road Design and Traffic, NCHRP Report No. 111, p. 17-19

TABLE 17-3

Excess Gallons of Gasoline Consumed Per Stop-Go Speed Change Cycle-Automobile[1]

Speed (MPH)	Excess Gasoline Consumed (Gal) by Duration of Stopped Delay (SEC):[2]						
	0	30	60	90	120	150	180
10	0.0016	0.0021	0.0026	0.0031	0.0035	0.0040	0.0045
20	0.0066	0.0071	0.0076	0.0081	0.0085	0.0090	0.0095
30	0.0097	0.0102	0.0107	0.0112	0.0116	0.0121	0.0126
40	0.0128	0.0133	0.0138	0.0143	0.0147	0.0152	0.0157
50	0.0168	0.0173	0.0178	0.0183	0.0187	0.0192	0.0197
60	0.0208	0.0213	0.0218	0.0223	0.0228	0.0233	0.0238
70	0.0243	0.0248	0.0253	0.0258	0.0263	0.0268	0.0273

[1] See footnote, Chart 2, for identification of composite passenger car.

[2] Fuel consumption while stopped is idling fuel for composite car (.05 gph).

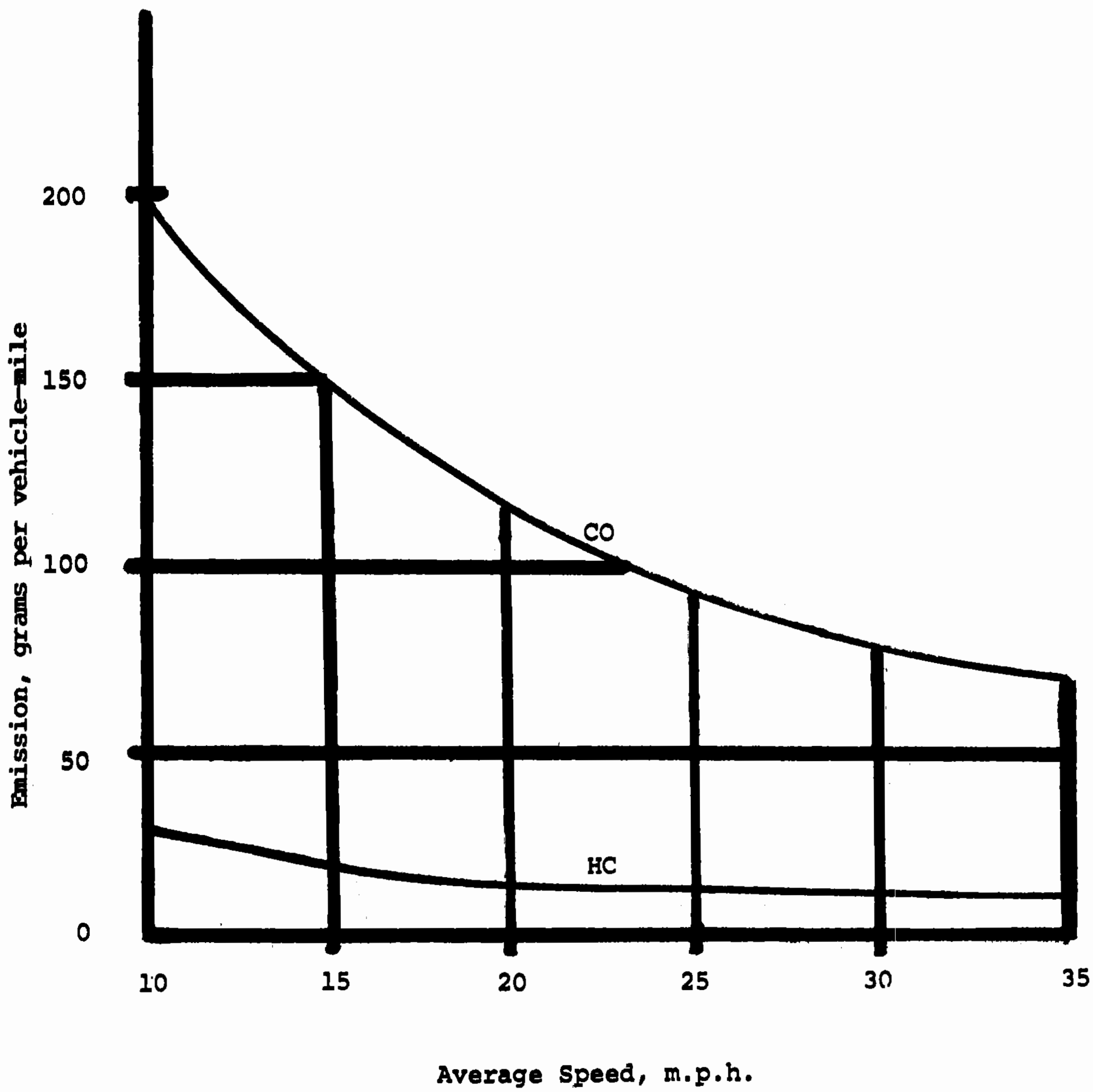
TABLE 17-4

Excess Gallons of Gasoline Consumed Per Slowdown Speed Change Cycle-Automobile[1]

Speed (MPH)	Excess Gasoline Consumed (Gal) by Amount of Speed Reduction Before Accelerating Back To Speed (MPH):					
	10	20	30	40	50	60
20	0.0032	—	—	—	—	—
30	0.0035	0.0062	—	—	—	—
40	0.0038	0.0068	0.0093	—	—	—
50	0.0042	0.0074	0.0106	0.0140	—	—
60	0.0046	0.0082	0.0120	0.0155	0.0190	—
70	0.0051	0.0090	0.0130	0.0167	0.0203	0.0243

[1] See footnote, Chart 2, for identification of composite passenger car.

Figure 17-1: Relationship of Carbon Monoxide and Hydrocarbon Emissions to Speed



Source: A Guide for Reducing Air Pollution through Urban Planning EPA, Office of Air Programs, December 1971.

the relationship of carbon monoxide and hydrocarbon emissions to speed. The chart suggests that raising the average speed in a congested area from ten to fifteen miles per hour would reduce the amount of CO emissions by 25 percent. Pollution costs imposed by congestion are then rather substantial and can be reduced by raising average speeds and reducing slow-downs and stop and start conditions.

4. Other Costs:

It may be desirable to charge users a price which is higher than might be calculated by the above criteria. These surcharges may reflect the desire to radically change travel modes, employment and residence patterns or other planning objectives which are not strictly related to "paying as you go."

In summary, user costs will vary in relation to remaining demand. (Remaining demand is defined as the level of demand willing to share actual or arbitrary costs after pricing has been imposed.) Under plans of true pricing, user costs will probably vary greatly but would have these characteristics depending on the pricing policy selected:

- During peak periods, costs would probably be highest of all, reflecting the first three categories of cost mentioned above.
- During off-peak periods costs might still be fairly high since fixed costs might be distributed among few users even though variable costs would be low.

Since decision makers may be more interested in reducing congestion and unfavorable environmental impacts, they may neglect to establish and impose fixed cost levies in which case road use charges would rise almost directly proportional to increases in total user demand.

Another estimate of costs imposed by road users is from testimony by Peter S. Craig, former Assistant General Counsel of the U.S. Department of Transportation.[15] Craig says that the city subsidizes each commuter to the extent of $5.00 a day (the article does not say whether this is based on one commuter per automobile). The $5.00 goes to:

- highway construction
- loss of tax revenue from land used for highways (30 percent of city land may be dedicated to highways)

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15 "The Washington Post," "Proposal to Tax Parking in D.C. Stirs Hot Debate," April 5, 1972, pp. A1, A14.

- highway maintenance:

  - snow removal
  - street cleaning

- traffic police

User costs for parking would also be affected if road pricing were adopted. Roth feels that the costs for the spaces should be set at levels that would create 85 percent average occupancy. Prices reflecting other occupancy rates could alternately be established, if found desirable. The eighty-five percent figure was chosen in response to two principal considerations:

(1) if occupancy were higher than 85 percent, these sources contend, spaces might be somewhat difficult to locate. Congestion and "mobile parking" would result, thus undermining the aims of pricing. (2) Occupancy under eighty-five percent would indicate that parking space was under-utilized. Under-utilization is another problem that pricing seeks to eliminate. In order to sustain this occupancy rate pricing must be flexible, changing for various hours and days. Other considerations are also important in determining parking pricing. If parking charges are part of a complete road pricing system, then the fees charged would only be expected to cover the costs incurred by the stationary car. If a parking fee is the only component of a "road pricing" scheme, however, the fee would be expected to be higher and cover costs incurred by the vehicle when it was moving also. A second important issue concerns the economic scheme into which the metering pattern fits. The actual costs incurred in providing on-street metered parking involve these items:

1. purchase and installation of meters

2. collection of fees and maintenance of meters

3. enforcement of meters against violations

Costs of building and maintaining the roadway itself are not included here. Parking is presumed to be allowed only at non-peak periods when the lane is not needed to carry traffic.

If meter fees are levied and revenue from them does not equal the costs listed above, then the parking is underpriced in that the fee charged is insufficient to meet costs. However, even if the fees are raised to a level equal to costs, the metered parking may be underpriced in another way. If nearby commercial off-street parking is priced higher than the metered parking, then metered parking is underpriced as far as what the market will bear. Road pricing, if adopted, would probably readjust all parking charges to reflect total economic costs of parking and/or road use.

Roth[16] proposed a simplified set of user road pricing costs that could be imposed in the early stages of implementation and which, Roth claims would somewhat undervalue congestion costs. This undervaluing of costs would make road pricing more easily accepted than if it were introduced at full costs. He suggests that in congested areas with speeds of fifteen to twenty miles per hour, the fuel tax should be raised beyond the level merely needed to cover road use costs. This congetion tax might be 1s.2d (16¢) a gallon, giving a 2s0d. (28¢) total tax cost, including the 10d. (10¢) to cover road use costs. In more congested areas, the recommendation is for a 6d. (6¢) a mile tax rate (with present speeds twelve to sixteen miles per hour) and 8D (8¢) a mile (where present traffic speeds are twelve miles per hour or less). However, there may be some problem in getting people to buy their gasoline at the point of congestion.

In summary, no firm conclusions can be made as to how driving costs, with road pricing in effect, would compare with current driving costs. However, the important variables affecting user costs are:

1. The type of road or parking pricing policy adopted:

2. The policy on what constitutes costs (fixed costs <u>and</u> congestion costs). The ultimate utilization of road pricing revenues: if these revenues are used to reduce other costs such as vehicle registration or tire excise tax this will obviously affect the driver's costs. If revenues are used for non-transportation purposes, then the charge becomes an additional burden.

3. Driver usage pattern changes: user costs will be strongly affected by user reaction to pricing: switching to carpools or mass transit, or changing journey times to non-congested hours will lower individual user costs. For the remaining auto drivers the costs may well go down if substantial congestion allevation is obtained, or under a vehicle pricing plan go up as fewer and fewer vehicles are left to share costs.

Final judgement in absolute terms on user costs is not available pending more definite studies of particular applications.

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16 Roth, <u>Paying for Roads</u>, pp. 56-7

Implementation Costs

A. Road Use Pricing

1. Vehicle On-Board Systems

a. Point Pricing

Meters cost £ 5-15 ($14-42) ea. depending on whether they are equipped to display accumulated charges. With approximately 10 million vehicles in Britain in 1964, total cost would have been £ 5 million + ($14 + Million) for the meters. Road equipment costs are £250 per pricing point. The number of pricing points required to cover urban areas in Britain, it is estimated, is 20,000. These points would cost approximately £250 ea. ($700) so that the total cost of point set up in England would be 20,000 points @ $700 ea. = $14 million. In 1970, eighty-nine million automobiles were registered in the United States.[17] At a cost of $14-42 each, the total cost of meters for these cars would be between $1.2 billion-$3.5 billion.

b. Continuous Pricing

Meter cost is 30s ($4.20) for a manual meter (actuated by the driver when changing pricing zones). Cost is £3-5 ($8.40) for each automatic meter, £10 ($28.00) for a clockwork timer--this meter is rewound, or exchanged, when run down with payment of a road charge at a "meter station" [Smeed estimates a cost of £8-10 ea. ($22.40 - 28.00) for such a meter.]

2. Off-Vehicle Systems

William Vickrey submitted a set of cost estimates to the Congressional Joint Committee on Washington Metropolitan Problems in 1959. The following cost estimates, then, are from that year. Many technical and system operating efficiencies have been introduced into data processing over the last decade, thus cutting costs. However, it

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[17] M. Harth and T.M. Bernstein, Family Almanac 72, New York, New York p. 593

is not known whether cost reductions from increased operating efficiencies were substantial enough to counteract inflation. Costs given are for the Washington, D.C. area only.[18]

a. Central processing equipment (this figure represents the cost for tapes and computer processing. The computers will process data indicating which cars passed certain electronic monitoring devices at which time)	$9 m.
b. Peripheral detection and recording equipment (sensing devices installed on the roadways at pricing points)	$4.5 - 8 m.
c. Response blocks (the on-vehicle devices that indicate to the roadway sensors the identity of the vehicle being registered by them)	
Approximately 2 million @ $20 ea.	$40 m.
TOTAL (a maximum figure)	$60 m.

3. Differential Licenses:

Implementation costs for a system of differential licenses should be low but exact figures are not known.

B. Parking Pricing Changes

Many different variables affect the costs of parking pricing. If a metering scheme were adopted, parking times, zones, and prices could be registered on the metering equipment.

[18] Vickrey, William. Cost Estimates submitted to the Congressional Joint Committee on Washington Metropolitan Problems, 1959.

If tickets or licenses had to be purchased in advance for journeys to the CBD during peak hours, extra fees for CBD parking could also be collected in advance.

Costs of using meters to enforce parking regulations is quite variable. Roth[19] quotes the cost for meters for a section of Westminister in metropolitan London:

> Installation (in approximately 1960) of 1,822 meters = £69,000 ($193,200) or about £38 ($106.40 per meter, including costs of necessary signs and road markings). Annual costs = £84,000 ($235,200) or £46 ($128.80) per meter yearly.

These costs include amortizing initial costs over a ten year period, full maintenance of meters, road markings, etc., plus salaries and expenses of employees. However, costs of enforcing the meters are not included in these figures.

A study done in the United States in 1968 listed cost per parking meter at $75 including installation, maintenance, and the expense of collecting and accounting for revenues. No life span for the meters was given nor was it indicated whether the operating costs were for the first year only.[20]

Enforcement similar to that provided by meters could be arranged by ticket issuing parking meters. These machines are similar to machines issuing tickets in parking lots. However, the machine in question is coin-operated. (They were being produced as early as 1964 by one British manufacturer.) Two of these machines could service a whole block previously covered by numerous parking meters. Also, no parking bays need be marked out. While Roth states that use of the ticket issuing meters will reduce costs as opposed to conventional parking meters, he does not list prices of these ticket issuing meters.

Operating Costs

A. Road Use Pricing

1. For on-vehicle road pricing systems the main operating cost would be: collecting money owed by the road users and guarding

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19 Roth, Paying for Roads, p. 106

20 Deleuw, Cather & Company, "Parking Study and Improvement Program for Three Business Districts," Chicago, Dec., 1968, p. 20.

against violations. Two basic alternatives for collecting money are: (1) that on-board metering devices be sold with a given capacity with replacements sold at various stores or garages; (2) that permanent meters be placed in cars with the car being taken to meter booths to be read and paid for. The literature available does not have cost estimates for either of the proposed alternatives.

Enforcement costs associated with on-vehicle road pricing systems have not been conclusively estimated. The consensus among those who have studied road pricing is that the amount of fraud in connection with metering charges will not be great. One argument made is that currently used gas and electric meters are similar to the proposed vehicle meters and that fraud seldom occurs in the use of these utility meters. A reasonably securely designed meter box with the method of operation of the mechanism not evident to users is seen as being important to deterrence, as is a system of regular and random checks of the meter. Prepayment of meter fees might well be used. One meter would be allotted per vehicle and the driver held responsible, thus discouraging him from tampering with the meter. The driver-operated meter (proposed for use in zone pricing systems) presents more of a chance for dishonest behavior. However, for a meter with good visibility characteristics, chances of a long-range avoidance of detection should be slim. For continuous pricing enforcement, vehicle meters could have lights which would indicate that the meter was functioning and that the proper zone color was used. Inspectors could be stationed at pricing points to make sure that drivers dialed the appropriate zone on their meters. Apparently, in 1967 there were automatic cameras being used in Frankfurt to photograph vehicles that ran red lights.[21] These cameras could be adapted for use in detecting meter-use violations. Costs of enforcement should be balanced out by reduced need for police to handle congestion, with cost saving in that area. One test estimated that conversion to road pricing would save $2.24 million in police costs for congestion control in central London alone. The time period over which the savings would accrue was not mentioned.

2. For off-vehicle road pricing systems the main cost would be in producing periodic billings of customers. This involves the operating costs of the central processing system plus administrative and clerical personnel needed in the billing and public relations capacities. The set-up would probably be quite similar to the telephone companies in the United States.

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[21] Roth, <u>Paying for Roads</u>, p. 58

3. Differential Licenses:

Differential license systems could be administered and enforced much like present licenses, inspection and related regulations. The degree of enforcement could be varied as the levels of congestion increase or decrease.

B. Parking Pricing Changes

Operating costs for parking pricing depend on the road-cost system that parking is linked to. With on or off vehicle metering parking would be another zone or charge. If meters are retained with fees adjusted to reflect different hours and locations, maintenance costs for meters and bays should not change too much. If coin operated meter ticket machines replaced regular meters, maintenance costs should drop since fewer meters would be required - perhaps only two meter outlets per block.

Enforcement costs associated with parking would be affected if any of the new systems were adopted. It has been suggested that limited-time parking spaces might well be eliminated in most areas since they probably do not contribute to easing congestion. A person's ability to pay for a space would be the criterion for whether a person parks and how long he parks. With no time limit on parking, enforcement costs now associated with checking for overtime parkers and writing out tickets would be eliminated.

These may well be reasons not related to congestion, however, for retention of time limit parking. Also, costs associated with enforcing payment of parking fees would remain in any case. But, as detailed under Operating Costs, Road Use Pricing road user charges should be fairly easy to collect. If parking charges were recorded on the same meter that records road use charges, the parking fees could probably be collected with little difficulty.

Other Costs

An important social consideration associated with the off-vehicle pricing system is that it would provide a record of information which is not currently available: a record of trips, when and where taken, for a particular vehicle. This information would be on file, and the billing would contain a long and detailed account of a person's driving activities (much as his telephone bill contains long distance towns and numbers). The information relating to vehicle trips may provide valuable input for increasing processing efficiency. Traffic engineers can work with trip data information to set user costs accurately, to change costs when necessary, and to provide optimal speeds and volumes in urban areas. However, the information might also be used for purposes unrelated to transportation, thus raising invasion of privacy questions.

Indirect Economic Effects

The first measure of indirect economic benefits to the community is in savings from higher speeds resulting from reduction and re-allocation of traffic. Smeed puts these benefits at $280-$420 million per year. These benefits fall into these categories: [22]

a.	Savings in paid work time (including crews of commercial vehicles and buses, and persons who travel during working hours)	+40% saved
b.	Other time savings (to and from work, shopping etc.)	+63% saved
c.	Savings in fuel and other vehicle running costs	+ 7% saved
d.	Less capital investment in buses since lessened congestion allows the same number of journeys to be made by fewer vehicles	+10% saved
e.	Losses to people who no longer make journeys they would have made without pricing	-20%
f.	Lower police enforcement costs due to less congestion	Variable

The completeness and accuracy of Smeed's list is questionable. For example, there is no estimate of savings from reduced need for new road facilities due to less road congestion. And, those items surveyed appear to benefit from overly optimistic forecasts.

Pricing may not have to be applied under most traffic conditions. Smeed argues that it need only apply to those times and places where speeds below twenty miles per hour exist. A desirable pattern of habits might form and remain because the tariff on peak hour travel is there. Such changes include people traveling at cheaper times, by cheaper routes, or by cheaper modes (transit). Commercial operators might make fewer trips, but with full trucks each trip (they rarely travel with full trucks at present). More commuters than at present might travel in carpools . In all these cases after congestion is reduced through these various means, the road pricing continues in force, thus insuring that congestion does not return.

In determining the exact mechanisms under which road pricing will operate, we must set up rather subjective standards. We know that some exceptions to road pricing will in all likelihood be established. The handicapped and the highest officials, for example, may well be exempted from charges or be reimbursed for what they have spent on road pricing.

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[22] Smeed, op. cit., p. 37

Also, a main requirement for success of the system is that alternate forms of transportation <u>must</u> be available. The prime target of the pricing system, after all, is the reduction of peak hour congestion. Most peak hour trips, particularly in the AM, are work trips. Tables 17-5 and 6 show the peak. During the AM peak in Memphis, 82 percent of cars parking in the CBD were driven to work. In the PM peak, however, 69 percent of the cars leaving the lot had been driven for the work trip. In Baltimore the figure for work trips during the PM peak was 65 percent of the total person trips. Very little chance for postponement or total cancellation of these work trips is possible. During the AM peak most inbound routes are quite congested, offering little opportunity for route switching.

One crucial alternative which should definitely be available is a frequently scheduled mass transit system which has routes or branches covering the entire metropolitan area, particularly in low and middle income areas. Otherwise the lower income workers, who have no flexibility as to what time they arrive at work and who have no adequate means of public transit available to them, will be the most heavily penalized by peak hour road pricing and unsubidized parking. Increased carpooling would probably improve their situation to some degree and reduce congestion somewhat. It appears that not only are the social implications of the pricing system suspect without an adequate transit system, but also the actual feasibility of pricing is at stake without good mass transit to handle the potentially large numbers of commuters who are diverted from automobiles. It is on the interchangeability of travel modes, then, that the success of road pricing may ultimately rest. It is unlikely that any city in this country has a fully adequate mass transit system which could serve as an effective alternative for those "priced out".

Perhaps some people would argue here that once commuters are diverted from automobiles and begin riding buses in fairly large numbers, new bus routes would surely be added. However, judging from past behavior of mass transit systems; their losses in ridership, fare increases, and inflexibility in routing and scheduling, it will be essential for the success of road pricing to have advance guarantees of transit cooperation (see Institutional Background discussion).

<u>Impact on the Disadvantaged</u>

Social benefits of a pricing system depend on the specific way in which it is carried out. <u>Per se</u>, it seems to have no special social benefits. Provision of an adequate public transit system is the key to social benefits. Arguments presented in this paper suggest that pricing will be impossible without comprehensive mass transit. Pricing without effective transit will prove onerous to the lowest income groups, for many low income people drive and park cars and would most likely be charged the same fee as the richest person is charged for doing so. Road pricing, if viewed as a tax, is regressive resting comparatively more heavily on the poor than the better off.

TABLE 17-5: Accumulation of Parked Vehicles By Trip Purpose
Memphis CBD

	Work	Other	Total	Work Trips as Percent of Total Trips For These Vehicles
Cars parked before 10 AM	8690	1960	10650	82%
Cars leaving 4:30-6 PM	5925	2633	8558	69%

Adapted from Table C-6, p. A-18, Harland Bartholomew and Associates, 1968, Volume 3 Comprehensive Parking Studies, Memphis Urban Area, Transportation Study.

TABLE 17-6: **PM Peak Period Person Trips**
All Modes - Baltimore

Person Trips	Observed	Work Trips As Percent Of Total Trips
Work	241,569	
Other	130,241	65%
Total	371,810	

From: Alan M. Voorhees and Associates, Inc., Development and Calibration of a Model for Predicting Peak Period Travel, August 1969, adapted from Table 3.1, p. 9

The non-economic impact of pricing on old, young, and handicapped is hard to assess. A city with less auto traffic would aid pedestrians, since there would be fewer impediments on pedestrian movement. There would be lower levels of air pollution for all. On the other hand, the transportation disadvantaged would be particularly impeded in meeting those travel needs not served by public transit.

Environmental Impact

Reduction of peak hour congestion through pricing should have a positive, though not readily quantifiable, effect on the environment. The two important factors in the reduction of pollution are: (1) The number of cars eliminated from the traffic stream due to carpooling and diversion to mass transit; fewer cars would mean less total pollution. (2) The speed at which the cars are moving; faster movement of cars on arterials would produce less pollution per vehicle.

The automobile moving at a steady thirty to thirty-five miles per hour produces a minimum of air pollution (see Figure 17-1). Minimizing the number of stop and start conditions and speed changes will also minimize pollution since more pollution is given off by an accelerating or decelerating internal combustion engine.

Noise is also minimized when vehicular traffic travels at low, steady speeds without accelerating or decelerating due to congestion.

These environmental improvements would particularly benefit central city residents where pollutants are more concentrated. Researchers have found that ghetto children are breathing air which has greater lead concentration than their suburban counterparts.

Safety Impact

Generally speaking, metering studies have shown that reduced congestion will improve accident rates. Similar accident rate reductions might be expected under a plan of pricing which served to decrease congestion. The extent of such reduction would depend on the plan involved and could only be guessed at this time.

Speed or Time and Volume (Joint Discussion)

The central purpose of road pricing is to relieve congestion particularly during peak hours by reducing vehicle volumes, thus increasing speed and reducing travel time. Calculations (rather than actual demonstrations) indicate that under certain conditions pricing would reduce volumes sufficiently to also increase speeds. Roth[23] writes that his calculations suggest these prices:

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23 Roth, Paying for Roads, p. 23

Present Traffic Speed	Suggested Price	Expected Traffic Speed with Pricing
12 mph	7d. (7¢) to 1s.0d. (14¢)/mi.	15 - 16 mph
10 mph	10d. (10¢) to 1s.4d. (18¢)/mi.	13 - 14 mph

These prices might divert sixteen to thirty percent of current vehicles, and raise speeds of remaining vehicles by three to four miles per hour.

Smeed suggested these figures in 1963:

Tolls: From 4d. (4¢) a mile when traffic speed is 20 mph to 6s.(84¢) a mile when speed is only 8 mph

Results: Changes in average speed.

Before Road Pricing	With Road Pricing	Reduction in Traffic Flow Needed To Achieve These Speeds
10 mph	14 mph	20 - 25%
14 - 15 mph	17 mph	15 - 20%

Smeed says, "there would be little purpose in extending direct pricing to roads where traffic speeds are already over twenty miles per hour. [24]

A suggested best parking surcharge is estimated to have this effect on traffic and congestion. [25]

6s. (84¢) a day	Percent Reduction in Traffic Volume	Speed Changes: Prior Speed	Speed Changes: New Speed
Off Peak	11%	10.7 mph	12.6 mph
Peak	7%	9.8 mph	11.1 mph

The main positive effect of parking charges would be to achieve an eighty-five percent occupancy rate. This rate suggests adequate utilization of parking facilities (not under-utilization) while allowing enough empty spaces so that congestion due to cars searching for space is largely eliminated. Although appropriate parking pricing, then, could have a positive effect on cutting down congestion due to circulation while searching for parking spaces and could reduce CBD congestion somewhat, sources used in this review warn against the use of a parking surcharge without road pricing. The reasons for this warning relates to the relative inequity of the parking surcharge as compared to general road pricing. Arguments to this effect were given in detail earlier in this paper.

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[24] Smeed, op. cit. p. 36

[25] Smeed, op. cit., p.

Calculations have been made to estimate effects of the proposed Washington, D.C., parking surcharge on automobile and transit use. Estimates were made on the effects of a $1.00 all-day tax covering government lots as well as private ones. The analysis suggested that a four to eight percent decrease in auto use would result from persons switching to transit, and that an additional four to eight percent decrease in auto traffic would result from persons forming carpools.

These percentages are based on the amount of traffic which is traveling to work sites in the surcharged area, and do not include traffic passing through the area, or non-work trips. Those who presented the data regard the four percent figure as being the appropriate estimate of the more immediate effects of the tax on transit and carpooling usage.

Amplification of the Washington, D.C. data follows:

The area under consideration (as of April 4, 1972) for imposition of the tax had 81,500 parkers who drove downtown for work purposes in 1968.

Allowing for an upward adjustment since that time, but excluding about ten percent of the drivers who stay for less than four hours, a total of 80,000 drivers remain who could be affected by the tax.

If four percent of these riders were diverted to transit, transit use would increase by 4,800 riders each way, a total of 9,600 daily. The combined reduction of eight percent due to increased transit use and increased carpooling would reduce total auto use by 6,400 vehicles each way daily.

No conclusive data is available as to speed and volume effects of the San Francisco parking surcharge. Apparently, the surcharge had little effect on congestion or on bus ridership. Vehicle counts, as observed by the traffic department, changed very little.

State-of-the-Art

A. Road Pricing

The numerous equipment systems appear to be technically feasible. For both on and off vehicle pricing systems, the theoretical operations of the systems, as described in the literature, do not sound particularly complex; the major problem is in actually constructing the systems and testing their operation -- problems may appear at that time. Until actual demonstrations have been completed, however, further certification of workability must be held in abeyance. A partial list of components needed for these systems is discussed below:

1. On board vehicle-point pricing:

   Vehicle meter - basically an instrument counting electrical impulses; probably solid state, could be exchanged when exhausted or else taken to a government station to be read and the money paid.

Pricing points - electrical cables carrying very low current would be laid across the road at these points and the impulses picked up by the vehicle via its meter. Cables could be laid out in groups so that the number of impulses received could be varied according to time of day., etc.

2. On board vehicle-continuous pricing:

Vehicle meter - would be switched on or off either manually by the driver or automatically by electrical impulses at price zone borders; in both cases the meters would carry a light to indicate they are switched on; the meters could be permanent and activated by a special purchased battery, or else temporary -- they would be rewound or exchanged when they ran down.

3. Off Vehicle System

Vehicle meter - "response block" (the on-vehicle devices that indicate to the roadway sensors the identity of the vehicle being registered by them).

Pricing points - "link tracers", static electric elements embedded in plastic blocks, would require no batteries or power connections; "interrogator apparatus would scan the road with electromagnetic waves, and reaction of the 'link tracers' would identify the cars carrying them." [26] One technological probelm brought up here is that the link tracer identifying a large number of different combinations -- possibly 30 million -- would present major difficulties.

Central processing - Data recorded by the interrogator apparatus would be transmitted to a computing center to be processed. Apparently, while data transmission can be worked out, it will require quite a bit of equipment. In all, the off-vehicle systems appear more complicated technologically than the on-vehicle systems. These systems of pricing do not suggest state-of-the-art difficulties:

"Stickers" or licensing ("Differential licensing") - daily or yearly

Elimination of parking subsidies

Consolidation of parking meters into coin operated ticket issuing stands

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[26] Roth, op. cit., p. 50

This state-of-the-art discussion must be concluded by stressing that none of the methods mentioned above have yet been made operational. Small scale trials of the pricing systems were proposed years age. Lack of operational examples or even small scale testing leaves serious gaps in the credibility of costs, benefits, and processing efficiency related to the suggested pricing systems.

Systems of enforcement and administration have not been tested sufficiently at this time to indicate which systems will have the most cost efficient administration and enforcement.

Institutional Background

These groups will probably be greatly affected by and react strongly to any pricing or parking costs changes or proposals for change:

1. Downtown (CBD) merchants' groups
   In San Francisco, for example, reaction by the Chamber of Commerce was strong enough to alter the set-up of the parking surcharge after it was in effect for 18 months. For the first 18 months the surcharge was 25% of the parking fee for cars using commercial CBD lots. The surcharge is now only 10% for short term parkers while long-term parkers still pay the additional 25% rate. The Chamber of Commerce claimed that the surcharge was diverting potential shoppers from the downtown shopping area.

2. Parking lot operators, both municipal and private

3. Organizations of or representatives from suburban commuters.

4. Taxi cab companies

5. Transit operators --they must provide comprehensive routings and scheduling to make transit a viable alternative.

The institutional problem with road pricing is highlighted by the fact that no area has yet adopted it.

A system of road pricing will probably be strongly resisted by most motorists and government officials. Some of the road pricing literature is almost ten years old, but not even a small scale test of the system has been conducted.

Traveler Response

Demand for roadway facilities will probably decline as prices rise. To some extent demand for less expensive road time will rise somewhat. Of course, this is the objective of road pricing.

Summary and Critique

Road use pricing, as outlined in various techniques in this paper certainly in theory, has the potential to reduce traffic volumes and increase speeds in congested CBD areas.

A major problem with the system is the lack of institutional and popular acceptance, which has resulted in no implementation of full-scale road pricing and only limited implementation of the parking surcharge. It is expected that heavy resistance will surround further attempts at implementation.

From the failure to implement this concept comes the second major shortcoming: the lack of practical data on processing efficiency, costs, and the other criteria on which a more reliable evaluation might be pinned. While the suggested technologies appear feasible, no realistic tests have yet been undertaken of the more esoteric which involve electronic or computer elements.

A third major problem is that adequate mass transit will be a necessary element for the success of total road pricing or a parking surcharge. Only with fully adequate mass transit can pricing be regarded as not having substantial regressive taxation effect on lower income groups. (There are probably few, if any, transit systems in existance that could meet the definition of "fully adequate.") Finally, the tendency of road pricing to be confused with discovery of a new source of municipal revenue by hard pressed urban decision-makers could seriously undermine and jeopardize the congestion abatement objectives of pricing.

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CHAPTER XVIII

URBAN GOODS MOVEMENT IMPROVEMENTS

Operating Description and Summary of Findings

Removal or redirection of truck traffic is one way in which additional roadway capacity may be made available in congested times or places. Three basic techniques were reviewed: (1) time of day restrictions (2) reducing the total number of trucks needed in urban areas and, (3) parking and movement regulations.

In general it was found that trucks did not constitute a significant enough portion of urban traffic such that removal, even allowing for greater size, would greatly improve other vehicle flow. It was observed however, that many of the techniques proposed for reduction of truck trips would improve the efficiency of shipping and receiving. Thus, while only slight traffic management benefits may be expected they may be achieved at little or no cost or may actually improve the economics of urban goods movement.

I. INTRODUCTION

Other reports in this study have focused on improvements in the modes of transportation which directly convey people. The concept discussed here, urban goods movement by trucks, has the same objective, but the focus is more indirect. The emphasis is on removing or at least reducing the demand for highway facilities by trucks during peak period transportation demand or in places with substantial continous congestion. In this way it is hypothesized that additional capacity for other more passenger oriented modes could be made available.

In this paper two distinct areas were isolated for study:

- Truck contributions to metropolitan wide peak period congestion.

- Truck contributions to congestion in parts of the city which are congested most of the day (such as certain CBD shopping areas).

In the following paragraphs an attempt is made to identify the extent and nature of congestion which might be attributed to truck traffic. As will be seen, however, conclusions and findings had to be drawn from indirect sources since so little useful data on these two topics is directly available.

To obtain perspective on the role of trucks in traffic, certain available general statistics are most useful.

First, it is interesting to note that trucks comprise about fifteen percent of all vehicles in the urban traffic stream. Seventy-one percent of the trucks observed in motion are light vehicles which behave much as automobiles. Medium and heavy trucks account for less than five percent of all the vehicles in average urban traffic stream. Medium and large trucks are generally considered to pose the most serious congestion problems. They are awkward and more difficult to maneuver than other vehicles; they have greater turning radii; and they are of larger size and have lower ratios of motor power to gross weight.[1] Thus trucks are a small but significant part of all traffic. In many cases, as will be pointed out later, a very small number of vehicles can seriously disrupt traffic.

In order to carry this quantitative analysis further, it is necessary to look at several indirect indexes of truck movement and to generate several plausible hypotheses. For example, Wilbur Smith & Associates put together a table which provides an aggregate set of figures on the number of trucks on the streets by time of day in eleven cities with populations ranging from 75,000 to 1,600,000. These studies, dated mostly in the 1960's, indicate that

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[1] Wilbur Smith and Associates, Motor Trucks in the Metropolis (under commission from The Automobile Manufacturers Association). New Haven, Conn., August, 1969, p. 87.

truck travel during peak hours of the day tends to be about the same or slightly less than in off peak hours. For example, truck trips beginning in the four peak hours of 7:00 AM, 8:00 AM, 4:00 PM, and 5:00 PM, comprise 6.7%, 9.7%, 7.6%, and 5.1% of all truck trips beginning between 6:00 AM, and 6:00 PM. On the average, one would expect from this data that about 7.6% of all total truck trips would begin at each hour from 6:00 a.m. to 6:00 p.m. (See Table 18-1).[2]

An analysis of medium and heavy truck travel during the four peak hours discussed above shows that at 7:00 a.m. and 8:00 a.m. about 7% and 10.9% respectively, of all medium and heavy truck trips begin in these morning peak hours. Data on the afternoon peak hours show about 6.4% and 3.1% of these trips beginning at 4:00 and 5:00 p.m. The expected average of 7.6% of truck trips beginning at each of thirteen hours during the day is exceeded in only one period, 8:00 a.m. Medium and heavy trucks are more likely to contribute to morning peak congestion than afternoon. It is significant to point out that truck traffic as a whole does not decline substantially during business day non-peak hours (See Figure 18-1).

While data on truck travel <u>per se</u> is reasonably good, the critical need for this study is data on the relationship between truck travel and overall traffic congestion particularly in peak hours. Data on this aspect of traffic behavior is poorly documented.

It is possible to obtain a rough, indirect estimate of the amount of additional traffic attributable to trucks during the peak periods of travel. Based on data taken from the Wilbur Smith report, <u>Motor Trucks In The Metropolis</u>,[3] the proportion of trucks in all traffic during the peak period varies substantially (See Figure 18-2). During the morning peak hours between 7:00 and 9:00 a.m., trucks comprise about eighteen percent of all traffic. In the evening peak, trucks range from a steadily decreasing high of about sixteen percent of all traffic at 4:00 p.m. to a low of about ten percent at 6:00 p.m. Since evening general traffic congestion is slightly greater than morning congestion, a decrease in truck induced congestion in the evening may be more than offset by the additional non-truck traffic. (In absolute numbers 4:00 to 6:00 PM truck trip beginnings decline about twenty-five percent when compared with the period 8:00 to 10:00 AM.)[4]

It is useful to further break down the truck component of all traffic into light truck traffic and medium and heavy truck traffic. Approximately thirty-seven percent of the morning peak period <u>truck</u> traffic is composed of medium and heavy trucks; in the evening this figure drops to about twenty percent. This means that roughly speaking, in the morning 7% of all traffic is composed of medium and heavy trucks and in the evening that figure declines to about 3% of all traffic (See Figure 18-2).

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[2] <u>Ibid</u>., p. 185

[3] <u>Ibid</u>., p. 55.

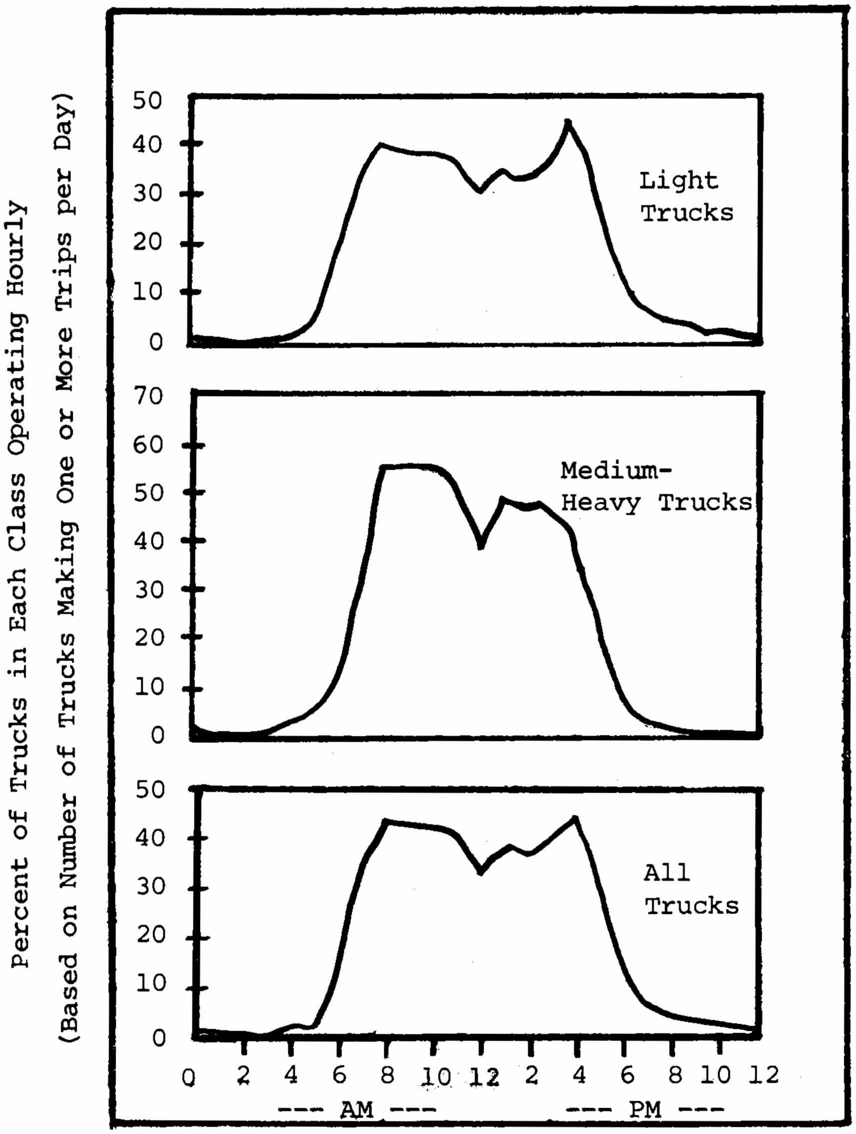
[4] <u>Ibid</u>., p. 52, 185.

TABLE 18-1: Percent of Truck Trips Starting Each Business Day Hour

By Time of Trip Hour Beginning	TRUCK CLASS Light	Medium-Heavy	Total - All Truck Types
6:00 A.M.	.032	.035	.033
7:00	.066	.070	.067
8:00	.091	.109	.097
9:00	.101	.116	.106
10:00	.104	.114	.107
11:00	.101	.109	.104
12:00 Noon	.079	.075	.078
1:00 P.M.	.090	.095	.091
2:00	.085	.088	.086
3:00	.076	.080	.078
4:00	.082	.064	.076
5:00	.061	.031	.051
6:00	.027	.010	.022

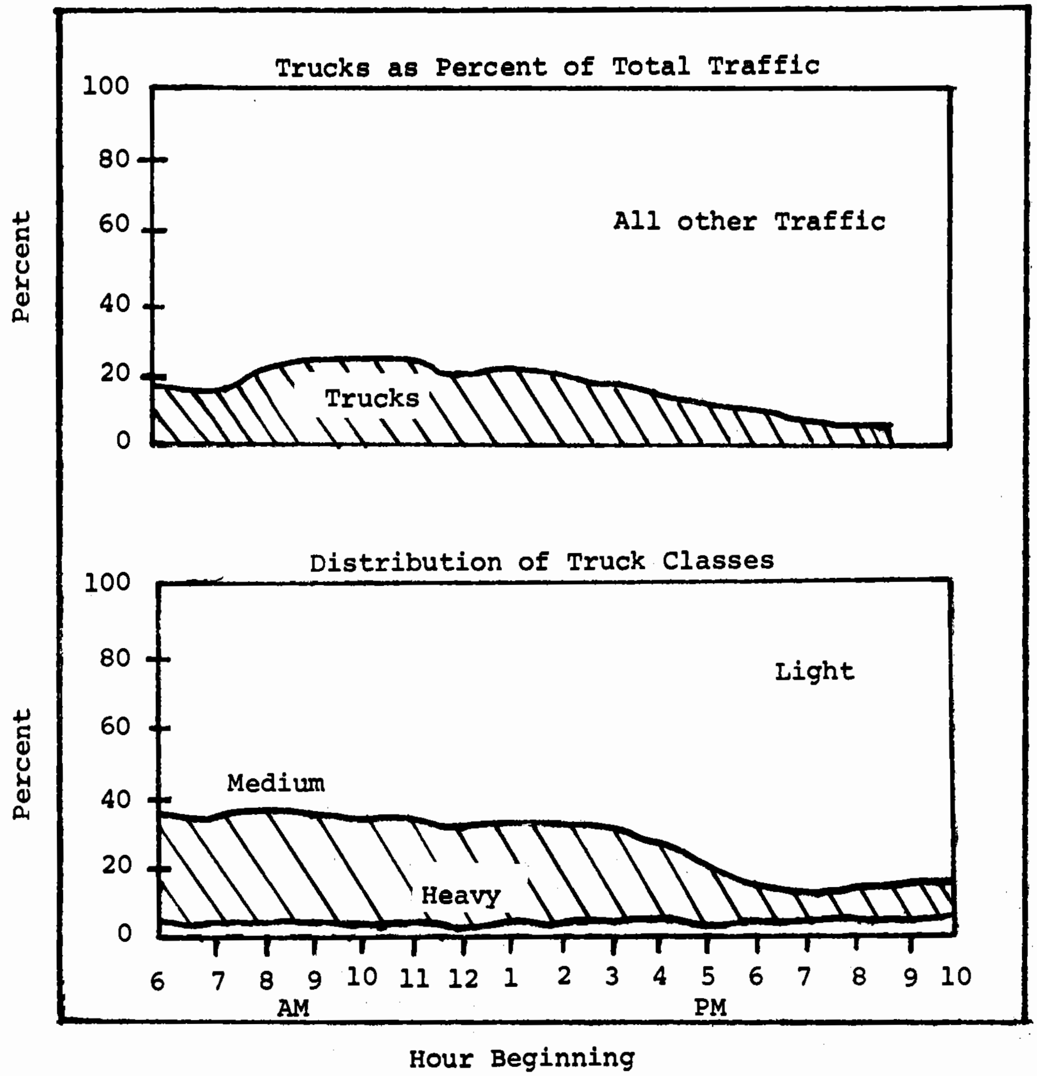
SOURCE: Percentage derived from Table A-7L, "Truck Statistics" in Wilbur Smith & Associates, Motor Trucks in the Metropolis, 1969, p. 185

Figure 18-1: Percentage of Truck Class in Motion by Hour of Day.



Source: Motor Trucks in the Metropolis, Wilbur Smith and Associates, 1969, p.55.

Figure 18-2: Hourly Variations in Truck Traffic as Percent of Total Traffic and by Truck Class



Source: Motor Trucks in the Metropolis, Wilbur Smith and Associates, August, 1969, p. 52.

Generally, medium and heavy trucks should be considered as equivalent to at least two average automobiles when considering their impact on traffic.[5] If we convert the previous statistics on travel during the peak to vehicle equivalent figures, then we can say that about 14% of the highway capacity use in the morning peak is attributable to medium and heavy trucks. In the evening peak this relative capacity use is about 5%. However, heavier vehicles are less likely to use oversubscribed commuter arteries. Data on land use and its relationship to truck traffic, for example, indicate that medium and heavy truck traffic is primarily attracted to outlying destinations such as plants and warehouses.

More specific data on the use of important commuter arteries by trucks is available from the District of Columbia annual cordon count. Information derived from the 1970 count on the relative proportion of trucks in peak and reverse flows on radial arterials is provided in Table 18-2.

A truck is defined in the D.C. Cordon Count as a goods carrying vehicle having more than two axles and/or dual tires on one or more axles. Essentially this is the medium and heavy truck category. Truck traffic in the District of Columbia may be somewhat affected by the lack of much heavy industry, but the relationships found between truck flows and peak commuter flows are probably not atypical compared to what one would expect on the approach to any large central business district.

As indicated in Table 18-2, the total D.C. cordon line truck count for the ten hour period of the count equalled 5.4% of all traffic. For individual sectors the corresponding percentage ranged from 2.7% for the northwest quadrant of the city to 7.0% for the southeast quadrant. However the percentage of trucks in the peak direction of peak hour flow was consistently about half or less the percentage counted for both directions over the total ten hour count.

Comparison of the absolute numbers of trucks counted in the peak and reverse directions and in the peak versus off peak periods indicates that it is not a lack of trucks that occasions the low peak period, peak direction truck percentages but rather the high peak volume of passenger vehicles. Nonetheless, medium and heavy trucks do appear to represent quite small proportions of peak commuter vehicle flows.

A major deficiency of available statistical studies of truck trips is that they fail to indicate actual truck impacts on highway peak hour commuting or to what extent removal would increase capacity and speed. The reduction of medium and heavy truck trips would appear to have only marginal benefits to the general traffic stream since light trucks constitute the majority of truck trips.

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[5] Charles A. Hedges, "Urban Goods Movement: An Overview," paper appears in "Proceedings: Twelfth Annual Meeting, Transportation Research Forum," 1971, p. 174.

TABLE 18-2: Percentage of Trucks in the Traffic Stream -- D.C. Cordon Count*

	Trucks as a Percentage of All Traffic				
		Peak Two Hour Count			
		AM		PM	
	Total Ten Hour Count	Peak Direction	Reverse Direction	Peak Direction	Reverse Direction
Potomac River Bridges	4.1%	2.0%	3.8%	1.8%	2.3%
Western Avenue	2.7%	1.1%	3.2%	1.1%	1.4%
Eastern Avenue	6.8%	3.9%	8.9%	3.1%	5.2%
Anacostia Bridges	7.0%	3.6%	9.8%	2.0%	4.9%
Total D.C. Cordon ("Old Cordon Area")	5.4%	2.9%	6.4%	2.2%	3.6%

*Summary Report of the D.C. Cordon Traffic Survey 1970 prepared by the District of Columbia Department of Highways and Traffic.

Light trucks may or may not have more than a marginal impact on traffic flow depending on the proportion of light trucks used for non-commerical purposes.

The second aspect of urban goods movement-induced congestion refers to non-time specific, locational concentrations of vehicles. In these concentrated areas heavy traffic may be experienced at all hours of the business day.

The degree to which trucks contribute to increased congestion in these concentrated activity areas is difficult to assess. However, for the purposes of this study it is assumed that this is a serious problem in certain instances. An example that can be used to show that this is a reasonably safe assumption and that there is a problem is the so-called "one square mile" that was intensely studied by the Tri-State Transportation Commission. The "one square mile" studied refers to a section of Brooklyn, New York, which is an older urban, commercial, manufacturing, and residential district whose freight needs are served exclusively by trucks. It was estimated that during the average day 4,200 trucks entered or left this one square mile area.[6] While this statistic suggests that there are a great number of trucks in congested portions of the CBD, unfortunately it does not tell us in what way or how much traffic is affected.

Another indirect index, land use data, clearly supports the general hypothesis that trucks are attracted to high activity areas of the CBD. Interestingly enough, though, the character of this truck traffic as one study points out differs with the land use pattern. Congested portions of the central business district with land use centering on retail activities, offices, and restaurant-taverns are served primarily by light trucks. Areas not normally associated with severe traffic congestion such as manufacturing plants, warehousing and wholesaling activities are served primarily by heavy trucks. The author of this study, R.C. Barnstead, Chairman of the Urban Transport Research Committee of the Canadian Trucking Association, contends that "light truck traffic already constitutes the majority of goods traffic in the core and promises to greatly increase."[7]

Light trucks moving in congested areas are less of a problem in traffic than heavier vehicles; however, these smaller vehicles are very likely to become a significant factor in traffic congestion because of the need for curbside loading and unloading in older CBD's. (For that matter, any curbside loading in peak periods any place is likely to be disruptive.)

Data on the quantity or net impact of such truck induced congestion is missing, but quantification may not be as relevant as whether or not instances

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6 Robert T. Wood, "Structure and Economics of Intraurban Goods Movement" in Urban Commodity Flow, Special Report 120, Highway Research Record, report of a conference held December 6-9, 1970, pp. 30-33, p. 37.

7 R.C. Barnstead, "Truck Activities in the City Center," in The Urban Movement of Goods, Organization for Economic Cooperation and Development, October, 1970, p. 109.

of blockages are recorded. After all, one truck double-parked may effectively block a lane of traffic as much as five double-parked trucks in instances of heavy demand.

Thus, in recapitulation, national averages indicate trucks comprise between ten to twenty percent of all traffic in the peaks; if we consider medium and heavy vehicles alone this figure declines to between 2.4% and 7.4% of all traffic, and between 5% and 13.8% of volume if we use vehicle equivalent figures.

In concentrated areas of the city the primary truck mode seems to be light trucks and the chief congestion contribution is probably blockage of traffic as a result of loading or unloading.

In this study three generic solutions were analyzed in an attempt to reach conclusions about ways that improvements in urban goods movement handling, here meaning trucks, could lead to general overall improvements in street traffic during peak period commuting and all-day in certain dense urban core areas. These three techniques are:

- Restricting the movement of trucks by time of day.
- Restricting the total number of trucks permitted to enter the urban area or a portion of that area.
- Restricting the movement and parking of trucks in urban areas.

Each of the above generic concepts encompasses a variety of specific applications, a few of which are discussed below. However, for the purposes of this analysis only the generic impact is discussed, assuming that if the general impact is valuable, tailored applications would be developed for specific situations.

<u>Restricting Truck Movement By Time of Day</u>:

Various proposals have been presented for limiting the time of day in which trucks could operate within the traffic stream. The most obvious solution is to restrict trucks during peak periods of travel. Other approaches would attempt to divert a portion of the traffic to night-time deliveries or restrict deliveries to certain specific periods when traffic is not congested.

<u>Restricting Total Truck Movement</u>:

A number of proposals have been advanced to limit the actual number of trucks in the traffic stream at all times of day. Perhaps the most promising of these approaches is the use of consolidation terminals at the outskirts of major metropolitan areas. Such terminals permit loads to be made up for intra-city delivery. The effect of such a technique is to increase the average load of each vehicle, and therefore, decrease the number of vehicles operating in the urban environment. (The "one square mile" study pointed out that the average truck internal load was only 160 pounds.)[8] Another technique would impose economic or other penalties on truck drivers so that only the most necessary truck trips were made. Finally, improved trucking company dispatching operations would theoretically also reduce truck trips.

Improvements in communication technology is thought to decrease the need for actual physical transferance including delivery of a great many official papers, small packages, and the like. Use of specially designed capital intensive facilities such as underground conveyor belts or people movers with freight handling capacity has also been suggested; however, these seem to be outside the scope of the study.

Restrictions on parking and movement in selected urban areas:

Variations on this technique are already currently in practice. Restrictions as to where and when trucks may load or unload at curb side are the most common. Examples of new and untried approaches to regulation which are frequently mentioned include restrictions on the number of minutes a vehicle might park for loading or unloading at the curb side and charges for use of urban streets as loading platforms. These and other variations are all concerned with either assessing penalties or eliminating urban goods movement vehicles blocking the normal traffic stream.

Further discussion in this paper makes no attempt to detail the particular version of a concept which might actually be suitable for application in a particular situation. In this way it is hoped that a broad feel for the effectiveness of improvements in urban goods movements involving trucks can be obtained.

II. TECHNICAL EVALUATION

User Price Impacts

In this study, the concept of user costs has been defined as direct out-of-pocket person travel costs for the involved commuter or urban area traveler. In this sense, there is no change in direct costs accruing from urban goods movement improvements.

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[8] Wood, op. cit., pp. 30-33, p. 37

Implementation Costs:

1. Restriction of Trucks by Time of Day:

Examples of time of day (TOD) restrictions tend to rely primarily on administrative or legislative action to implement a plan. There may be some start up and day-to-day incremental costs associated with enforcement procedures but these are probably not excessive and in some instances might even be offset by fines levied.

2. Restrictions on Total Numbers of Trucks:

Substantial costs can be associated with efforts to limit the total number of trucks (LTNT) entering or at large in an urban area. The least costly approach would be simple administrative or legislative regulations. The most costly would be development of one or several metropolitan area freight consolidation terminals including facilities to computerize bills of lading, dispatching, arrival, and departure scheduling. Estimated terminal lease costs for outlying suburban areas would be about $1.00- $2.00 a sq. ft. annually. Between 100,000 and 1,000,000 square feet of actual terminal facility would be needed depending on the specific area to be served.

No estimates were available to pinpoint costs associated with start-up of an improved dispatching function. However, costs for software development and equipment would be difficult for most individual trucking firms to absorb.

3. Restrictions on Parking and Movement in Selected Areas:

Examples of parking and movement (PM) restrictions tend to rely primarily on administrative or legislative action to implement a plan. There may be some costs associated with enforcement procedures but these may well be minor and in some cases partially offset by fines levied.

Operating Costs:

Possible operating costs vary from minor to substantial.

1. Under T.O.D. restrictions shippers would have the burden of providing a full day's work if a trucker is unable to operate for eight hours straight. For example, if a truck was restricted to operations between 9:30 and 3:30, 6 hours, the shipper would have to account in some way for the other 25% of an eight hour day. These costs might be minimized through arrangements to use

the vehicle and driver in non-congested areas and offset by other economic advantages accruing from T.O.D. restrictions.

2. The L.T.N.T. approach may involve building and operating facilities to make possible fewer trips. The terminal strategy would require a small permanent staff to supervise and assist in the activities of the facility. Compensating for the additional trucker costs would be savings associated with higher utilization rates for fixed capital investment and economies associated with terminal consolidation of dispatching and communication facilities, and perhaps even maintenance and service facilities.

No data were available on these costs. However, proponents of such service contend these arrangements would save money over existing individual arrangements and any effort which did not fulfill that promise would be difficult to implement.

3. Under changed regulations on parking and movement, it is difficult to pinpoint all costs. The major source of additional costs probably would be enforcement. Truckers may need to reschedule their movements to coincide with regulation patterns and this, of course, would add mileage and time if not closely coordinated. Again savings are projected as a result of these arrangements which may offset increased costs. Operating costs for truckers may show a net reduction due to efficiencies associated with various plans.

For measuring regulatory efforts little or no data is available. However Table 18-3 summarizes the results of Project Transim for a Southern California city.[9]

Consolidation of pick-up and delivery through the use of various terminal arrangements to reduce the number of trucks on the urban street network would save, according to one model, the amounts indicated in Table 18-4.[10]

Although based on a theoretical and specific application, this table alludes to substantial savings available to truckers if the terminal techniques or restricting truck movements in concentrated areas are utilized. One reviewer notes that it is not clear whether capital costs for the facility were taken into account in developing these cost savings projections.[11]

Similar projected freight forwarding savings have been shown as the result of improved manual or computer dispatching. The data, reproduced in Table 18-5, are actual observations of a series of British firms which implemented the technique.[12]

The most significant observation to be made from these data is that efforts discussed here which would alleviate truck induced congestion may not involve higher costs for truckers (and presumably receivers too), and in some cases would be significantly more economical when compared with existing

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[9] Ibid., p. 29.

[10] Chart adapted from Wood, Robert T., and Leighton, Robert A., "Interim Technical Report - The Economics of A Rational Urban Pick-up and Delivery System." Tri-State Transportation Commission, Feb., 1970, pp. 20-21

[11] Edward K. Morlok and Peter L. Watson, "Urban Goods Movement" - A Background Report under Commission from The Committee on Transportation of the National Academy of Engineering, July, 1971, p. 15.

[12] Ibid., p. 15

TABLE 18-3: Effects of Restrictive Municipal Regulations on Motor Carrier Operations and Costs

Regulation	Effect on Costs
Prohibit Movement on Certain Streets	Increase 1.5¢/cwt. on LTL Increase .8¢/cwt. on TL
Prohibit Movement in CBD Between 7 and 9 AM and 4 and 6 PM.	Decrease costs for all four carriers, .1 to .5¢/cwt. on LTL
Prohibit Line Haul Trucks in CBD	Increase 9¢/cwt. on LTL Increase 1¢/cwt. on TL
Restrict Terminal Location	Increase 1.75¢/cwt.on LTL and TL on carrier affected
Require Consolidated Terminal	Decrease 2¢/cwt. for LTL but lose some control
Require Consolidated Terminal and Pickup and Delivery	Decrease 4¢/cwt. for LTL Increase 9¢/cwt. for TL
CBD Mall Development (increase tailgate distances)	Increase, 4.16/cwt. for LTL and TL

NOTES: Metropolitan area of 500,000 population, southern California.

One cwt. is 100 lbs., often termed a "hundredweight".

Source: Project Transim, The Effects of Restrictive Municipal Regulations on Motor Carrier Operations and Costs, Report No. 65-6 (Los Angeles: Dept. of Engineering, University of California, May 1966)

TABLE 18-4: Savings Projected From Consolidated Terminal Operations

	Percentage Cost Reductions Model Area	Percentage Cost Reductions Region as a Whole
A. Terminal Function:		
vehicle miles	36%	36%
vehicle hours		
transit	51%	51%
waiting	New added cost [(a)]	51%
Terminal Platform Cost	New added cost [(a)]	New added cost [(a)]
Additional Helper	New added cost [(a)]	New added cost [(a)]
Subtotal	4%	10%
B. Line Haul Function (Inter-cluster Traffic)		
vehicle miles	99%	95%
vehicle hours	99%	90%
Terminal Platform Costs	New added cost [(a)]	New added cost [(a)]
Subtotal	20%	24%
C. Other Costs		
Billing and Collecting	7%	12%

(a) New costs were assumed in some cases as a result of terminal consolidation; these costs were subtracted from other savings and account for the lower subtotal savings.

TABLE 18-5: Examples of Actual Cost Savings From Use of Computer Techniques and Improved Manual Techniques In Pick up and Delivery Trip Planning

Company	Size	Method	% Savings in Vehicles	% Savings in Vehicle-Miles
J. Lyons (food)	27	Manual	36%	-
Schweppes	9	Computer	10%	15-20%
Cadbury Bros.	22	Manual Computer	18%	9%
Thomson Org.	26	Combined Man. and Comp.	11%	12%
Anonymous Newspaper Dealer	42	Combined Man. and Comp.	24%	-
Dorothy Perkins Ltd. (clothes)	-	Computer	-	5%
Calor Gas	13	Computer	15%	14.8%
Air Products	10	Computer	-	.8%
Anonymous Steel Company	20	Computer	10% reduction in operating costs	
Anonymous Oil Company	-	Computer	12% reduction in total trans. costs	
British Gov. Post Office	30,000 trips per week	Computer	Savings in 9 mos. paid for 5 yrs. of development costs	

patterns of operation. Thus it would superficially appear that a reduction in congestion by the methods discussed in this study would perhaps benefit both general travelers and truckers. A further study of these situations would be in order before firm statements about these dual benefits could be made.

Other Costs

The principle non-economic costs associated with most of the above concepts are interruptions and inconveniences occasioned when limits on time or place of delivery are made. This may involve receivers rescheduling shipping room activities, and in the extreme (such as in the case of night time deliveries), actually may become an additional economic cost to the receiver.

Indirect Economic Effects

The indirect economic benefits associated with the three techniques discussed above can be covered in general terms. Such benefits would accrue primarily from reduction in traffic congestion and would include the possibility of the oft-mentioned reduction in person travel time and alleviation of needs for new highway facilities. Certain general economic benefits also might include reducing time and costs to consumers resulting from efficiencies in freight forwarding. The reduction in vehicle miles generated could also be expected to reduce wear and tear on roadway from loaded trucks. And improved scheduling might increase delivery reliability while providing substantial planning and coordination efficiencies. These benefits seem marginal, however.

Minimum Effect Impact on the Disadvantaged

Environmental Impact

The suggested improvements are potentially helpful in reducing the number of trucks needed to deliver a fixed amount of goods to certain receivers, thus decreasing total emissions and noise pollution in the CBD.

Safety Impact

Data quoted in the Wilbur Smith study show that accident rates per 100 million vehicle miles is higher for trucks - both large and small - than for passenger cars.[13] However, while the Wilbur Smith study is concerned with urban goods movement, these data entitled "Accidents on Main Rural Highways" have questionable relevance to urban traffic. If movement in the CBD is subject to similar comparative accident rates, then a decrease in truck volumes should also lower accident rates.

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[13] U.S. Department of Commerce statistics, from 1964, as quoted in Wilbur Smith *op. cit.*, p. 82.

Speed or Time

Time savings for persons traveling in urban areas during the day might result if trucking was consolidated, dispatched more efficiently, shifted to other hours, and/or supported by a different set of municipal regulations concerning vehicle movements.

Unfortunately, very little is known about the degree of congestion and delay that can be attributed to trucks. While trucks account for a small proportion of total daily trips in the Urban Area (about 15%), it is clear that at times and in places they are a disproportionally large segment of traffic. In such instances it seems reasonable to expect some reductions in congestion and delay if trucks were removed and other congestion sources did not replace trucks (cars, double-parking, etc.). Most authorities contend that reduction in truck traffic would result in improving the functioning of the city.[14] However, even if substantial numbers of trucks were removed from the traffic stream, there is no assurance that the resulting number of trucks would not aggregate in time or place in making their rounds.

It is also important to note that it is not so much the number or volume of trucks in traffic that generates delay, ". . . but rather any condition or object (and this may be any type of vehicle including a truck) that is parked, delayed or otherwise used so as to block or physically interfere with the roadway and thus the flowing movement of the traffic stream."[15]

The Wilbur Smith report concludes: ". . . since trucks comprise only about 15% of the traffic stream and 71% of truck trips made on a typical day are by light trucks which equate equally (sic) to automobiles in traffic flow, it is apparent that truck contribution to traffic congestion rests more with medium and heavy trucks which account for less than 5 percent of all vehicles in the average traffic stream. It is apparent, therefore, that it is not the performance of these vehicles in traffic per se which creates traffic congestion, but rather the manner in which trucks (or any type vehicle) are used and misused." [16]

To sum up, we are not able to pinpoint travel time delays traceable to truck traffic but there undoubtedly are some. Implementation of the three basic techniques mentioned earlier certainly would help speed up traffic, other things being equal.

Volume

There are two ways to view volume or capacity as related to truck traffic: trucks occupy space in the traffic stream. Trucks, when stopped, block traffic flow.

Trucks occupy space in the traffic stream which might otherwise accommodate personal vehicles or, if no additional demand was generated, would permit traffic to flow more effectively and increase average traffic speed.

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[14] Wood, "Interim Technical Report," p. 21.

[15] Wilbur Smith, op. cit., p. 78.

[16] Ibid., pp. 86-87

Since trucks compose about 20% of the AM peak traffic and between 16% and 10% of the PM peak traffic, removal of some of these vehicles would appear to contribute to these ends. On the other hand, there is no way at this point, to ascertain the extent of these benefits without actual experiment. There is some probability that the net impact would be slight so that compensating circumstances would negate any advantageous situation.

It should be noted that removing medium and heavy trucks from traffic would provide about 14% more capacity in the AM peak and 5% more capacity in the PM peak as a function of their larger size.[17] However, medium and heavy truck trips are less likely to be destined for the commercial-retail-government land use areas of the city and the impact of medium and heavy truck traffic on peak hour traffic into and from dense areas of the CBD is quite probably less than these figures on over-all impact indicated. The absence of firm data and the appearance of marginal benefits prevent the formation of any clear conclusions about this aspect of volume.

The second consideration concerning volume is lane obstructions. A truck illegally or legally parked in the curb lane or double parked has some effect on the capacity of that lane of traffic to move vehicles and people. Under conditions of substantial demand the extent to which capacity is diminished varies. With no cars entering or leaving the traffic stream the obstacle could disrupt a substantial number of miles of roadway. If demand is diminished before the obstruction, as when a large number of autos are reaching their destination and turning off the roadway with little or no new traffic entering, then the loss of lane capacity might have a much less disruptive impact on traffic.

In any event, enforcement of regulations against lane disruption would need to be close to 100% effective under conditions of high demand. For example, reducing the number of illegal or legally parked trucks from 20 to 4 in five miles of congested highway would not increase volume by 80%. One truck may be as much of an obstacle as many.

It seems likely that freeway or other limited access facilities would be less subject to obstruction by trucks since trucks would not load or unload on freeways.

No data was available to this study to estimate savings impacts that might be realized by restrictions on crub lane and/or illegal parking. For a particular roadway in question, fairly universal compliance would seem to be necessary for a realizable benefit. It is worth noting that the principle element of traffic, cars, are also responsible for illegal parking. To be effective, prohibitions on traffic lane blockage must also insure that cars do not block lanes.

In congested portions of the CBD the same traffic lane blockage impacts can be noted. Again data are not available to indicate the loss of volume directly traceable to such circumstances.

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[17] Calculation performed as follows: AM peak medium and heavy trucks about 37% of all trucks, all trucks 18% of all traffic, medium and heavy, trucks 7% of all traffic. Truck equivalency data from Highway Capacity Manual, 1965, p. 101.

It can be argued that lane blockage may not substantially interrupt traffic on some roadways; in that case there is some question whether prohibition is needed on that roadway.

In summary, a moderate amount of capacity is undoubtedly lost when trucks use streets during peak hours and when lane blockage, caused mostly when trucks unload or load, disrupts traffic and decreases traffic flow. Removal of trucks during peak hours would expand capacity somewhat; elimination of lane blockage would only be effective if a high degree of compliance by both trucks and cars was achieved.

State-of-the-Art

All techniques under consideration here are practical and proven to be operationally sound. Questions about enforcement methods, the kinds of regulations needed, and the system of implementation need further study particularly for the application under consideration.

Institutional Background

The trucking industry is a powerful institutional force not given to easily accepting or implementing suggested innovations.

Undoubtedly further regulations would be opposed. Terminal consolidation is generally opposed by large firms because they already have many of the benefits of consolidation due to their large size and a consolidation scheme would aid their smaller competitors.[18]

Improved dispatching is hindered largely by economic considerations.

Any attempt to change working conditions, operating procedures or hours worked would undoubtedly require union consultation and deference.

Merchants may oppose any restriction on delivery during their normal hours of business.

In general it is expected that inertia and organized powerful interests will work against any well meant effort by the community as a whole to restrict or modify truck operations.

III. Summary and Critique

Truck traffic undoubtedly contributes somewhat to urban traffic delay and congestion. How much is not known, although indirect evidence suggests that truck operations are not a major factor responsible for congestion and delay.

However, the major conclusion reached in this superficial survey is that the three general techniques reviewed above would improve both trucker economies and mixed traffic movements. Thus, while we cannot pinpoint the traffic benefits that would accrue as a result of improved truck operations, the reforms themselves appear to have economic benefits that may, in some cases, more than offset all costs of implementation and operation.

Any attempt to improve the efficiency of truck movement will undoubtedly meet stiff industry and union resistance.

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[18] Wood, "Interim Technical Report," p.5

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CHAPTER XIX

PARA-TRANSIT (JITNEYS, TAXIS, AND LIMOUSINES)

Operating Description and Summary of Findings

Para transit service includes a number of less well known travel modes which fill a gap between the services provided by conventional transit and private automobiles. Included would be limousine and jitney services as well as taxi. All services are for hire. The chief advantage of para-transit lies in its ubiquitous nature which potentially, at least, allows it to serve any pattern of origins and destinations.

In general, the study found that the greater flexibility offered by these services was effectively counterbalanced by higher user costs. There is a real possibility that encouragement of para-transit would lead to abandonment of some forms of mass transit. Little evidence is available to indicate that demand for new facilities would be relieved through expansion of para-transit. It is expected that attempts to develop more para-transit service would be heavily resisted by powerful institutions.

I. INTRODUCTION

The middle ground in the urban transportation spectrum lies between private cars at one pole and mass transit at the other. This middle ground, referred to here as para-transit, is the domain of such public transportation systems as the taxi, jitney, limousine, and special purpose bus, to name a few. While taxis, jitneys, limousines, and special purpose buses are classified as para-transit, this investigation is concerned with identifying possible new business and organizational arrangements that might be developed within the field of para-transit to enable existing facilities to be better utilized.

These systems alternatives to normal public or private transportation usually return a profit to the owners. Often they are the only means available in areas where traditional public transit does not provide service.

The operation of public para-transit systems is essentially similar in that they are regulated by an agency. The regulated elements are:

(1) Entry into the market (either by licensing requirements or the need to purchase the franchise).

(2) Charges (usually by the amount of service).

(3) Areas of operation as a public transporter.

(4) Safety (the inspection of vehicles, diverse insurances, and compliance with the established rules).

The market domain of para-transit is defined more precisely in Figure 19.1. The market range in Caracas is extensive due to poor bus service and expensive taxi. The estimates for Washington indicate a more limited market in the public transportation sector.

There is another element in the public para-transit spectrum that has, until recently, received little attention outside the transit and taxi industry. This element is the illegal operation of gypsy cabs or jitneys, many of which operate with the unofficial approval of local authorities. Such activities are associated with areas where the competing modes, including licensed taxis and limousines, will not serve for a variety of reasons ranging from high crime rates to excessive deadhead time on a return journey.

Para-transit, in all its forms, exists by providing more choice in quality of service for the urban traveler making any specific trip. It thus follows that applications of this concept could provice the "filler" type transit service needed where travel demand is subject to unexpected fluctuation or could provide the total transit service where public transit cannot. Further, para-transit might reduce demand for new facilities by absorbing demand in peak periods which might otherwise be handled in a more costly manner. This might occur, for example, as a result of group cab riding or jitney "full load" service.

II. TECHNICAL EVALUATION

. User Price Impacts

The user costs in most para-transit systems have been fixed either by regulation or by what the traffic will bear. Since most para-transit systems are privately owned, they must operate at a profit over the long run to stay in business. Figure 19-1 shows a range of relative user prices in two cities.

In relative terms, user prices are least for traditional mass transit and highest for taxi trips. Jitney and limousine prices fall somewhat in between these extremes. This relationship appears to be generally true in cities around the world no matter how cheap or expensive the basic transit service is.

. Implementation Costs

The cost to the community to implement a para-transit may be almost zero if the operation is left to small entrepreneurs and only minimum regulation imposed.

The cost to the operator involves the purchase of a twelve-passenger vehicle (van type) at a cost of $3.5 to $5.5 thousand. The necessary jitney permit cost is approximately $2,000 in San Francisco with insurance being some $800. Jitney permits may cost nothing if public authorities wish to encourage operation. A small operator should have approximately $6.3 to $8.3 thousand to implement his own jitney service.

The comparable cost to get into the taxi business is $3,500 to $4,000 for the equipment plus almost zero to $20,000 to be allowed entry into the market. In this business, however, it is not uncommon for the entrepreneur to be able to capitalize much less expensively through purchase of used equipment.

. Operating Costs

The typical operating costs of a newly implemented para-transit system would be similar to that of a taxi; in some cases certain savings are realized by not needing a radio or dispatcher. Other savings are realized through the use of associations to purchase tires, gas, etc. The existing operations by small entrepreneurs also manage to keep the normal overhead costs down by doing most of the associated accounting and routine maintenance themselves. These savings permit the para-transit to remain competitive and show a small profit for the operator. After all this, however, costs often may not exceed average auto charges.[1] The labor cost is usually a function of the individual operator. If para-transit is to be organized to use existing roadways more efficiently, then an administrative cost should be added. Based on existing experience, it is suggested that in most operations this would increase costs by 1.5¢ to 8¢ a mile.[2]

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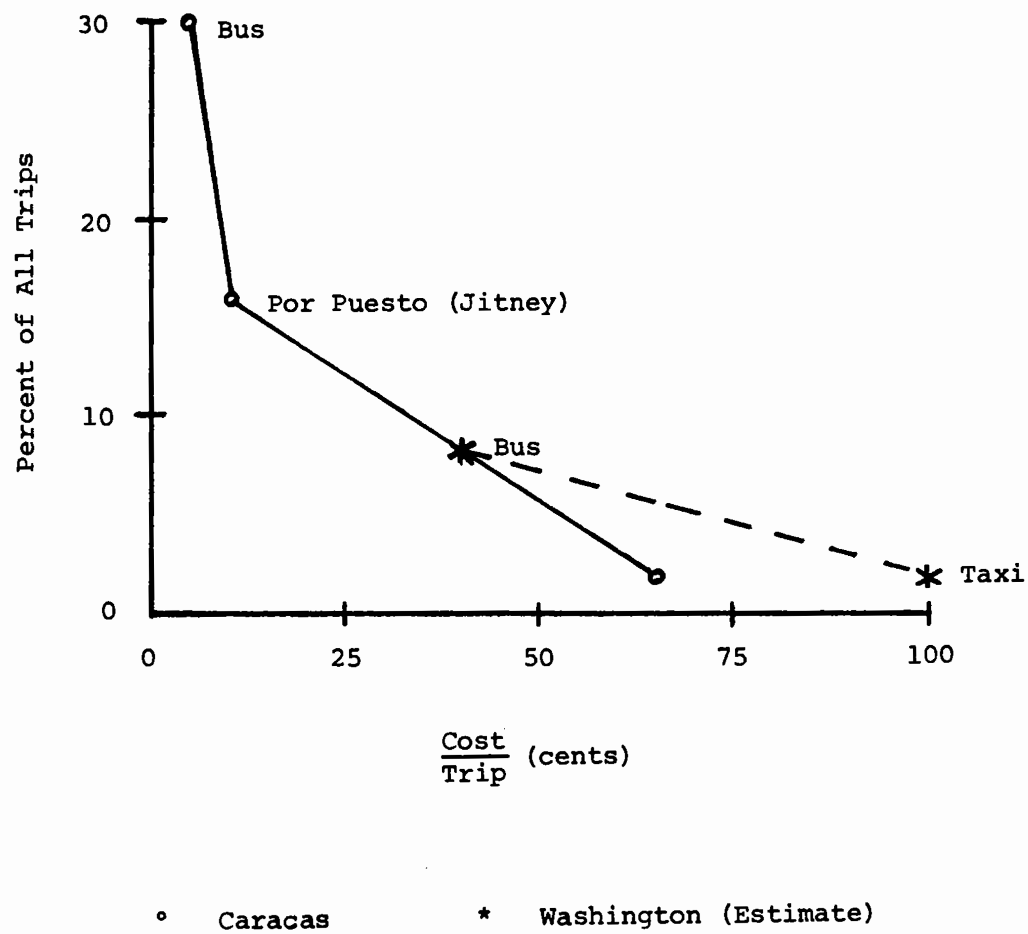
[1] Suburban Washington cabs average about 135 miles per day and cost $11.00 a day to operate (no labor costs). This works out to about 8¢ a mile.

[2] Informal survey of taxi operating costs and analysis of ATA statistics on bus operations.

Figure 19-1: Para Transit and Traditional Transit
(Data from Two Cities)



. Other Costs

Added vehicles and congestion will result if para-transit diverts passengers from buses (higher capacity vehicles) or if additional trips not formerly taken (due to lack of acceptable mode) are generated by the availability of a good para-transit system and corresponding reductions in auto travel do not materialize.

. Indirect Economic Effects

The indirect benefits that may result from a policy encouraging para-transit are:

(1) Reduced investments in parking facilities in high land cost areas.

(2) Reduction of the public funds investment in transit hardware.

(3) Improved mobility for transit captives in areas not adequately serviced by public transit but having sufficient demand to warrant a few small vehicles.

(4) A reduced demand for new transportation capital facilities, especially in low demand areas.

These benefits would be most appreciable if para-transit was widely accepted as a substitute for individual auto use.

. Impact on Disadvantaged

Para-transit is a labor intensive service and as such could benefit the poor and less educated members of society by developing many low-skilled jobs.
Given sufficient regulation (not excessive regulation to protect a monopoly) social benefits could be gained in many areas through a wide ranging improvement in total accessibility provided by a safe public transit system. However, it should be kept in mind that rates would not necessarily remain at transit levels in all applications, if operator profit is to be guaranteed.

. Environmental Impact

The amount of environmental improvement is related to the substitutability of para-transit for the private automobile. Probably little if any improvement would be noticed since the principal aim of para-transit is to service a potential demand not presently satisfied. There is no data on this point.

- Safety Impact

Para-transit implementation would do little if anything for improvements in travel safety. The notorious Por Puesto system in Caracas is feared by riders and pedestrians alike. A potential hazard would be the lack of true vehicle maintenance control since most would be privately owned by a small operator. In another aspect, public protection (financial via insurance) could be improved over the illegal operations now being undertaken in many cities.

The frequent stopping to pick up and discharge passengers may prove to be a liability by increasing physical damage to vehicles. Insurance rates on taxis are costly ($1,000 a year in the Washington, D.C. area) but on a per mile basis are about the same as private automobiles.

- Speed or Time

Para-transit is in principle tailored to satisfy a specific need and as such should offer more rapid service than a bus system. Coupling the small capacity with the operating policy of picking up persons until full, then driving directly to the first destination (either along a prescribed route or deviating to a faster route if acceptable by all), also encourages faster trip speeds. The use of corridors, fairly well fixed, also allows for increased speed or reduced travel time since most drivers would be very familiar with all minor considerations to maximize their travel speed (this is similar to the knowledge of a travel route held by the daily commuter as opposed to the casual traveler). The high frequency of vehicles anticipated along a route would also reduce the waiting time, and thus speed the entire trip for the passenger.

Experience on Mission Street in San Francisco indicates that jitneys may travel at fifteen to sixteen miles per hour during the rush hour. This is slightly faster than the usual average of eleven miles per hour assumed for regular bus operations under the same traffic conditions.

One drawback of para-transit is the random stopping along the route to pick up or discharge customers. This practice in congested areas would do little to increase road utilization.

In all likelihood, the travel time improvements may not be significant and could be lost under operating schemes where vehicles deviate to pick up and discharge passengers.

- Volume

A volume increase in the movement of persons is attainable only by removing some persons from their automobile and encouraging others to make trips in the urban area via para-transit they would normally not undertake. The influence of para-transit in the peak hour depends on the substitutability of this mode for the automobile. The influence probably should be towards increased utilization, in the event para-transit is encouraged, but data available to substantiate this point is inadequate. A real concern would be that if para-transit proves attractive (convenient, economical, fast, etc.) it might draw riders from existing transit service and increase the absolute number of vehicles on the roadway.

- State-of-the-Art

There is no technological development required to implement para-transit services; all that is needed is legislative action and the formation of a controlling agency (either independent or within an existing agency). Sufficient experience exists in the United States and elsewhere to enable adequate regulations to be developed prior to implementation.

- Institutional Background

Major conflicts could be expected from the existing transit industry and taxi operators. There is no easy solution to these potential conflicts, since each will view any proposed para-transit capable of competing for the urban travel market as "skimming the cream". The vested interests of public transit are responsible for the demise of para-transit in the form of jitneys in the United States. Naturally, unions would view para-transit as a threat to job security unless they were assured of jurisdictional authority over the para-transit service.

The few places in the U.S. that have jitneys as para-transit have experienced good service and few institutional problems. Restriction of the entry of new taxi operators in major cities such as New York and Chicago is one reason why many illegal operations have evolved in areas they "refuse" to serve because of high crime rates. The more easily entered taxi industry of Washington has not experienced many of the labor and service problems found in New York or Chicago.

- Traveler Response

Demand is not likely to be generated easily from existing automobile users. Patrons using current transit service and non-auto users not making trips are likely to be more easily attracted depending on price and range of mobility. It is not easy to estimate the net impact on demand for alternative travel modes or para-transit at this time.

III. SUMMARY AND CRITIQUE

The major value of para-transit is in the added choice (flexibility) introduced into the urban public transportation market. This addition will also provide additional employment opportunities for those persons being displaced from more technologically advanced industries.

In most cases, increased provision of para-transit service would not satisfy overall demand for more capital facilities. Indeed, there is some justification to the opposite charge. If, for example, substitution of small vehicles for large buses occurs, there may be a net increase in congestion on existing facilities. There are possibilities, on the other hand, for improved utilization of existing facilities in certain circumstances:

(1) Substitutability of para-transit service for private automobile traffic. The reduction in auto traffic may be slight in actual numbers, but may be sufficient to reduce actual street congestion.

(2) Substitutability of organized para-transit for major transit facility investment, such as rail line extensions, before demand justifies the investment.

It appears that the primary demand for para-transit service would be generated from persons currently using transit or not making trips. Little data is available to support the thesis that substantial automobile traffic would be removed from the street system.

There is adequate evidence that operators of current taxi and transit service would work to oppose increased para-transit service, if perceived as a threat to existing operations. To this date, as evidence of the significance of this opposition, no federal funds have been available to support proposals of demonstration or operation of these techniques. The absence of federal funding is significant in that cities are probably unlikely to implement anything without outside financial assistance.

The question of impact on existing operators and operations needs to be resolved more clearly.

In summary, para-transit can be a source of increased mobility with almost no direct public cost (when the operator is self-supporting) but it is questionable whether demand for new capital facilities would be abated.

As an aside and final comment, the fact that illegal operations can become established within a local area and have the unofficial acceptance of authorities is symptomatic of deficiencies in the existing supply of public urban transportation. Making such operations official will allow some degree of regulation, thus increasing public safety and protection while filling an observed social need for transit.

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CHAPTER XX

THE RAIL BUS

Operating Description and Summary of Findings

The rail bus is a standard transit or over-the-road bus which is equipped with an extra set of special wheels enabling it to travel on conventional railroad tracks.

The rail bus would operate on abandoned or lightly used railroad tracks much as a train. When not using the railroad tracks the bus would retract its wheels and operate conventionally on city streets. In this way the usual collection and distribution convenience of a bus could be combined with the line haul speed of a rail vehicle.

In order to permit rail bus operations the trackage must be extensively upgraded at a fairly high cost and each bus must be specially equipped to operate on railroad tracks.

The major justification for the rail bus approach to the utilization of rail rights-of-way is to permit conventional rail operations to continue. Except in this latter instance it appears that the best use of rail rights-of-way is to pave.

As in the case of Paved Railroad Rights-of-Way, the big question is whether available rail rights-of-way are located in areas that correspond to patterns of transportation demand.

I. INTRODUCTION

The rail bus is a standard rubber-tired bus equipped with rail guide wheels enabling it to travel on conventional railroad tracks.

In many cities existing railway lines have been abandoned or are lightly used, providing uncongested transportation corridors for such vehicles. Under certain conditions, it has been proposed that normal railway traffic would continue to utilize the same tracks.

Proponents have offered the argument that the rail bus provides the best of both worlds-- complete collection and distribution flexibility utilizing the ubiquitous street network while taking advantage of the speed potential of fixed rail rights-of-way during the line haul portion of the trip.

The several prototype vehicles that have been built and demonstrated are all conversions of conventional buses. Rubber-tired bus suspension systems are not built to sustain the same types of stresses as are experienced by rail tracking vehicles (principally lateral sway). The small rail guide wheels have, to date, been inadequately suspended; roadbed shocks are transmitted to passengers. All studies of the use of lengthy portions of trackage for rail bus applications have noted that it would be necessary to rebuild the road bed and replace jointed rail with seemless welded rail. This appears to be directly traceable to the structural inadequacy of the bus when subject to normal railroad sway and stress.

II. TECHNICAL EVALUATION

- User Price Impacts

User price impacts are likely to be a function of changes in operating costs. These expected higher operating costs are discussed below. If all or a portion of these costs are passed on to the user, then fares would go up.

- Implementation Costs

The capital costs associated with the rail bus are of two types:

(1) Bus Conversion Costs - These costs are estimated at $10-$15,000 for adapting the vehicle for rail travel; $10-$15,000 for adapting the vehicle to signal and safety requirements: Total $20-$30,000.[1] Since several manufacturers have quoted prices in this range, this appears to be a valid estimate.

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[1]Institute of Public Administration, "Track Sharing for Urban Transportation", Washington, D.C., 1970.

(2) Track, Roadbed and Related Costs - Based on figures which were prepared for three cities, costs are estimated at \$200-\$225,000 a mile.[2] These costs include provision of safety signals and controls, fencing and grade crossing work. Additional costs will vary depending on local needs and could include radio or other communications equipment, computer facilities, stations, landscaping, and the like.

. <u>Operating Costs</u>

Proposals for service experiments have all emphasized that vehicle operating costs per mile will not differ from those costs associated with ordinary bus operations. However, the possibility of higher vehicle maintenance costs is real, especially during the shakedown period; costs for repairs to a regular bus average about seven cents per mile. Twice this cost (not an unreal estimate) would add about seven percent to total operating costs (1968 figures).[3]

In all proposals advanced to date, rental of the right-of-way has been included. Figures for this range from a low of \$1.00 a year in Hartford, Connecticut (1971) to a high of \$66,000 a year in Miami (1969) including track maintenance. This is estimated, in the case of Miami, to increase costs about 14.2¢ per vehicle mile, or about twenty-five percent.[4] It seems reasonable to expect to pass some of these costs on to rail bus users.

Capital costs associated with track rebuilding and conversion of the vehicle should be annualized so that additional burdens are identified. As indicated in Table 20-1 at an assumed maximum headway of ninety seconds, about nineteen cents per vehicle mile in added costs would accrue as the result of track rebuilding capital costs.

The vehicle conversion costs would run, at maximum estimate, \$30,000 each vehicle. Under average circumstances, each vehicle might make two trips in each three hour peak period, averaging twenty miles each trip, for a total of eighty miles per day. Vehicle conversion costs prorated over ten years would amount to about fourteen cents a vehicle mile or another twenty-five percent in costs. Table 20-1 also summarizes these costs. If federal mass transit capital grants are taken into account, these charges would drop substantially.

These cost figures are not completely consistent and have not been adjusted for greater operator productivity in higher speed service. They should be subject to thorough scrutiny before being accepted.

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[2] <u>Ibid.</u>, an average range of costs taken from estimates prepared for Miami and Washington, D.C.

[3] Alan M. Voorhees & Associates, Inc., "A Short Range Program for Transit," (Prepared for Comprehensive Regional Plan of Columbus and Franklin County, Ohio, McLean, Virginia, 1969).

[4] <u>Op. cit.</u> Institute for Public Administration

TABLE 20-1: Operating Costs per Mile for Rail Bus Service

	Proposed Miami System[a]	Typical Large City Bus System	Typical Smaller-Sized City Bus System
Normal Operating Cost	57.9¢	$1.10	.75
Added Maintenance Estimate (See Text)	N.A.	.07	.07
Track Rental	14.2¢[b]	.142[b]	.142[b]
Track Rebuilding	Not Included In Study	.30[c]	.96[d]
Vehicle Conversion Costs	.14[f]	.14[e]	.19[f]
Total	$1.05[g]	$1.75	$2.11
Percent Increase	81%	59%	181%
Total Less 2/3's Capital Costs (Under Federal Funding)		1.50	1.34
Percent Increase		36%	78%

[a] Estimate prepared by Miami Study, as reproduced in Institute for Public Administration Report

[b] Also from the Miami Study as reported in I.P.A. Report; it is not known if these figures are representative but they are the only good example available

[c] Ninety seconds headways, twenty year life, $223,000 per mile, five percent annual interest, 260-days year, six peak hours per day

[d] Five minute headways, twenty year life, $223,000 per mile, five percent annual interest, 260-days year, six peak hours per day

[e] $30,000, life ten years, used eighty miles per day on rail, 260 days per year, (no interest)

[f] $20,000, life ten years, used forty miles per day on rail, 260 days per year, (no interest)

[g] Not including amortization of track rebuilding costs

SOURCES: ATA Transit Operating Reports--1970, Part II, Motor Bus Operations, Washington, D. C., 1970. Institute for Public Administration, Track Sharing for Urban Transportation, Washington, D. C., 1970

. Other Costs

A possible cost may be incurred if rail bus scheduling interferes with regular rail schedules.

The ride quality of the rail bus is expected to be inferior to most modes now in use with excessive sway, bumping, and higher noise levels anticipated. This discomfort may prove unacceptable to users.

. Indirect Economic Effects

Avoiding capital facility construction through development of rail bus facilities is heavily contingent upon finding sufficient rail rights-of-way for such use. There appear to be few such facilities that would be acceptable, thus this impact is expected to be minor.

As in the above case, the small number of possible applications would generate small accumulations of user time savings.

. Impact on Disadvantaged

Since rail tracks are located near factories and other blue collar employment centers, there may be improved opportunities for the disadvantaged.

. Environmental Impact

Environmental impact is directly related to the number of autos removed from highways. At this time no estimates have been provided in this regard. It is probably a safe estimate, as with any urban corridor transit service improvement, that at least a small portion of auto drivers and passenger riders may be lured by the improved service. This, in turn, may be sufficient to decrease major congestion, reducing vehicle hours and thus total vehicle emissions. The net urban area impact, however, appears to be minimal because of the small number of applications possible.

. Safety Impact

No data are available; however, it is reasonable to expect that those rail lines which are candidates for abandonment would have a higher proportion of at-grade crossings. Such crossings are more dangerous.

. Speed or Time

The chief rationale for adopting the rail bus is that it would have a speed or time advantage over existing highly congested facilities. The essential element in calculating any specific time saving is the expected average rate of speed on rail and the measured average rate of speed on normal facilities. Rail bus studies generally agree that an operating average speed of thirty to thirty-five miles per hour is obtainable for the rail portion of the trip. On the other hand, average speed on congested streets is estimated at twelve miles per hour. Average speed of the rail bus will be influenced by whether station stops exist along the rail portion of the trip. If fifty miles per hour is top speed (as demonstrated in New York) and stops are few, it may still be possible to achieve high operating speeds. Time required to mount or dismount from rails is estimated at one minute or less.

While there is an obvious speed advantage, for a reduction in total trip time to occur, the distance involved would have to be fairly great to compensate for any deviation from a straight path as well as to provide for access to the facility (probably over congested roads) and egress to trip destinations. This fact limits application to medium and large cities or to circumstances where there is a long line haul trip involved (i.e., to outlying airports or employment centers, etc.).

In order to provide meaningful comparisons a specific application would have to be analyzed so as to compare total travel time via either route. A simple model could be used to generate pertinent data. The construction costs associated with service which did not result in savings of more than ten minutes would probably be hard to justify. Table 20-2 provides estimates of trip time impacts for various length journeys.

An important advantage, due to the exclusive right-of-way, is the avoidance of congestion delays. Thus the resulting travel times are more consistently obtained.

- Volume

The rail bus would provide additional transportation corridor capacity. A range of volumes that might be carried (and associated capital costs) is shown below.

HEADWAY	POTENTIAL* SEAT-VOLUME/ HOUR	NO. VEHICLES PER HOUR	CAPITAL COST* PER BUS/MILE	CAPITAL COST** PER SEAT-PASSENGER/MILE
30 min.	106	2	$3.70	.07
15 min.	212	4	2.12	.04
10 min.	318	6	1.06	.02
5 min.	618	12	0.53	.01
2 min.	1,590	30	0.26	.005
1 min.	3,180	60	0.11	.002

The practical limit on headways will be a function of railway/rail bus braking requirements and FRA and other safety regulations. Simpson and Curtin point out that minimum rail rapid transit headways are ninety seconds. If this limit is applied to the rail bus, it would permit achieving a capacity of around 2,000 passengers an hour. This is slightly less than the expected maximum capacity of one lane of highway carrying mostly automobiles. The rail bus does not enjoy the same capacity advantage as other exclusive busways.

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* Fifty-three passenger bus.

** Capital costs distributed over six peak hours (thus 1 hour=1/6 daily capital costs), and utilize a twenty year life. Costs are figured at $225,000/mile with five percent interest charged. Usage is figured on a five day week basis. Some studies have defined these variables in more favorable terms which would further reduce costs per mile.

TABLE 20-2: Rough Estimates of Time Savings

	Total Trip Distance					
	4	8	12	15	20	30
Total Conventional Trip Time (Minutes)	20.0	40.0	60.0	75.0	100	150
Total Rail Bus Trip Time (Minutes)	26.6	33.5	40.5	45.5	54	71.2
Time Saved[a]	-6.6	+6.5	+19.5	+29.5	+44	+78.8

[a] Calculated as difference between conventional trip @ 12 m.p.h. and rail bus trip time. Rail bus estimates based on collection and distribution mileage at speed of 12 m.p.h. for three miles of collection and distribution, line haul portion at 35 m.p.h. plus a one-mile standard access and egress penalty (at 12 m.p.h.) which should be added to total trip mileage as conventionally figured to compensate for likely indirectness of rail facility.

. State-of-the-Art

It is alleged that all necessary technology is available. Certain items in the technology have not been satisfactorily demonstrated at this point. These include:

(1) Scheduling hardware and software to assure smooth integration with existing rail traffic in instances of joint usage.

(2) Vehicle braking - small rail contact wheels mean excessive braking force per square inch or conversely, that less area to brake is available.

(3) Demonstrated solution to acceleration/deceleration retarding forces. Specifically, weather, slippery curves and the like prevent good traction. A number of suggested solutions seem reasonable; however, these should be demonstrated.

(4) Better suspension system for the metal rail contact wheels.

(5) Assurance is needed that shunt signals will be activated by the light-weight bus.

At high speeds the ride quality noticeably deteriorates. It has been suggested that an entirely new vehicle be designed which could better sustain metal-to-metal vertical stress and the excessive lateral stresses peculiar to rail travel. The consensus of most observers is that technical questions about the vehicle could be easily resolved, and favorably, with adaptations of existing proven technology.

. Institutional Background

Institutional difficulties have been cited as the chief reason why rail buses are not widely utilized. These are identified and discussed below.

(1) Railroad Reluctance - The Institute for Public Administration notes in their summary concerning rail bus that railroads have been reluctant to consider plans for joint usage. This is generally felt to result from a fear of the effect on other operations of additional schedule-critical vehicles in the system.

(2) Union Restrictions - The Federal Railway Administration has classified the rail bus as a locomotive. It was thought that this would enable rail unions to justify three-man crews. However, when Hartford, Connecticut applied to the Urban Mass Transportation Administration for a rail bus demonstration grant, the Labor Department ruled that this was a transit operation with one driver only required.

(3) Federal Regulatory Codes - The Federal Railway Administration (charged with enforcing ICC codes) and the Association of

American Railroads have safety and signal codes which must be met. The rail bus, an unconventional rail vehicle, does not interact well with normal railroad signal systems primarily because it is too light.

Cost estimates for equipping cabs, providing wayside signal equipment, and modifying track so that complete integration with safety and signal systems is achieved is included in the figures presented earlier.

State and local codes may affect rail bus operation: A rail bus vehicle may be too heavy to travel on regular roads with the extra 4,000 pounds of rail bus equipment. Registration and licensing requirements need analysis. Full crew laws in some states (requiring five or six-man train crews) may be applicable.

In general, the most severe institutional constraints are related to union crew requirements. Since that issue apparently has been resolved, it seems likely that the balance of these restrictions can be resolved if a community puts its full support behind an effort in this direction.

- Traveler Response

Traveler response is likely to be enthusiastic if definite travel time advantages are shown over competing modes. Support for this conclusion is drawn from studies of busways which reveal that travel time advantages generally result in increased ridership.

III. SUMMARY AND CRITIQUE

The rail bus is an attractive, low-cost method of opening up completely new transportation corridors as an alternative to providing more service by building more conventional facilities. The cost of rail conversion is apparently about the same as paving a right-of-way. Thus, the added investment in bus equipment for rail bus needs to be justified on some grounds peculiar to the individual operation, such as the requirement to continue the use of track for rail operations.

The use of existing rails on a lease basis (plus some provision for sharing of maintenance costs) may be, in some cases, substantially less costly than acquiring right-of-way for paving. Paving costs assume that bridges, tunnels, and other clearance restrictions are suitable for non-guide rail travel.

Technical and institutional problems seem resolvable and hesitation on those grounds seems unwarranted.

The important issue for local planners contemplating use of rail right-of-way is that accurate mode choice behavior and transportation demand estimates be made before the community commits itself to the required investment in either rail bus facilities or paved rail right-of-way (see paved right-of-way discussion). The absence of applications to date is largely explained by the fact that demand does not often coincide with the location of a rail facility.

There is no definite rule to determine whether paving or use of rail bus is the most judicious application. The following hypothetical range of applications illustrates circumstances under which either decision might be made. The tabulation presupposes that feasibility for one or the other has been demonstrated.

Number of Vehicles Using Facility Per Hour	Number of Miles of Right-Of-Way	Restricted Clearances	Freight Usage	Likely Cheaper Choice
4	1 (bottleneck)	No	Yes	Rail Bus*
4	1 (bottleneck)	Yes	No	Rail Bus
4	3	Yes	Yes	Rail Bus
4	3	No	No	Rail Bus
20	3	Yes	No	Rail Bus
20	3	No	No	Pave
20	8	Yes	Yes	Rail Bus
20	8	No	No	Pave
50	1 (bottleneck)	Yes	Yes	(Probably cheaper to build separate roadway link)
50	3	Yes	Yes	(Depends on circumstances)
50	8	Yes	Yes	(Depends on circumstances)
50	1-8	No	No	Pave

*In the case of a short stretch of rail right-of-way which provides an efficient method of bypassing bottlenecks, it may not be necessary to rebuild trackage.

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CHAPTER XXI

DEMAND ACTUATED TRANSIT SERVICE

Operating Description and Summary of Findings

Demand actuated transit has been presented in a number of operating configurations. In most cases buses, whether large or small, are routed according to passenger requests and feature door-to-door service. Most often mentioned applications are feeder bus service to rail lines and to provide extended mobility for the transportation disadvantaged.

At this time there is little evidence to indicate that demand actuated transit would alleviate demand for new facilities. The high operating cost and unresolved technical, institutional, and demand questions dictate a cautious approach to this concept.

I. INTRODUCTION

Demand actuated transit goes by a variety of names such as Dial-A-Ride and Call-A-Ride, and has been implemented in a number of operating contexts. The basic concept involves providing a multi-passenger vehicle which will go to any requesting patron's home, collect him and other passengers within a specified time, and deliver all to their individual destinations. Demand actuated transit is designed to provide service only when needed and at a level which minimizes the more disagreeable elements of present transit service such as long walks and outdoor waits for vehicles during inclement weather.

Three basic types of service are usually considered:

(1) Many-to-one situations where patrons are collected from many diverse origins and delivered to a common destination such as a rapid rail station or shopping center.

(2) Many-to-few in which patrons from many origins are delivered to a few locations usually within close physical proximity such as within the CBD.

(3) Many-to-many where patrons are collected from any origin and, through close coordination of other patrons' origins and destinations, delivered to any destination in the service area.

Reverse service of that discussed in types 1 and 2 above is provided as well.

A variation in the previous service types is route deviation. Route deviation involves running a bus along a traditional route, usually where transit demand is greatest, and then deviating in low density, low transit demand areas according to actual requests for pick-up and drop-off.

Demand bus has the potential for increasing facility utilization in two ways:

(1) Demand actuated transit provides service when and where it would ordinarily not be provided by conventional transit and thus may serve as a useful substitute for private auto ownership, with consequent conservation of existing facilities.

(2) Demand actuated transit provides a unique tailored service; as a result demand may be stimulated thus assisting in rationalizing the economics of transit service to low density areas. At the same time, by providing service only when requested, the cost of unnecessary service can be eliminated. This two-fold potential to generate more revenue while cutting costs may have the effect of increasing overall levels of community transportation service or of reducing transit operating deficits.

- User Price Impacts

Most approaches to demand actuated transit service advocate a fare which is typically somewhere between that of a bus and a taxi. Naturally, that figure would vary according to the particular application.

Some examples based on experimental operation are presented starting with Table 21-2. Note that with the exception of Mansfield, Ohio fares were not set up to pay costs and thus are not representative of the true cost of operations. The Mansfield experiment is somewhat unusual in that the route deviation service was provided during periods of otherwise idle time in schedules. Thus, revenues generated as a result of route deviation were largely "bonus" revenues since additional costs accrued were minor (gas, oil, etc.) with labor and fixed costs unchanged. However, the operator did have to add radios for route deviation service. Extra service (route deviation) was added in an attempt to gain more passengers and, uniquely, a large portion of any increase in revenues went to the operator. Of the total fifty cent fare for route deviation service it is estimated thirty cents was returned to the operator as pure profit. Also, much higher costs would be associated with longer trip lengths than those served by the experimental projects.

Typically, fares seem to exceed the $0.12 per mile figure used in this study as the cost to operate private automobiles. Communities would have to face the question of whether the extra cost should be subsidized in the case of riders captive for economic or other reasons.

- Implementation Costs

Demand actuated transit systems can be set up and operated at varying levels of sophistication which are directly related to the number of vehicles in the system and the method of dispatching. One-time costs for two examples are given below:

Example 1: Five buses, radio dispatching (manual)

Vehicles	5 x $7,389	=	$ 36,945.00	
Radios	6 x $1,000	=	6,000.00	
	Total		$ 42,945.00	plus planning charges

Example 2: One Hundred bus system, computer dispatched, radio communication[1]

[1] A. Altshuler and D. Roos, "Dial-A-Bus", Advanced Urban Transportation Systems, Carnegie-Mellon University, Pittsburgh, Pennsylvania, May 1970, p. 7.

Vehicles	$ 700,000.00	
Radios	124,000.00	
Garage + System Other Fixed Expenses	63,600.00	
Computer + Communication Equipment	428,400.00	
Total	$1,316,000.00	plus planning charges

- Operating Costs

There is only limited operational experience and even less data on the total accounting of demand transit bus systems. The estimates generated for this analysis are based on the experiences in Bay Ridges, Ontario, Canada and Mansfield, Ohio, and on the analytical projections prepared by the Massachusetts Institute of Technology. A summary of the estimated costs and revenues per mile are provided in Tables 21-1 through 21-4. The productivity of the three systems is different, with that in Bay Ridges being eleven patrons/hour/bus; Mansfield, 5.5; and the MIT estimate, ten. The fares are also different, reflecting the local prevailing rates. The summary table indicates that to cover costs in most metropolitan areas the fare would need to be approximately $1.00.

It is apparent that small bus fleets are very sensitive to labor costs and the handling of the dispatcher function. The dispatching cost experienced in the Bay Ridges many-to-one system was slightly more per mile than that estimated by MIT for a many-to-many system. The cost of a computer for such a small system as Bay Ridges would be very high unless shared facilities could be used. Studies by General Motors indicate that the two dispatching methods (manual and computer) have equivalent costs for systems with peak hour demands of 225 requests. A fifteen bus fleet is needed to handle this demand (a productivity of approximately fifteen persons per bus in the peak hour).

The experience of Columbia, Maryland is quite revealing concerning the total costs for any demand bus system. Columbia has experienced a true cost per passenger (including all planning costs) of $2.10 with a three vehicle fleet. The system has maintained a maximum average productivity of approximately six demands per hour.

The Mansfield, Ohio experiment with route deviation indicated that the additional patronage generated by personal service produced a profit for the operation. The additional fifteen cents for doorstep service covered nearly all the fixed costs for route deviation; when the base fare of thirty-five cents was included, a gain of approximately thirty cents per additional patron was experienced.

- Other Costs

There is a possibility of increased congestion due to the substitution of many small vehicles for large buses as envisioned by typical plans. There may be a problem where narrow streets or cul de sacs are involved or at terminal points.

TABLE 21-1: Breakdown of Estimated Demand Bus Costs per Mile[a]

	Small Fleet Five-Bus System		Large Fleet 100-Bus System
	Many-to-One	Route Deviation	Many-to-Many
Fixed costs			
• Vehicle	10.44¢	7.23¢	17.72¢
• Computer	--		7.51¢
• Base personnel	17.61¢	11.70¢	9.15¢
Variable costs			
• Gas, maintenance	8.86¢	8.45¢	6.85¢
• Driver @ $5.00/hr.	38.95¢	37.47¢	41.22¢
@ $3.50/hr.	27.27¢	26.23¢	
• Dispatcher			Accounted for in computer and base personnel
@ $5.00/hr	15.41¢	--	
@ $3.50/hr	10.79¢	--	
Total costs (labor)			
• @ $5.00/hr	91.27¢	64.85¢	82.43¢
• @ $3.50/hr.	74.98¢	53.63¢	--
Estimated revenue	19.18¢	25.00¢	28.77¢
Estimated subsidy (labor)			
• @ $5.00/hr	72.09¢	39.85¢	53.66¢
• @ $3.50/hr	55.80¢	28.63¢	--

[a] The detailed estimates used to generate this table are noted in Tables 21-2, 3 and 4.

TABLE 21-2: Demand Bus Estimated Costs and Revenues--Five Bus System (As per Bay Ridges, Ontario)

	Annual Costs in Dollars		$ per Mile[a]
Fixed costs			
Vehicles[b]	$ 8,200		
Communicat'n equipment[c]	2,200	$ 18,380	.1044
Insurance license	3,980		
Building (800 sq. ft. @ $5.00/ft.)	4,000		
Supervisory[d]	31,000		.1761
Total	49,380	49,380	.2805
Variable costs			
Gas, Oil @ $0.30/gal.	6,800	15,600	.0886
Maintenance @ 5¢/mile[e]	8,800		
Drivers @ $3.50/hr.	48,000		.2727
Dispatcher @ $3.50/hr.	19,000		.1079
Total	82,600	82,600	.4693
Total costs		131,980	.7498
Revenue (25¢ basic fare)			
Weekday service	30,411		
Weekend service	3,348		
Total	$33,759	- 33,759	-.1918
Total (subsidy)		$ 98,221	.5580

[a] Estimated miles of travel equals 176,000 miles

[b] Five buses @ 7,389, ten-year diminishing balance with 30% salvage at five years with 8% interest

[c] Six radios @ 1,000, depreciation 6% annually over 15 years, 8% interest, replace each five years

[d] A director @ $15,000, supervisor and spare driver @ $10,000, secretary @ $6,000

[e] Maintenance experience is very limited--proponents of the system claim 1.4 to 2.0 cents per mile--other experience indicates 5 cents per mile; conventional bus systems operate at 8-9 cents per mile

TABLE 21-3: Demand Bus Estimated Costs and Revenues--Five Bus System (As per Mansfield, Ohio)

	Annual Costs in Dollars		\$ per Mile[a]
Fixed costs			
Vehicles	\$ 8,200		
Radio-telephone[b]	3,000	\$ 19,180	.0723
Insurance license	3,980		
Building (800 sq. ft. @ \$5.00/ft.)	4,000		
Supervisory	31,000		.1170
Total	50,180		.1893
Variable costs			
Gas, oil	9,153	22,399	.0845
Maintenance @ 5¢/mile	13,246		
Driver, dispatcher @ \$3.50/hr.	69,510		.2623
Total	91,909	91,909	
Total		142,089	.5363
Revenue			
25¢/mile for 264,932 miles[c]	\$ 66,200	- 66,200	-.2499
Total (subsidy)		\$ 75,889	.2864

[a] Estimated miles of travel is 264,900 miles

[b] Five radio-telephones with other customers @ \$50.00 each

[c] Observed income for route deviation bus in Mansfield with 35¢ base fare and 15¢ to pick up or drop off

TABLE 21-4: Demand Bus Estimated Costs and Revenues--100-Bus System[a] (As per Massachusetts Institute of Technology[b])

		Annual Costs	$ per Mile
Fixed costs			
Vehicles	$ 700,000		
Radio	124,000		
Insurance license	120,000	$1,010,600	.1772
Garage + system fixed	63,600		
Computer + communicat'ns	428,400	428,400	.0751
Base personnel	522,000	522,000	.0915
Total	1,958,000	1,958,000	.3438
Variable costs			
Gas, oil, maintenance	391,000		.0685
Drivers' wages	2,350,000		.4122
Total	$2,741,000	2,741,000	.4808
Total		4,699,000	.8243
Revenue			
(469,000 riders) @ 35¢ = $1,640,000		-1,640,000	.2877
Total (subsidy)		$3,059,000	.5366

[a] Summarized from page 7, Advanced Urban Transportation Systems, Carnegie-Mellon University, Pittsburgh, Pennsylvania, May, 1970. "Dial-a-Bus" by A. Altshuler and D. Roos.

[b] Operates on fixed routes during the rush hours then switches to a many-to-many "Call-a-Ride" at all other times

. Indirect Economic Effects

Indirect economic benefits are to a large extent dependent upon the amount of substitutability that demand actuated transit can provide for the automobile. To the degree that demand actuated transit is accepted as a substitute, the following are among the indirect benefits of most importance:

- Avoiding further capital investment in automobile oriented facilities such as parking garages, lots, and additional roadways.

- Provision of improved mobility to captives, therefore providing more readily accessible job opportunities.

. Impact on Disadvantaged

The demand actuated bus is of definite benefit to economically and other disadvantaged groups. In theory it provides any individual with access to any economic or social service, whereas before the disadvantaged were dependent upon the access provided by more rigidly structured transit service. In practice, however, high fares and service limitations may drastically limit the practical value of such ubiquitous mobility. Again, this will depend on a particular plan of application.

. Environmental Impact

The environmental impact is directly related to the number of automobiles replaced by the demand actuated transit service. The expected impact under most service plans would probably be minimal.

. Safety Impact

No data are available, but little impact is expected.

. Speed or Time

Demand actuated transit will operate at the same speed as existing traffic. The time associated with a demand actuated transit trip will vary, but it will be longer than a comparable trip by personal automobile due to collection and distribution requirements; in some cases it will be longer than the conventional transit trip. The speed and time disadvantage is offset to a degree by the greater flexibility of origin and destination location. For captives, this is a definite advantage which may well be worth the time disadvantage. For those who have a choice between private auto and demand bus, the time penalty may be too great. The actual relationship between the time of a trip by auto and demand bus is partly a policy decision based probably on the level of service that is feasible.

The attitude studies conducted by General Motors indicated a desirable ratio of transit time to auto time of approximately two to one for trips of ten minutes by auto and 1.5 to one for trips of twenty minutes by auto. The efficiency of demand bus systems would probably be quite low for trips in excess of twenty minutes. Therefore, patrons desiring an "express bus" type of demand actuated service would have to be satisfied by atypical arrangements or conventional express service.

- Volume

The additional volume which can be carried in demand actuated transit is a function of the number of automobile users diverted to higher capacity vehicles. Suitable vehicles can accommodate twenty passengers, which is equivalent to taking approximately thirteen cars off the road if all passengers are diverted from auto usage. If achievable, in practice this would raise person capacity levels on existing highways and street systems. Projections of actual volume levels would have to be derived from specific applications analyses.

- State-of-the Art

The only components needing further development at this time are the software and hardware associated with automatically routing and dispatching vehicles in the more sophisticated versions. While it is claimed that solutions to the automatic dispatching and routing problems are available, no adequate tests are available to confirm this.

Manually dispatched systems have been operated under a number of policies in North America and Europe. The systems are:

Type of Service	Location	Status
. Route Deviation	Mansfield, Ohio	Out of business
. Many-To-One	Bay Ridges, Ontario	Expanded
	Holland	Expanded
. Many-To-Few	Bay Ridges, Ontario	Expanded
	Holland	Operating
. Many-To-Many	Columbia, Maryland	Operating (evenings only)
	Bay Ridges, Ontario	Operating (with constraints; must meet a train)

- Institutional Background

Major conflicts exist between operators of existing public transit and taxi operators as to whether such service should be provided and, if so, who should provide it. No easy solution appears to be likely for this problem as, in the few applications known, both taxi and bus operators have ended up operating the service. In most applications the fears of the taxi industry were either disregarded (Bay Ridges, Ontario) or unfounded (Mansfield, Ohio). Larger urban areas may pose more formidable problems.

A full scale test of public utilities commission regulations and responses to demand actuated transit is yet to be generated. Transit legislation must be checked to see if any laws exist which specify rigid routes and stops. In Minnesota the only legislative change needed was the elimination of the need for a prescribed route. The legislation in Maryland allows any type of operation and defines transit and taxi by the seating capacity of the vehicle.

It can be expected that in most cases of demand operation, transit wages at union scale will have to be paid to drivers. Under some circumstances unions may demand more pay for the more complex work involved in non-regularly routed transit service. All the applications to date have been in non-union systems and often have had the potential of using part-time personnel to get by peak periods. Because demand transit is so labor intensive, transit wages and work rules may make transit operation of such service extremely costly.

- Traveler Response

To date, experiments indicate that demand transit appeals most to present transit users. Some auto users have been attracted to the service but not in large numbers. Modifications or larger-scale experiments may lead to greater response from travelers.

III. SUMMARY AND CRITIQUE

The principle value of demand actuated transit is in the increased flexibility of service offered. This service is achieved at substantially higher user and/or community costs when a comparison is made with conventional transit service. While it would provide substantial benefits to transit captives and the disadvantaged as a whole, there are conflicting projections of the impact on utilization of existing facilities. If many smaller vehicles are substituted for conventional transit service, congestion and demand for new facilities may increase. If travelers can and will in large numbers substitute demand bus trips for personal auto trips, then congestion on existing facilities might be alleviated and demand for new facilities decreased. Experience to date has not been able to clarify which of these outcomes will be most likely to materialize. However, travel time delay and high cost strongly suggest, based on empirically derived mode split data, that auto travelers will not generally opt for demand bus service; thus the opportunities afforded to avoid investment in new fixed capital facilities seem minimal. Table 21-5 provides a comparative summary of demand transit and other urban transportation modes and the relative advantages associated with each.

The technological risk associated with implementing a small manually dispatched system is low. The risk associated with a large computer dispatched system is high since such systems are yet to be demonstrated in actual operation.

The demand bus system's most promising aspects are:

TABLE 21-5: Summary Comparison of Urban Transportation Modes

Item	Demand Bus: Many-to-One	Demand Bus: Many-to-Few	Demand Bus: Many-to-Many	Taxi	Transit	Auto
Speed of trip	Moderate	Moderate	Slow	Fast	Moderate	Fast
Destination selection	Many with transfer	Many with transfer	Many	Many	Limited	Many
Waiting time for vehicle	Moderate	Moderate	May be high	Little	Moderate	None
Location of waiting	Home building	Home building	Home building	Home building	Exposed	None
Distance to vehicle pick-up point	Little	Little	Little	Little	Variable	Little
Passenger comfort	Fair	Fair	Fair	Good	Fair/ poor	Good
Expected fare costs	Moderate	Moderate	High	Very high	Low	--
Flexibility of service	Low	Moderate	High	High	None	Very high
Ease of schedule control	High	Moderate	Difficult	--	High	--
Arrive at a destination when planned	Good	Good	Fair	Very good	Good	Very good
Labor needs	High	High	High	High	Moderate	None
Area of usefulness by density of demand	Moderate	Moderate	Low	Moderate to high	High	Moderate/ low
Average passengers/hour[a]	16	16	16	4	25	--
Average cost per vehicle hour[a]	$9.00	$9.00	$9.00	--	$9-12	--
Average cost for a 3-mile trip[a]	$0.55	$0.55	$0.55	$2.00	$0.40	$0.30

[a] SOURCE: Table 6-2, D. Roos, et al., "Summary Report of the Dial-A-Ride Transportation System," MIT Urban Systems Laboratory, Cambridge, Massachusetts, March, 1971

- The increased mobility and employment opportunities to captives and others forced to depend on limited public or private transportation opportunities.
- Demand bus is a labor intensive industry which could employ large numbers of low skilled workers, if widely implemented. However, it should be noted that many bus operators have extreme difficulty in locating sufficient qualified drivers at prevailing high transit wage rates.

Questions that require answers are as follows:

(1) Much information is needed on the character and quantity of expected demand and the relationship of this demand to the potential for making better use of existing facilities.

(2) Optimum service characteristics need to be analyzed and described.

(3) Several technological questions surrounding computerized dispatching and routing need resolution before some of the more esoteric and large scale applications might be feasibly undertaken.

CHAPTER XXII

BUS TRAFFIC SIGNAL PREFERENCE SYSTEMS

Operating Description and Summary of Findings

By controlling traffic signals to favor buses, it may be possible to decrease bus travel times. One version would permit buses to change lights to green or hold lights green whenever a bus approaches. Another would only change lights or hold a green when side street traffic queues were manageable and ample downstream capacity existed. The latter is felt to be the only practical large scale system application, although the former may prove useful in certain specific circumstances.

Under mixed traffic circumstances, the impact on bus travel time is expected to be too minor to warrant implementation. Further, without appropriate large scale schedule adjustments, this slight travel time advantage may not be fully realizable. However, this is one technique which may prove more valuable if implemented in conjunction with an exclusive bus lane. (See Volume II)

I. INTRODUCTION

Transit planners have investigated, in their efforts to improve public transit operations, techniques which might increase the average speed of conventional bus operations. Any increase in bus speeds should have two effects. First, increases in bus speeds would reduce bus travel time as well as the time advantage of the automobile undertaking similar trips. Increased transit speeds usually result in increases in transit usage and thereby may possibly reduce the number of automobiles on the highway. Second, an increase in speed could have an effect on the productivity of bus operations. Shorter trips would mean quicker bus turn-around and possibly reduction in fleet size without reductions in service or even more service with the same size fleet or labor force.

One suggested method of increasing the speed of buses is to decrease the number of traffic signal stops. A running time survey taken in Tampa, Florida showed that approximately eleven percent of the bus running time was spent waiting at traffic signals.[1] This figure is consistent with other studies. A bus priority system is designed to decrease the time delay of buses at traffic signals by providing buses with control over signals so as to minimize time spent waiting for lights. There are two types of signal preference systems:

(1) The pre-empt system
(2) The priority system

The pre-empt technique senses the bus approaching a traffic signal and either: (1) holds the green light for the bus, or (2) actuates the green light as soon as possible. The priority technique senses the approaching bus and will hold the light green for a certain length of time if the bus can go through the intersection in that time period. A priority system will not change a red light, hold the green for buses when traffic is backed up ahead, or hold a green light when severe backup exists on side streets. The Kent State University project is essentially a pre-emption system while the proposed Washington, D.C. project is essentially a priority system.[2]

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[1]Alan M. Voorhees & Associates, Inc., "Transit Studies, Tampa Urban Area Transportation Study," prepared for the Hillsborough County Planning Commission, McLean, Virginia, February 1968.

[2]Kent State University, A Bus Priority System for Traffic Signals, Urban Mass Transportation Administration Project, OHIO MTD-4, 1971., and Sperry Systems Management Division, Advanced Control Technology in Urban Traffic Control Systems, Volume 1A, Bus Priority System Description, prepared for the Department of Transportation, Great Neck, New York, March 1970.

- User Price Impacts

Transit user prices should not change if a bus priority system is in operation. Capital, installation, and operating costs would probably be born by a local governmental agency so that transit systems savings, if any, could be used to improve service or lower fares (very unlikely). The automobile user may be adversely affected. The Kent State project showed a decrease in the average automobile speed of approximately four percent, theoretically attributable to the additional waiting time at the signals. This may result in higher costs for the individual driving his car.

- Implementation Costs

The bus priority system as developed for the Washington, D.C. experiment consists of the following equipment:

- Bus detectors which differentiate between "stopping" and "through" buses at all intersections.
- Communications equipment to send bus data to the Urban Traffic Control System control site.
- Cabinets to house the on-street equipment.
- A digital computer system at the central site.

The intersection cost for this equipment is about $312.00 for an average of two and one-half detector receivers and loop antennas per intersection. Bus transmitters cost about $125.00 each. The telemetry equipment associated with each intersection costs about $1,350 per intersection.[3] The cost of leased lines and the central computer facility was not available. Some of this equipment is likely to be utilized for other traffic management objectives.

While the Kent State project report did not give the estimated capital cost, the equipment was less sophisticated and therefore less costly than the Washington project. Conversations with project personnel placed this cost at about $1,000 per intersection.

- Operating Costs

There will be maintenance associated with the electronic equipment used in a bus priority system, although none of the reports attempted to estimate this cost. Maintenance could be carried out largely by the present signal maintenance staff in most highway agencies.

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[3] Ibid.

. Other Costs

Drivers in cars on non-bus routes may be penalized with extra wait-times at lights. To some extent this is counter balanced by the extra speed of vehicles once they enter the same traffic stream as buses.

. Indirect Economic Effects

A bus priority system has as its objective that a person's travel time is reduced. This was one of the design criteria for the Washington experiment. In such cases the user would benefit from the time saved. It would be reasonable to expect that if bus passenger speeds increased that more travelers would find bus usage attractive. The net effect, however, is probably too small to result in a reduction in needs for new facilities.

. Impact on Disadvantaged

It would appear that there would be little or no social impact from a bus priority system as usually conceived. An unregulated preemptive system might result in traffic congestion on side streets and subsequently vocal highway user dissatisfaction. To some extent, the high proportion of disadvantaged travelers who must use public transit would realize a travel time advantage over the more affluent auto traveler.

. Environmental Impact

A bus priority system may tend to increase air pollution. Since design criteria emphasize minimization of person time and not vehicle time this may mean increased delay of automobiles. Thus, if vehicle hours increase as a result of the delayed automobiles, there will be more total emissions. None of the reports explicitly addressed this fact and quantification of the increase of pollution is beyond the scope of this review.

. Safety Impact

It would appear that a bus priority system would have little or no affect on safety.

. Speed or Time

The main purpose of the bus priority system is to increase the speed of buses. The Kent State preempt system showed a ten percent increase in bus speed. Unfortunately, this increased speed is paid for with a subsequent decrease in the speed of automobiles. This delay was very slight at Kent State. Estimates for the proposed Washington, D.C. priority system (a more likely candidate system for widespread implementation) are that delays at signals would decrease thirty percent. If average figures on delay at signals are between ten and eleven percent of total trip time, then total trip delay would be reduced only about three percent with bus priority systems. This does not seem significant, although the thirty percent reduction in time stopped at signals may give the appearance of a faster ride to some transit passengers.

- Volume

It would be expected that the increase in volume (measured in units of persons) would be proportional to the increase in speed. That is as bus speeds improve more person trips would be attracted to buses.

The theoretical volume advantage of buses is about forty to one assuming fifty-three passenger buses and an average car load of 1.3 passengers.

- State-of-the-Art

The Washington, D.C. project investigated the availability of components and although all components are not off-the-shelf items they can be produced using standard techniques.

Considerable software is available as a result of the work carried out in the Washington, D.C. project. Once the hardware is installed in Washington, the project staff expects to use the system as a laboratory to develop efficient operating techniques and additional software.

- Institutional Background

There would appear to be no significant institutional constraints prohibiting the application of a bus priority system. A possible public outcry as a result of longer waits on side streets might develop.

- Traveler Response

Ridership demand formulas developed by transit planners and based on empirical evidence list speed as the major component affecting a person's decision on whether to ride a bus (assuming that a person is not a captive). If a bus priority system can noticeably decrease bus travel time, or perceived bus travel time (and this has not been conclusively demonstrated) then it would attract new patrons to transit. Since a very small increment of increased speed is anticipated with bus priority systems, a big increase in demand cannot be expected.

III. SUMMARY AND CRITIQUE

A bus priority system, such as the proposed experiment in Washington, D.C., would appear to be an attractive technique to increase the speed of buses with a minimal disruption to other modes. However, the actual decrease in delay is estimated at a very low three percent. The pre-emptive systems, similar to the Kent State project, would further reduce the bus signal delay but with greater automobile delay. The Kent State system could not be applied to a long sequence of traffic signals such as typically exist on a long travel corridor because that system fails to account for downstream queues. Thus, a pre-empt system may increase speeds more than a priority system, but it can only be installed in isolated congested areas. The cost of a bus priority system would not appear to be high.

Data is not available on the relative desirability of alternative traffic engineering approaches to speeding bus traffic through intersections. Possible alternatives may include simpler techniques such as placement of near-side versus far-side bus stops in the optimum location for bus use of existing or modified traffic signal timing progression in interconnected signal systems.

By way of a final comment, it should be mentioned that one major problem for bus operators is keeping drivers from running ahead of schedules with the effect that buses bunch and patrons experience long waits. A bus priority system may unwittingly exaggerate this phenomena if schedules are not or cannot be appropriately adjusted.

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CHAPTER XXIII

AUTO DRIVER AIDS AND DIRECTIONS SYSTEMS

Operating Description and Summary of Findings

Systems of changeable roadside message signs are designed to warn motorists in advance of undesirable traffic conditions and to advise on more favorable alternative routes. As a result it is hoped net travel time delays would be reduced.

Studies of this technique have failed to indicate any substantial benefits from use. In addition, there remains serious questions about whether a workable and understandable message technology has been developed.

I. INTRODUCTION

The directional aids (information signing) system referred to in this discussion consists of changeable message signs regulated by computer-processed inputs from electronic or similar sensors typically imbedded in the roadway. The information signs give the motorist dynamic real-time information on the advisability of taking a specific route, based on possible congestion, accidents, and other variable conditions on the alternate routes. Thus far, little practical experimentation has been done in the field of directional aids.

All of the practical data and projections used in preparing this report were taken from directional aid work done in two locations: (1) a specially equipped segment of the John C. Lodge Freeway in Detroit, and (2) portions of the Eisenhower Expressway in Chicago.

An important point to remember throughout this discussion is that the directional aid system, as described in the first paragraph of this report, has been tried only in connection with ramp metering. (Ramp metering per se has been described more fully in the concept paper in this series entitled "Freeway Ramp Metering.") Both of the above mentioned freeway sections in which directional aids were tested were also equipped with ramp metering devices.

In his paper, "Control of a Freeway System by Means of Ramp Metering and Information Signs," R.L. Pretty[1] gives a hypothetical description of a directional aid system that could be used in connection with freeway ramp metering. The system would consist, in part, of changeable information signs. These signs would light up to point the motorist toward the next downstream ramp or optimal downstream ramp, if congestion on the ramp and/or the freeway was excessive at the motorist's original preferred entry point to the freeway. If sufficient numbers of motorists actually follow the advice of the signs when an alternate route is suggested, then surface street and freeway routes should reach a state where the travel time would be about equal for each route. Pretty suggests that the changeable signs could be adjusted at regular intervals, such as every minute. The ramp queue length at the beginning of the minute would then determine whether or not the sign state should be changed. The condition for making the change should be that a test car moving to enter the freeway from the choice point at that minute should save time by following the sign when it is pointing to the freeway ('green') and lose time by choosing the freeway when the sign is pointing to an alternate route ('red'). An allowance, Pretty points out, should be made for the expected number of vehicles to arrive at the ramp before the test car has traveled from the choice point to the ramp.

The information signing systems that were actually in operation in Detroit and Chicago conform generally to Pretty's theoretical description. The Detroit and Chicago systems had similar physical layouts. The Chicago expressway control system consisted of: (1) entrance ramp metering signals at four successive westbound I-90 (Eisenhower Expressway) interchanges, and (2) four supplementary informational signs located on southbound and westbound approaches to two major surface street intersections which handle expressway bound traffic.

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[1] R.L. Pretty, "Control of a Freeway System by Means of Ramp Metering and Information Signs," Greater London Council, England, presented at 51st Annual Meeting of the Highway Research Board, January, 1972.

These informational signs show traffic conditions at the two nearest outbound expressway interchanges by color-coded, changeable arrows: GREEN=NO DELAY; YELLOW=MODERATE; RED=CONGESTED. If a motorist finds that the eastern-most of the ramps is congested, he can continue to travel west on the arterial, observing the other informational signs, and avoiding the peak period queue on the ramps, instead of contributing to it. While the arterials in question appear to provide a fair alternate route for avoiding a congested freeway, they do not serve as a frontage road for the freeway. These major arterials are located several blocks away from the freeway; thus, the motorist cannot readily pass from the freeway to the alternate routes. In Detroit, however, a frontage road serves much of the Lodge Freeway. Thus, a relatively easy alternate route to the freeway is available. Freeway informational signs were located at two entrance ramps on the frontage road, and at two locations on a parallel arterial street where drivers decide whether to turn onto the freeway. Also, nearer to the ramps themselves are six "Freeway Stopped Ahead" signs. These signs usually appear blank, but can be illuminated to display the "Freeway Stopped Ahead" message during periods of congestion. Although these sets of directional aids all serve metered ramps on the freeway, there are other metered ramps in the vicinity that are not served by the directional aids.

The actual directional aid signs themselves were similar for Chicago and Detroit, consisting of a series of color-coded arrows as described above. Each sign contains a simplified map or diagram of that portion of the freeway it serves, and the changeable-color arrows appear on the ramp and freeway portions of the diagrams.

Another important component of the directional aids scheme is the computer system that determines what information appears on the directional aids signs at any given time. In Chicago, the informational signs along with the ramp metering signals, are automatically controlled from continuous expressway and ramp traffic measurements. An electronic detection system monitors expressway and ramp traffic on a six-mile outbound portion of the expressway, including the segment containing the four metered ramp entrances. Forty-five detectors were placed on most of the metered ramps at approximately one-half mile intervals on the expressway, thus providing information on traffic at these points. These data are handled by a small, real-time digital control computer and several analog computers. System surveillance, control, and evaluation outputs are received. The control observer works with a display of expressway traffic conditions, prevailing metering rates, ramp signal changes and violations, sign conditions, and other information provided by an office control console.

II. TECHNICAL EVALUATION

. <u>User Price Impacts</u>

The user is not directly charged for the directional aids system. It is not expected that much change in vehicle operating costs will occur after introduction.

- Implementation Costs

Costs for the system are moderate. Most of the expense is incurred when the directional aids system is tied into the ramp metering system. Courage and Levin[2] estimate the annual installation and operational costs (without research costs) as being $58,755 for the surveillance and control facilities. More detailed information on costs of surveillance and control facilities can be found in the concept report on Freeway Metering, Monitoring, and Control Techniques referred to previously in this paper.

The implementation costs for actual signing systems are very small:[3] Initial costs for each changeable ramp information sign, including installation, were $237.50 each in Detroit for four signs. The cost of each blank-out "Freeway Stopped Ahead" sign, including installation (total of six signs used in Detroit) was $90.00 each.

The signing system is estimated to have a ten-year life.

- Operating Costs

The operating costs for the signing system described above are presented by Levin and Courage:[4]

Item	Estimated Annual Cost
Telephone Circuit Rental - 14 circuits @ $60 per year	$ 840
Maintenance	1,100
Power	750
TOTAL ANNUAL OPERATING COST 10 sign system	$2,690

High operating costs were partly responsible for the discontinuing of directional aid signing in the Chicago area. A revolving color wheel was used to change colors of the arrows on those signs. The wheel was quite expensive to operate and experienced operational difficulties. In cold weather the turning mechanism froze, necessitating extra spending for repairs (this does not appear crucial).

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[2] K.G. Courage and M. Levin, A Freeway Corridor Surveillance, Information and Control System, Texas Transportation Institute Research Report No. 488-8, December, 1968.

[3] Ibid., p. 281.

[4] Ibid., p. 281.

- Other Costs

None of significance

- Indirect Economic Effects

The main indirect economic benefit accrueing from this technique is the value of user time saved. While some individual trips may well be longer with a ramp metering-directional aids system, combined trip time for all trips should be lowered. Further, the purpose of directional aids themselves (as opposed to the ramp metering) is to give the individual trip taker the information on freeway conditions that he needs to know in order to choose between the freeway and the normally slower-moving arterial. The trip taker must then supply his own information such as length of trip and ultimate destination in order to decide whether to opt for the freeway, a downstream entrance ramp, or a route on the arterials.

Another potential but undocumented economic saving due to ramp metering and directional aids is that use of this system may allow the corridor, and freeway itself, to handle traffic more efficiently with some increased capacity. This is expected to be marginal and would probably not ease the need for new capital facilities.

- Impact on Disadvantaged

None of significance.

- Environmental Impact

More efficient use of corridor facilities should result in reduction in stop-and-start traffic movement and reduced overall vehicle operating time. This should lead, in turn, to reduction in emissions. To date, quantification of this benefit has not been obtained. The expected few opportunities to implement this strategy means that cities can expect minor benefits.

- Safety Impact

The ability of ramp control systems to reduce accident rates has been previously documented and discussed in the concept study on Freeway Metering, Monitoring, and Control. In short, it was felt that reduction in congestion reduced accident rates by as much as 17%.

Directional aids systems seem to offer no additional safety improvements.

- Speed or Time
- Volume

: Combined Discussion

While McDermott reported that reduced congestion has improved expressway travel in Chicago, it must be stressed that the improvement was due to both metering and information signing; it is hard to isolate their respective impacts.[5] The only Chicago-area data gathered that dealt specifically with directional aids referred to the problem of whether corridor users responded to the information on the signs when deciding on their routes. The findings, to be discussed in more detail later in this paper, indicate that the corridor users generally did not respond to the information on the signs.[6]

In contrast, the data from Detroit seemed to indicate that the informational system when added to the ramp metering system was able to further improve traffic flow. This improvement in flow was measured in terms of travel time savings, with these savings classified into three categories:[7]

(A) Decreased travel time was measured by higher speeds and ability of more vehicles to use the freeway. When vehicle speed increases more vehicles are allowed to use the freeway in a given time period. According to the report, this amounted to 486 additional vehicle miles per day with a saving of 3,000 vehicle hours per year. Analysis of the report's data base, as shown in Table 23-1, indicates this savings amounts to only a 1.2% increase in miles traveled for cars entering the freeway in this area.

(B) Time savings resulting from earlier satisfaction of entrance ramp demand. This was asserted to be 163 vehicle hours per day (41,000 annually). However, this calculation was not clearly explained nor its relative impact measured.

(C) Increased delay due to heavier loading on alternative routes such as parallel frontage roads. This negative value was felt to be equivalent to the savings generated in "A" above.

The authors of the report say that the savings cited above must be tempered by several facts, among which are these:

(1) "While response to the sign message is apparent, the extent of the real-time response (as opposed to a permanent change in patterns of ramp usage) is not known."

(2) "The actual travel time saving is not too large, and is likely to be reduced under a fully operational ramp metering system when the queueing patterns have become completely stabilized."[8]

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[5] Joseph McDermott, "Operational Effects of Automatic Ramp Control on Network Traffic," in "Highway Research Record No. 202," Highway Research Board, Washington, D.C., 1967, pp. 5,6.

[6] Gerald C. Hoff, "Development and Evaluation of Experimental Information Signs," Chicago Area Expressway Surveillance Project, Report #18, December, 1965 (revised June, 1968), see especially pp. 19-22.

[7] Courage and Levin, Op. Cit., pp. 49-50.

[8] Ibid., p. 51.

TABLE 23-1: Informational System Effects On Mileage Savings

Ramp	Total Volume: Before Informational System	With Informational System	Volume Difference	Average Trip Length	Travel Time Difference (Miles)	Total Miles Traveled By Vehicles Entering Freeway at This Ramp Before Information System
W. Grand Blvd.	3270	3170	-100	5.27	-527	17,232.9
Seward	1150	1177	+ 27	4.98	+135	5,727.0
Chicago	1031	962	- 69	4.07	-282	4,196.2
Webb	725	919	+194	3.53	+685	2,559.3
Davison	3772	3941	+169	2.81	+475	10,599.3
				TOTALS	486	40,314

$486 \div 40{,}314 = .012 - 1.2\%$

Savings in miles traveled, due to informational signing, as percent of total miles traveled by vehicles entering freeway at metered ramps.

SOURCE: Courage & Levin, adapted from Table D-3, p. 264.

Statement number two was not clarified further. It is included here only to indicate that the people involved in the Detroit studies had serious doubts concerning potential time savings due to informational signing. Nor were the authors able to separate the impact of the "Freeway Stopped Ahead" signs from the effect of the ramp informational signs on real-time rerouting of traffic.

An experiment to test driver response to informational signing in Chicago yielded even fewer favorable results. The data discussed here, presented by Hoff in his paper[9] did not deal directly with the question of processing efficiency improvements due to the signing, but rather with the question of whether drivers look at the signs and respond in a positive, dynamic way to the information presented. The data gathered indicated that in the 3:30-6:30 PM period, for the two ramp areas which were tested, there was a statistically significant difference between the "without" control and "with" control volumes at each ramp. Thus, ramp metering itself (without considering directional aids) did have an impact on ramp volumes, decreasing them significantly. Isolating the impact of directional aids involved further experiments. Diversion due to both the ramp metering and/or informational signing was divided into two components:

(1) Real-time response (day-to-day change)

- (a) Those drivers who drive to the ramp each day and, based on actual inspection of the queueing, decide whether to take another route, and
- (b) Drivers who use the information on the directional aid signs in deciding upon the best route.

(2) Permanent diversion

Those drivers who once used the ramps, but no longer do because of the delay caused by the metering.

The total diversion (components 1 and 2, permanent and day-to-day diversion) at the two ramps tested was found to be 508 over the three-hour period, while the day-to-day diversion only was 177 for the two ramps. A further study of data gathered was made in an attempt to separate the two components of day-to-day diversion. A count of certain traffic turning patterns near the entrance ramp was made in order to distinguish those drivers who drove all the way to the ramp and then made their routing decision.[10] The results of this phase of the study, Hoff writes, suggested that "the informational signs do not have a measurable effect upon the daily distribution of expressway-bound traffic." However, Hoff adds that "it does not necessarily logically follow that the concept of presenting expressway traffic information on arterial streets is invalid."[11] Hoff says that many factors, such as driver failure to understand the significance of the map or symbols on the informational sign would mean that he would either ignore the signs or not be able to use them properly.

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[9] Hoff, Op. Cit., p. 18.

[10] Ibid., p. 19.

[11] Ibid., p. 22.

Hoff also attempted to measure motorists' reactions to informational signing by passing out a questionnaire to PM peak hour motorists using the freeway corridor with the informational signing and asking them questions about the signing.

The questionnaire respondents answered in this way:

Item:	Total in Sample: 538 Yes	No	Total
Had seen the signs	443	95	538
Had seen the signs and understood the meaning of the colors	349	94	443
Complete comprehension of sign	308	41	349

Of those who said they completely comprehended the sign, 40% sometimes and 50% always bypass the expressway when the signs show it to be congested.[12] Also, 45% sometimes and 24% always use the signs to select the best ramp at which to enter the expressway. Thus, the questionnaires indicate much usage of the signs by motorists.

Hoff asserts that the contradictory nature of the traffic pattern counts and the questionnaires indicates the need for much more research in the area of informational signing and directional aids, particularly toward the end of making signs more understandable to the driver.

- State-of-the-Art

While software and hardware for ramp metering, and for most informational signing tasks is currently available, there are some more precise measurements of freeway travel rates that cannot be made with current technology in this field. The potential freeway driver cannot be completely informed by the signs of the length of the delay he might experience by using the freeway. The message appearing on the directional sign at any given time is determined by two inputs. The first input is the occupancy level of the freeway lanes, as measured by detectors located on the metered portion of the freeway. A second input to the directional signing is a measure of ramp delay. An approximation of this delay is obtained from two measurements:

(1) the frequency with which vehicles are released from the ramp queue to enter the freeway (the ramp metering rate), and

(2) the number of vehicles in the ramp queue.

The two inputs, the occupancy level of the freeway and the measure of ramp delay, form a matrix, with the matrix controlling the color of the arrow on the informational sign:[13]

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[12] Ibid., p. 31.

[13] Ibid., p. 15.

Metering Rate (vehicles/minute)
The metering rate is a measure of lane occupancy on the freeway

Measure of Ramp Delay:	Metering Rate: 12	10	8	6	4
No queue	G	Y	Y	Y	R
Queue	Y	Y	R	R	R
	Color of Arrow				

Lack of extremely precise information on freeway conditions conveyed by the directional aids may discourage some motorists from using the signs, although there may always be some motorists who trust their own intuition rather than the signs, no matter how accurate the signs are.

A second state-of-the-art problem is even more difficult to clarify with actual data. This is the problem of being able to read and understand the signs themselves, and the possibility that the type of information conveyed on the signs is not what the motorist wants. Hoff found that the questionnaires he used to gauge motorist response to informational signing contained many unsolicited comments on the signs, with most respondents charging either that the sign was too complicated or too inaccurate. Hoff says that the inaccuracy "is inherent because of the inability to predict what changes will occur in the traffic conditions from the time the driver sees the sign until he arrives at the expressway."[14]

Further work on motorist reaction to the appearance and content of directional aid signs was done by Dudek and Jones.[15] Their study sampled 505 motorists in Houston and Dallas, and was done with a questionnaire and slide presentation rather than gathering of data dealing directly with the participants' driving patterns. Four types of signs were displayed to the interviewees. The signs contained white lettering on a green background, a red indication to describe congested conditions, and a green indication specifying normal conditions. The four types of signs, in order of preference by the viewing group, are as follows:

(1) Sign with words and color indications to describe the traffic conditions.

(2) Sign with only color indications to reflect traffic conditions.

(3) Sign showing diagram of the area and illuminated color symbol indications to show traffic conditions.

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[14] *Ibid.*, p. 31.

[15] Conrad L. Dudek and Hal B. Jones, "Evaluation of Real-Time Visual Information Displays for Urban Freeways," in "Highway Research Record No. 366," Highway Research Board, Washington, D.C., 1971, p. 64.

(4) Sign showing diagram of the area and giving travel speeds between reference points.

The subjects were posed with various hypothetical routes involving frontage road and freeway driving, and were asked to choose which type of sign they would prefer for information on optimal routes. The researchers found that there was clear preference for the signs in the order listed above. Thus there is some evidence that user preference for certain designs of informational signs is greater than their preference for other signs. And it must further be noted that the sign ranked third in driver preference, out of the four tested, was most similar to the type of signing used in the Chicago and Detroit experiments. Thus, there indeed appears to be merit to Hoff's contention that problems with the signing itself may have reduced the degree of response to the directional aids system.

- <u>Institutional Background</u>

The reaction to directional aid systems is naturally tied to reaction to metering and control systems. For assessment of institutional reaction to metering systems, see Section VI. of the Freeway Metering concept study. In essence, the highway agency will be placed in the position of day-to-day operation of a system which will deny some citizens travel opportunities.

Funding for direction aids study appears to be adequate. The funding comes from state and federal highway agencies. The metering and directional aids projects have been conducted mainly by state highway departments and federally-funded research programs.

- <u>Traveler Response</u>

No special consumer desire for the informational signing system has been detected. Improved technology will likely increase the system efficiency and possibly generate some demand for the signs.

III. SUMMARY AND CRITIQUE

The ultimate value and applicability of informational signing appears to be minimal at present, even allowing for improvements in technology and wider experimentation. Some critical problems are evident from research cited in this report. A main problem is that time and mileage savings due to informational systems appear to be very minimal, judging from experimentation presently completed. The reason for the minimal savings is unclear. If it is due to technological problems, then refinements may prove useful. But if the concept itself cannot provide sufficient benefits in the area of time saving, it might well be abandoned in favor of more promising concepts.

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CHAPTER XXIV

THE MINICAR

Operating Description and Summary of Findings

Small two to three passenger vehicles would be rented by urban residents for short trips within a particular urban area. Typically, vehicles would be powered by low emissions engines and consume small amounts of capital facility whether operating on the street or parked. Typical plans call for the vehicles to be available at many convenient locations around the city. Trips could be charged by the mile and payment by credit cards which would be available only to properly licensed drivers. The minicar would serve as an effective substitute for larger space consuming traditional vehicles.

The substantial initial investment required appears to be as great as more traditional capital intensive solutions. Major technical institutional and operational questions remain unresolved and near term applicability is therefore unlikely.

I. INTRODUCTION

The minicar is a very small, relatively pollution-free vehicle designed to replace the conventional automobile for travel in or through central business districts, for commuting to and from fixed rail lines, and for making short local trips, both during rush hours and other periods of the day. Two proposed theoretical applications supply the base data for this evaluation. These are:

(1) A University of Pennsylvania study projecting the application of the minicar concept to the Philadelphia Central Business District[1].

(2) A Contra Costa County, California study on transportation needs specifically charged with recommending a feeder service for BART terminals.[2]

In the Philadelphia study, the concept is usually referred to as the "minicar" system; the Contra Costa study referred to the concept as the Public Automobile System (PAS).

In both applications, the system includes a fleet of specially-designed vehicles available to the consumer by short and/or long-term rental only, special parking and handling facilities, and use of state-of-the-art technologies for cost reduction and system efficiency.

The Philadelphia system will provide a minicar for the entire length of the commuting trip. The Contra Costa PAS (Public Automobile System) is designed to handle short distance transportation needs, specifically access to the fixed rail rapid transit facility (BART) or local service trips - - shopping, doctor, etc.

If minicars are used in sufficient quantity, theoretically the city and suburban neighborhoods will benefit from increased street capacity and reduced pollution, with greater vehicle capacity in existing parking lots, as minicars are substituted for standard cars. In this way demand for new facilities would be abated.

The success of the small rental car fleet concept is based on attracting a substantial number of current auto drivers from their private vehicles. To accomplish this, system planners count on both broad social impact appeals and personal economies. In the former case low pollution, mobility for the disadvantaged, and reduced congestion for all are expected to motivate private automobile owners. In the latter instance projections of savings on the order of several hundred dollars per year are expected to gradually reduce levels of second-car ownership.

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[1] Vukan R. Vuchic, et.al., Minicar Mass Transit System: Feasibility Study. Book 1, December, 1968; Transit System - Phase 1 - Feasibility Study. Book 2, December, 1968; Minicar Transit System. Final Report, 1970 (prepared for the Urban Mass Transportation Administration, U.S. Dept. of Transportation).

[2] DeLeuw, Cather and Company; Institute of Regional and Urban Studies Draft Report Contra Costa County Transportation Needs Study, December, 1971.

- User Price Impacts

For Philadelphia, two possible fare structures were considered. The first involved an individual trip rate; either $ .25 or $ .50 for the first 1.25 miles and $ .25 for each additional mile.[3] The second is a flat rate payment system and would be offered to the user at $75 a month, or approximately $.075/mile, based on projected vehicle usage of 1000 miles per month. The Philadelphia study contends that such a flat rate structure would be viable only after the fleet size reaches 2500 cars.

Under both fare structures described above, the cost-to-user figures include all charges: car rental, fuel, repairs, road service, maintenance and cleaning, insurance, and parking in minicar system terminals.

Data for the Contra Costa PAS system did not pinpoint projected user costs. However, the report indicated that vehicles would be rented on an individual trip basis only, and charges to the user would reflect both the mileage traveled and the time the vehicle was kept by the user.[4] It was also suggested that charges for distance or time might be varied in order to encourage trips during off-peak hours or to stimulate trips which result in a favorable redistribution of the cars.

An analysis of projected cost figures for the California system indicates that both capital and operating costs will total approximately 40¢ a trip (with an average trip of 2 miles).[5] User cost per trip would probably be somewhat above the 40¢ figure in actual operation. Data from both studies suggest that on a per-trip basis a 25¢ a mile cost is probably the least users could expect to pay, and due to unknown technical or implementation difficulties, this figure is not very firm (see Table 24-1 and 24-2).

The projected minicar costs listed above can be compared with the average cost figure of 12¢ per mile used in this study as cost to own and operate a private automobile (see Table 24-3).

The PAS study specifically assumes that the minicar will be replacing a <u>second</u> car, and computes direct economic benefits on the basis of saving the owner the cost of a second car. The study offers data showing that the more cars a household owns, the fewer the trips-per-car per day.[6] Other data in the PAS report shows that 43-52% of urban trips in three metropolitan areas are very short in length -- trips with airline lengths of two miles or under.[7]

It is stated that use of a small rental vehicle for both peak hour commuting trips and off-peak neighborhood shopping and recreation trips will save the suburbanite money, since a more costly second car is dispensed with.

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[3]Vuchic, <u>Final Report</u>, p. 15.

[4]DeLeuw, Cather, <u>Op. Cit</u>; p. IV - 19.

[5]Ibid., pp. IV - 33, IV - 47

[6]DeLeuw, Cather, <u>Op. Cit</u>., p. IV - 36.

[7]<u>Ibid</u>. p. IV - 7.

TABLE 24-1: Contra Costa County Total Annual Operating Costs Calculations [a]

Annualized Capital Costs

(assumes capital costs are amortized at 7% interest over 10 years)	$10m.

Above capital costs include:
30,000 PAS vehicles ($2000 per car) Total: $60 million
Stands, central computer system, and maintenance facilities
Total: $10 million

Annual Fixed Costs

Includes insurance, washing, and cleaning, and licensing fees These costs run $300 per car per year, with 30,000 cars in the system, the system total is $9m.	$ 9m.

Direct Operating Costs

These costs have been estimated to total 13.85¢ per trip, and include:	$10m.

Maintenance and redistribution costs	5.00¢ per trip
Information and systems costs	1.50¢ per trip
Over head plus contigencies	3.35¢ per trip

With 8 trips per vehicle per day, and 300 equivalent days a year, there would be 72 million trips in the system annually, for a total cost of $10m.

Total Annualized Capital And Operating Costs = **$29m.**

Cost Per Trip $\frac{\$29,000,000}{72 \text{ million annual trips}}$ = $0.40 per trip

Cost per Mile $\frac{\$0.40 \text{ per trip}}{2 \text{ mile trip length}}$ = $0.20 per mile

(a) Deleuw, Cather p.IV-36

TABLE 24-2: Philadelphia Central CBD Minicar Annual Operating Cost Calculations

<u>Annual Fixed Costs</u>

$300 yr. - Insurance

$115 yr. - Parking

<u>Direct Operating Costs</u>

$258 yr. - Direct vehicle operating costs - oil, gas, repair, (each car runs 1000 miles a month)

$ 72 yr. - Washing

$ 20 yr. - License

$765 yr. Per Car, <u>$.06 a mile per car</u>

NOTE: Annual cost data not complete for Philadelphia project, thus this figure might be unrealistically low. Unlike Contra Costa data, the Philadelphia study does not average annualized capital costs into the cost per mile figure.

SOURCE: Vuchic, Feasibility Study Book 2, p. 67

TABLE 24-3: Annual Operating Costs for Second Car

I. Insurance, Depreciation, License $450.

Depreciation	$190 - $450	(3rd yr. - 6th yr.) of car's life, respectively)
Insurance	$150	(2nd car, driven less than 7500 miles/yr. more than 5 yrs. old, no drivers under 25 yrs. old)

II. Operating Costs:

2-3¢ mile - direct fuel costs

$137 - average annual maintenance cost-as estimated by recent Department of Transportation Study

Average total cost for second car:

$620 to $702

SOURCE: DeLeuw, Cather, p. IV-39.

In order to arrive at these conclusions costs have to be estimated for second car operations. The Contra Costa Study estimated this cost at $620 a year (see Table 24-1).[8]

The figures in Table 24-2 are estimates appearing in the PAS report. It appears, and the report contends that, these figures represent a conservative estimate of second car costs. In contrast, the cost for using the minicar system for each of the 60,000 second car owners would average $483.33 a year if they were charged exactly the total annual capital and operating costs of the PAS system. The actual savings to the average family is hard to pinpoint. However, if the project estimates are correct then at least two hundred dollars would be saved annually, depending on the cost of maintaining the second car. This potential benefit may be tempered by the requirement of individual families that special purpose second cars be available for bulky package and do-it-yourself materials hauling or recreational trips. Note that the purchase of 30,000 minicars and their use by 60,000 former two-car families implies multiple use of minicars by an average of at least two families per car.

- <u>Implementation Costs</u>

Implementation costs are high. They are estimated at $70 million for the PAS system, categorized as follows:

30,000 vehicles @ $2000/car	$60 million
Equipment = (stands, the central computer system, maintenance facilities)	$10 million
Total	$70 million

Assuming capital costs were amortized at 7% interest over 10 years, total annual cost of the investment would be about $10 million.[9]

The Philadelphia study estimates that $13.5m is needed for initial financing.[10] No complete breakdown of this figure is available; however, the projected application would begin with a small fleet of 625 vehicles growing to a size of 5,000 vehicles over two years. A portion of its growth would be financed from revenues.

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[8] <u>Ibid.</u>, p. IV - 39.

[9] <u>Ibid.</u>, p. IV - 33.

[10] Vuchic, <u>Feasibility Study, Book 2</u>, p. 54.

- Operating Costs

For the Contra Costa PAS system, capital and operating costs have been estimated at $0.40 per trip.

The average trip length estimate is 2 miles, and thus costs per mile are about .20/mile. Table 24-1 provides details on the calculation of operating costs associated with the PAS system.

For Philadelphia, annual operating costs are summarized in Table 24-2.

- Other Costs

As discussed in the Processing Efficiency section, the Philadelphia minicar system may result in increased congestion if diversion from mass transit is sizable.

The added mobility for the disadvantaged, poor, teenagers, and elderly may stimulate trips not previously made and may actually increase levels of congestion. To some extent these new trips could be channeled into off-peak periods when congestion is less serious through various pricing or redistribution policies.

- Indirect Economic Effects

Both the Philadelphia and Contra Costa reports assert that a major benefit derived from the minicar system is the reduction in new capital construction and in particular, the need for parking facilities. In Philadelphia by 1982, with approximately 26,000 minicars in service, a saving of more than 16,000 parking spaces would be realized.[11] The valuable central city land would be freed for other uses.

The Contra Costa study stresses the reduction of parking requirements at commercial and industrial centers, BART stations, and private residences. The study cites 1968 studies done on parking needs for downtown Walnut Creek, a Contra Costa city. The report predicted a shortage of parking space and recommended construction of 1,323 additional spaces at $3.7m.[12] Even a limited minicar system would reduce some of this need for new facilities, since the minicar requires only about one-third of the space required by a normal car. General figures on parking garage land and construction costs are listed below in Table 24-4.

Savings might also be expected in the area of city and suburban freeway and arterial construction. The minicar's increase in processing efficiency at low speeds may lessen the need for extending or enlarging the metropolitan freeway systems and arterial network (see "Processing Efficiency").

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[11] Vuchic, Feasibility Study Book 1, p. 17.

[12] DeLeuw, Cather, Op. Cit., p. IV - 43.

TABLE 24-4: General Parking Costs (CBD)

	Dollars per Space
Site costs	$1500--3000
Construction costs	
Conventional Ramp structures	1500--1800
Mechanical Garages	2000--3000
Underground Garages	4000-- +
Total costs	$3000--7000 [a]

[a] In 1972 upper limits are closer to $10,000 per space

SOURCE: Parking in the City Center, Wilbur Smith and Associates, New Haven, Connecticut, 1965, p. 35

- Impact on Disadvantaged

Both the Philadelphia and Contra Costa reports mention potential social benefits of the minicar system. The Philadelphia report projects increased mobility for low income inner-city dwellers through use of the minicar.[13] The cars could take them to previously inaccessible job sites. If demand for minicars exceeds supply, as may well happen at particular times of day or in certain locations, some judgment will have to be made in assigning the cars to auto commuters, mass transit commuters, and people with low income.

Another potential use of the minicar for low income groups, mentioned in the Philadelphia report, involves off-peak usage when demand for minicars is lowest. The surplus of low income residents with driver's licenses as opposed to the number of cars owned by low income people indicates there would be some demand for minicars. This extra mobility opportunity provides for more shopping,visits, recreation, and non-rush hour business needs.[14] Minicars, with a lowered fare schedule, might provide complete mobility at a price tailored to meet all low income users' needs. If the system is efficient and well planned, it may demonstrate to a substantial segment of the city population that one can have convenience without owning a car.

The Contra Costa report foresees use of minicars by groups which do not ordinarily qualify for driver's licenses under current licensing practices: teenagers and the elderly.[15] The PAS report implies that teenagers and the elderly might be able to use the minicar as opposed to other cars, due to the limited performance capabilities of the minicar. A modified power plant will limit the car to a top speed of between 25 and 35 m.p.h.

- Environmental Impact

One of the most important benefits of the minicar, according to its proponents, is the potential for reduction in auto-emitted pollution. While more precise figures can only be provided when minicars are actually in widespread use, the Philadelphia report estimates that the introduction of 26,000 minicars would reduce pollution on congested streets, tunnels, or bridges by forty to sixty percent of those levels that would exist without minicars.[16] The hybrid gasoline-electric power train would allow the minicars to operate on electricity only, without any emissions, for short distances.[17] Noise pollution would also be reduced in the minicar. The PAS report also mentions possible use of a hybrid electric power train with similar environmental benefits. Quantifying data however are not available.

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[13]Vuchic, Final Report, p. 176.

[14]*Ibid*.

[15]DeLeuw, Cather, *Op. Cit.*, IV - 20.

[16]Vuchic, Feasibility Study, Book 1, p. 21.

[17]Vuchic, Feasibility Study Book 2, p. 4.

- Safety Impact

Safety factors have been of great importance in the designing of the minicar, according to the Philadelphia Report.[18] In addition to standard safety features, these extras will be provided: energy-absorbing fiber-glass-foam steel crash resistant structure, wrap-around protective bumper, foam-filled crash bolster around the passenger compartment, heavyweight protective frame, fixed seats, inertia-reel mounted seat belts and shoulder harnesses, and collapsible steering wheel. While the Contra Costa report doesn't mention similar safety features, photographs of the prototypes show a major resemblance to those in the Philadelphia report. However, vehicle construction is only one aspect of safety. The other aspect relates to the interaction of the small minicar and the typical traffic stream.

Maximum speed for the PAS as mentioned earlier would be 25-35 m.p.h., thus restricting their use on freeways. Many arterials and collector streets have higher traffic speeds than 25-35 m.p.h. and the small minicar may become a hazard if it cannot maintain speeds consistent with the traffic stream. Another problem which emerges from an analysis of the PAS report relates to suggestions that elderly people and teenagers, who would be ineligible for licensing under current laws, be allowed to drive PAS vehicles. The suggested new driver enfranchisements are based on the fact that the vehicles could not travel at very high rates of speed. However, it seems unlikely that the sole cause of accidents among teenagers or elderly drivers is excessive speed. There is thus a possible safety threat posed by such licensing policies.

- Speed or Time

The PAS concept as applied in the California study would not provide time savings for minicar users. Because the PAS system was designed for very short trips (about 2 miles) in suburban (not CBD) areas, congestion and time savings were not crucial factors affecting planned travel times. The PAS cars will operate at top speeds of about 30 M.P.H., hence they will not save time unless they are able to avoid areas of extreme congestion.

The Philadelphia researchers found that minicars, used on a large scale, do not offer much improvement in processing efficiency as compared to standard cars when operated at high speeds. However, there are substantial savings when minicars are used in areas of low speeds and congestion.[19] If all cars in a city were ten rather than twenty feet long, and there were few buses or trucks in certain lanes, then the flow would increase by 65-70% over normal circumstances. Average speed under these same conditions would increase from 2.4 to 3.75 m.p.h. (In order to assess the importance of this speed increase, it should be put in terms of percent of trip time saved.) Since it is not clear that a large percent of average traffic flow in congested areas can be converted to minicars, these projected time savings appear open to question.

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[18] Vuchic, Final Report, p. 9.

[19] Vuchic, Feasibility Study, Book 2, p. 89.

- Volume

Under the optimum conditions described in the preceding paragraphs, use of the minicar would also increase vehicle flow. The maximum flow attainable would increase by twenty-five percent, from 1140 to 1425 vehicles per hour of green. If mixtures of short and long cars are considered, the flow and average speed of travel lie somewhere between the above values.[20]

The minicar's biggest contribution to processing efficiency, however, is probably its small space requirement for parking. In an area that could accommodate six standard vehicles (with attendant parking) or four standard vehicles (which need individual retrieval) twelve minicars could be parked.[21] There is no need for individual retrieval of minicars, since the driver can use <u>any</u> car not just the car he drove in. This interchangeability saves time as well as space.

There are two significant potential impediments to added processing efficiency through use of the minicar. First, if more current mass transit users than current auto commuters were to opt for minicars, additional congestion of CBD facilities may result. While this could not happen in the Contra Costa situation, it appears to be a possibility in Philadelphia. Various mail and interview studies in Philadelphia indicate that a greater percentage of auto drivers than mass transit riders would want to transfer to a minicar. But since there are many more transit than auto users in downtown Philadelphia, the absolute number of mass transit to minicar conversions might exceed the number of patrons switching from auto to minicar.

The study concluded: "These estimates indicated that the number of commuters diverted from mass transit exceeded those drawn from autos by about 30%.[22] If under optimum circumstances the advantage in traffic is a space saving of about 50%, then savings in traffic flow occasioned by converting auto users will just about be matched by the additional space required when transit riders begin using minicars.

One survey indicated that as the monthly flat rate for the minicar is increased, the proportion of users who were former transit users will decrease. Deliberate measures may have to be taken to make sure that most minicar patrons are former auto users if this is deemed desirable. Some suggestions for accomplishing this might be: (1) raising CBD parking fees for automobiles (2) raising the minicar flat monthly fee[23] (3) imposing a limit on the number of vehicles issued to current mass transit users (seemingly discriminatory and unenforceable). The need for coordinated pricing of the city's transportation facilities to achieve desired transportation usage is discussed in the final report of the Philadelphia project.[24]

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[20] <u>Ibid.</u>

[21] Vuchic, <u>Feasibility Study, Book 1</u>, p. 19.

[22] Vuchic, <u>Final Report</u>, p. 23.

[23] <u>Ibid.</u>

[24] <u>Ibid.</u>, p. 34.

In assessing relative processing efficiencies it should be noted that it is not expected that vehicle occupancy rates will rise. The Philadelphia minicar seats three, while the PAS vehicle seats two adults. In all likelihood, only slightly more than one passenger per minicar would be carried.

Mass transit vehicles are far more desirable than either cars or minicars in terms of passenger/vehicle efficiency. There is a possibility that carpooling with standard vehicles or vans could provide improved passenger/vehicle processing efficiency ratios. There is no comparable possibility with the minicar. (The Philadelphia minicar system assumes that it cannot divert parties of four or more.)[25]

Minicars may be useful in supplementing carpools. An important objection to carpools is their inflexibility with reference to time - - the carpool member must arrive and depart along with other carpool members. Some workers have changing schedules and thus cannot join a carpool. However, if minicars were available to carpoolers who had to leave early or late once a week, they would have added flexibility while still utilizing the basic carpool.

In similar fashion, minicars might supplement mass transit services that are provided only during limited hours. This could apply either to feeder or trunk line services.

- State-of-the-Art

As of December 1968 the Philadelphia study suggested a demonstration phase consisting of: (1) the production of 150 minicars, (2) the conduct of operations studies and analyses of demand potential, to be started by November 1968 and (3) actual running of the 150 cars to begin by October 1969. Further studies and data collection and processing to determine user attitudes and potential demands for services apparently have been completed since then.

The technical and administrative aspects of the minicar system have already been carefully investigated. For example, cost estimates have been established for a computer system which would control and process vehicle checkout and billing, compute actual trip costs, and check identification, as well as provide system status reports. Development of the car design and computer checkout system considered such factors as minimizing temptations for vandals and screening out credit risks and improperly licensed drivers. Apparently, prototypes using high performance electric-hybrid engines are already available.[26]

Despite prototype availability and support system designs, extensive operational tests of this vehicle and its supporting systems have not been made. No production or operational capability is known at this time.

There is one state-of-the-art problem concerning the minicar that had no satisfactory solution in the PAS report or the Philadelphia Final Report. This problem is redistribution of vehicles among the terminals to meet user demand. The Philadelphia Final Report states that problems in determining volume of minicar distribution have been the underlying difficulty in developing specific recommendations for this operation. Two methods of redistributing vehicles are described in both the PAS and Philadelphia Reports: (1) shipping minicars between terminals on large carcarrier trucks (the method used for

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[25] Ibid., p. 15.

[26] DeLeuw, Cather, Op. Cit. p. IV - 15.

transporting new cars), (2) coupling of minicars into "trains" so that one driver can transport several vehicles between terminals (the minicars are designed with front and rear hitches to allow this form of transporting). However, the reports acknowledge that these transport methods are most practicable at night, when there is less traffic. Redistribution, on the other hand, will be necessary during the day to mesh with patron demand.

Other suggestions on the problem mentioned in both reports are: (1) that the larger the fleet size, the less frequently the redistributing need be performed; and with the larger fleet size, more vehicles can be processed (redistributed) at once. (2) that economic incentives be used to encourage those trips resulting in better redistribution of minicars.

The Philadelphia system and the PAS system each has unique problems in redistribution. In Philadelphia, a key problem is the day-use of vehicles outside the CBD. A method must be devised for transporting cars from the CBD, where they have been driven by commuters, to ghetto and suburban areas where they will be needed for day trips. Perhaps the minicars for these day trips are not the same vehicles as will be used for the flat rate commuter trips, but the Philadelphia Final Report does not clarify this.

In the PAS system, the key redistribution problems are: (1) getting the vehicles back to the neighborhood stands during the AM rush hours, so that each vehicle can be used more than once for the trip from home to BART stations. (The reverse problem exists during the PM peak, and must also be dealt with.) (2) transporting vehicles from BART stations, where they were driven during the AM peak, to neighborhoods for day use, and transporting them back to BART stations for the PM peak.

The redistribution problem should not be underestimated, for it introduces a new variable into mode choice behavior, a possibly unreliable mode in terms of availability. All other modes approach 100% availability. A car is there for one to use to go to work; it will be there to return home in. A transit vehicle will pass by a particular stop and, if that vehicle is full, another will be by shortly. It would appear that the assurance of availability would be difficult and expensive to provide for the minicar under either of the redistribution plans mentioned.

- <u>Institutional Background</u>

The Philadelphia study has identified several groups which must be contacted and their reactions to the minicar system accounted for. These groups include:

(1) Parking lot builders and owners
(2) Directors of existing mass transit facilities
(3) Car manufacturers
(4) Unions of transit vehicle operators and transit repair workers (in cases where use of the minicar might infringe on ridership of existing transportation facilities)
(5) Repair garages
(6) Consumer groups and individual commuters - - from suburbs, city, and low income areas

If the system is operated by the local government, no other state or federal regulatory agency would have jurisdiction.[27] But if a minicar system is privately owned, the state public utility commission would be involved.

A major institutional constraint on further development is the absence of authorization for government funding, without which production and operation of an experimental fleet does not seem possible.

- Traveler Response

The PAS minicars for Contra Costa County are to serve an area with an estimated 1 million person trips daily. The public system is aimed at capturing 10% (100,000) of these trips.

Projections developed in the Contra Costa study using mode-choice models show that the minicar is the most viable candidate for diverting auto users. The analysis performed indicated that, among others, Dial-A-Bus and conventional bus would have much more unfavorable rankings after a thorough cost benefit analysis.

The Philadelphia studies included an analysis which showed that one year after implementation of the minicar flat rate service at $90 a month, demand would be for 25,000 vehicles.[28] Thus, projected demand is about the same size as the projected system size.

In contrast to many other proposals, it is not easy to provide assurances concerning minicar demand. Most minicar demand projections are based on an assumed easy acceptance of the rental vehicle as a substitute for the private personal auto. Actually, little is known about how acceptable a substitute the small rental car would be. Thus, while heavy demand is critical to the benefits of a minicar system, it is most difficult to say that actual demand will conform to projections.

III. SUMMARY AND CRITIQUE

While the minicar concept does appear to have some possible applications, there are serious problems to be resolved before actual implementation can take place. The highly experimental nature of the techniques and technology required, and the resulting lack of conclusive empirical data make it difficult to develop confident projections. Assessments of costs and benefits are all based on a series of projected applications.

A further disturbing factor is the extent of the capital investment required to make the system operational. This evaluation would indicate that start-up costs are so great as to make the minicar a questionable candidate for this study's objectives: making better use of existing facilities.

A specific problem revealed by the Philadelphia study is the possible diversion of mass transit ridership if minicars are instituted at the scale

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[27] Vuchic, Final Report, p. 27.

[28] Ibid., p. 23.

proposed, with consequent increase in actual vehicles on roadways. Much of the processing efficiency projected for the minicar in Philadelphia might thus be negated.

The PAS study contends that given the peculiar circumstances of Contra Costa County, California, the PAS system ranks most favorably on a cost benefit scale among various alternatives. While the PAS system was judged optimal for this particular setup, it is very questionable whether it would be equally applicable to the transportation needs of other low density areas.

The calculation on economic benefits of the PAS system are contingent, the authors assert, on the substitutability of every minicar for two "second" cars. If the system cannot be implemented on the proposed scale, or if redistribution systems are inadequate, people may choose to retain their second cars.

Another area of question concerns the projected decrease in polluting emissions through use of the minicar. These special vehicles would be introduced in relatively small numbers, and thus their impact on total auto-caused air pollution would be quite small. The Clean Air Act of 1970 requires that car producers reduce emissions of smoky hydrocarbons and carbon monoxide by 90% by 1975, and nitrogen oxide emissions by 90% by 1976. While these deadlines may be extended, this law may well have a much larger and earlier impact than could the minicar on the problem of reducing automobile-caused pollution.

These questions, others raised in the text of this paper, and the largely hypothetical status of the minicar, all suggest that the minicar is not currently a useful concept in the context of this study.

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APPENDIX A

Concept Rating Sheet

The following is a guide to scale values for ranking concepts studied in the survey. A rating of -2 through +2 is possible (with the exception of "volume" where a +3 is possible). Where a criterion is of particular importance, it has been weighted.

		Weight
User Price Impacts		1
-2	Significantly increased price to users	
-1	Slightly to moderately increased price	
0	No effective change	
+1	Slight to moderate user savings	
+2	Significant user savings	
Implementation Costs		2
-2	Equivalent to similar fixed rail or highway facilities, i.e., expensive fixed capital investment	
-1	Capital facilities but substantially less expensive than above. (i.e., 100-250K a mile or total system investment 500K to 3 million).	
0	(No neutral value)	
+1	Vehicles or computer, little fixed capital (i.e., 50-500K total investment).	
+2	0 to Minor - i.e., signs, P.R., etc. (under 50K)	
Operating Costs (an increase in operating costs is defined as costs rising faster than increases in revenue).		1
-2	Significantly increased costs	
-1	Slight to moderate increased costs	
0	No change	
+1	Slight to moderate operating savings	
+2	Substantial savings	
Other Costs		1
-2	Substantial and/or very undesirable	
-1	Slight to moderate (i.e., more vehicles stimulated)	
0	No change	
	No positive values	

		Weight
Indirect Economic Effects		1
-2	Technique necessitates costly fixed capital investment, fairly short term, no reduction in demand.	
-1	Demand for new highways, rail facilities, etc., remains unabated.	
0	No neutral value	
+1	Slight or possible savings in fixed capital facilities over long run.	
+2	Directly avoiding major investment in new capital facilities over long run.	
Impact on the Disadvantaged		1
-2	Significantly detrimental to interests of disadvantaged or captives.	
-1	Slightly detrimental to interests of disadvantaged or captives.	
0	No direct effect	
+1	In general interest of disadvantaged	
+2	Substantial mobility opportunities for disadvantaged	
Environmental Impact		1
-2	Substantial negative impact	
-1	Slight negative impact	
0	No change	
+1	Positive benefit	
+2	Substantial benefit	
Safety Impact		1
-2	Very much more dangerous	
-1	Degeneration of safety - requires attention, but not severe	
0	No change, or slight degeneration or improvement, but of little concern.	
+1	Safety appears improved and a definite benefit	
+2	Greatly improved accident rate.	
Speed or Time		2
-2	Substantial user increase in time for trip or portion of trip	
-1	Moderate or slight increase	
0	No change	
+1	Moderate or slight user time benefit	
+2	Substantial user time benefit	

		Weight
Volume		2
-2		
-1	No negative values	
0		
+1	Unproven but definite increased capacity or very slightly increased capacity	
+2	Moderate but significant improvement over competitive systems	
+3	Very substantial increases in capacity as compared with competitive systems (order-of-magnitude improvements)	
State-of-the-Art		2
-2	Highly theoretical	
-1	Some development needed	
0	No apparent problems, but not adequately tested	
+1	Demonstrated technology, not completely refined	
+2	Operational, widely implemented	
Institutional Background		2
-2	Substantial resistance anticipated	
-1	Small group of critical opponents or critical approval required	
0	Inertia - slight resistance, no organization to push	
+1	Groups interested, community support	
+2	Substantial enthusiasm, few or no detractors, money available, organized agency to implement	
Traveler Response		1
-2	Substantial resistance - forced utilization required or substantial incentives	
-1	Potential users reluctant, requires P.R. + incentives	
0	Demand not changed, slight increase in useage	
+1	In theory more advantageous, therefore people would use to some extent	
+2	Many people eager to use	
City Size Applicable		.5
-1	Small cities only	
0	Moderate only, or, large only	
+1	Moderate and large	
+2	All cities	

APPENDIX B

DIAL-A-BUS SERVICE AND AIRPORT WORK TRIPS

Because of the lack of extreme peaking for airport travel, it would appear that a Dial-A-Bus operation might accommodate airport work trips on a reserved seat basis at very low cost. If the average load for the bus was ten air travelers in the peak hour, it would appear logical that a bus could carry an extra ten airport employees, on a contract basis, without reducing service to the air traveler. (Assuming minimum bus capacity of twenty seats -- a minibus.) Interestingly the marginal cost of providing this service is extremely low, and therefore, a different pricing policy could be used, reducing the fare for contract riders without adversely affecting the revenue cost ratio.

Calculations to establish costs are as follows:

A medium size airport (similar to Cleveland's John Hopkins Airport) would have on the order of 13,000 passengers on the average day with a peak hour demand of approximately twelve percent of the total day. If the Dial-A-Bus operation could capture thirty percent of the market, this would result in approximately five hundred passengers in the peak hour. The bus requirements to handle this volume would probably range from fifteen to thirty buses depending on the average trip time. For a twenty minute average trip, sixteen buses would be required, while for a thirty minute trip, twenty-four buses would be required. These trip times do not appear to be unreasonably low. Silence[1] found that for twenty-three large airports in the United States sixteen had a peak hour travel time to the central business district of less than thirty minutes; and seventeen of thirty-one medium size cities had travel times of less than twenty minutes. Assuming the peak hour bus requirement was used for sixteen hours per day and one-third the requirement was used for the remaining eight hours, this would require a fare between ninety cents and $1.50 to cover the costs of the Dial-A-Bus operation. This fare would appear to be well within the range of limousine service with a considerable increase in convenience. The marginal cost of subscription service, when associated with the trip deviations, would principally be the extra milage costs directed solely at picking up the work trips, assuming that no additional drivers or vehicles are needed. This might be as low as ten percent of average air passenger trip costs, permitting very low fares to be charged to low income workers.

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[1]Steiner M. Silence, "A Preliminary Look at Ground Access to Airports," in Highway Research Record No. 274, Highway Research Board, 1969, p. 16.