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ANALYSIS OF DUAL MODE SYSTEMS IN AN URBAN AREA

Volume II: Study Results

Peter Benjamin et al.

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16. Abstract
Various forms of Dual Mode transportation were analyzed in order to assess the economic viability of the Dual Mode concept. A Dual Mode vehicle is one which operates under manual control on a street network for some portion of its trip, and operates under automatic control on an exclusive guideway for some other portion. Specially designed new small Dual Mode vehicles, modifications of existing automobiles, and pallet systems, all operating in conjunction with Dual Mode buses, were examined. The study was conducted in a Boston 1990 scenario, in which an extensive Dual Mode system providing service for the entire urban region was presumed to exist. This study was not intended to be a proposal for Dual Mode in Boston. The following conclusions are considered to be generally applicable to other large urban areas as well: (a) Dual Mode systems appear to be sufficiently attractive to warrant further technological development; (b) for urban-wide applications, a Dual Mode system which includes both buses and personal vehicles is more effective than one consisting of either fleet of vehicles alone; (c) a Dual Mode transportation system benefits from the use of various Dual Mode concepts throughout its development.

An effective first step might be to install a limited network Dual Mode minibus system, with capacity for ultimate growth to a longer guideway network with personal vehicles and buses.

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PREFACE

This coordinated Department of Transportation program for the analysis of Dual Mode systems was initiated by Dr. Robert H. Cannon, Jr., Assistant Secretary for Systems Development and Technology, in the Spring of 1971. It was undertaken to provide sufficient insight into the benefits, impacts and costs of Dual Mode concepts so that the Department of Transportation could assess (1) the potential of Dual Mode as an urban transportation alternative, and (2) whether further research and development was warranted, and if so, in which areas.

The analysis was conducted using a 1990 Boston scenario in which an extensive Dual Mode system was presumed to exist. The scenario in a specific city was chosen to provide meaningful base data for this analysis. The study is not a proposal for a Dual Mode system for Boston; nor is it a transportation planning analysis for that city. The study was intended to evaluate the Dual Mode concepts in an urbanwide application to assess the relative merits of the various general design types, to determine the economic viability, and to conduct an assessment of technology required.

This report is made up of four volumes having the following general content:

- Volume I - Summary
- Volume II - Study results
- Volume III - Description of the analysis techniques and data sources
- Volume IV - Program documentation of the Transportation Economic Analysis Model which was developed and used for the cost/benefit portion of this study

The study was performed by the Transportation Systems Center under the sponsorship of the Office of the Assistant Secretary for Systems Development and Technology in conjunction with, and including participation by, the Federal Highway Administration, the Federal Railroad Administration and the Urban Mass Transportation

Administration. Close coordination was also maintained with the Office of the Assistant Secretary for Policy, Plans and International Affairs, and the Office of the Assistant Secretary for Environment, Safety and Consumer Affairs.

The Office of Systems Engineering in the Office of the Assistant Secretary for Systems Development and Technology was responsible for the management of the study. Overall program direction was provided by R. L. Maxwell; the Program Manager was R. L. Krick. Program coordination was achieved by the Dual Mode Transportation Working Group which reported to the Program Manager. The following Department of Transportation personnel served on the working group: R. Bruton, V. DeMarco, R. Fisher, S. Jackson, N. Kamalian, J. Leep, M. Miller, K. Okano and R. Reymond.

The cost/benefit, economic, and systems analysis portions of this study were conducted by the Systems Analysis Division of TSC, under the direction of C. H. Perrine. The primary contributors to the analysis were: P. Benjamin - task manager, analysis-team leader; J. Barber - performance, system characteristics, network analysis, final report; R. Favout - cost/benefit model; D. Goeddel - cost/benefit model; C. Heaton - impacts, network analysis, final report; R. Kangas - performance; G. Paules - ridership estimation; E. Roberts - network synthesis, scenario definition, ridership estimation; L. Vance - costs, fares, systems comparisons.

TSC direction of the Dual Mode Program and the technology assessment portions of the study were conducted under the guidance of G. Pastor, Chief of the Ground Systems Programs Division. The following persons contributed: J. Marino - task manager; A. Malliaris technology assessment; S. Pasternack - command and control; C. Toye- command and control.

In addition, D. Glater was responsible for the section on legal and administrative issues, and J. Wesler for the noise analysis. The firm of Peat, Marwick, Mitchell and Co. assisted in the analysis of potential system demand.

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ABBREVIATIONS

BART	Bay Area Rapid Transit System
CBD	Central Business District
C/D	Collection/Distribution
DM	Dual Mode
DOT	U. S. Department of Transportation
EMRPP	Eastern Massachusetts Regional Planning Project
FHWA	Federal Highway Administration
GM	General Motors Corporation
GRC	General Research Corporation
HUD	U.S. Department of Housing and Urban Development
JPL	Jet Propulsion Laboratory
PKG	Parking
PMT	Passenger Miles Traveled
PRT	Personal Rapid Transit
ROW	Right of Way
SMSA	Standard Metropolitan Statistical Area
SPV	Small Personal Vehicle
TEAM	Transportation Economic Analysis Model
TRW	Thompson Ramo Wooldridge
TSC	Transportation Systems Center
VMT	Vehicle Miles Traveled

1. INTRODUCTION

1.1 STATEMENT OF THE PROBLEM

The urban population of the United States has been constantly increasing (approximately 16% in the decade of 1960-1970). The people within these major urban areas are traveling more and are overwhelmingly choosing the automobile as their desired transportation mode. Its convenience, flexibility, comfort, and relatively low perceived cost have made it a most attractive choice, and construction of urban freeways over the last decade has encouraged the use of the automobile. The one-car family is rapidly being replaced by the two-car family, with the percentage of families owning two or more cars roughly doubling over the same period.

Yet, as the decade progresses, increasing concern is being voiced over relatively uncontrolled growth of automobile travel. Noise and air pollution effects due to the concentration of automobiles in urban areas is receiving increasing attention and criticism.

The divisive effect of ribbons of concrete cutting through neighborhoods is being recognized. The public has become more sensitive to the plight of those traditionally displaced by new urban freeways - minority groups and the poor. Environmentalists have generated an awareness of the destructive effect of new suburban highways upon the few remaining natural open spaces. Consequently public pressure has come to bear opposing new highway construction. In fact, in a number of urban areas, new roadway construction has come to a virtual standstill.

Yet the demand for transportation continues to grow, and as ever more automobiles clog the existing roads, the specter of hopelessly tangled traffic and totally jammed streets haunts those responsible for urban transportation. What is needed is a transportation system with the appeal of the automobile but without the associated congestion effects or large right of way requirements.

1.2 CURRENT APPROACHES

With a potential transportation crisis facing them, many transportation planners are turning toward traditional rapid rail transit, with varying degrees of automation, as a solution. The cities currently possessing rail rapid transit are planning improvements and extensions. The San Francisco Bay Area Rapid Transit system is operating and the Washington, D.C. Metro is und construction. Pittsburgh is in the early phase of installing a new automated transit line and voters in Atlanta have authorized a coordinated system of rail rapid transit and express busways. Baltimore is next in line for a subway system, and St. Louis, Minneapolis-St. Paul, Buffalo, Honolulu, Miami, Detroit, Dallas, and Denver are among the cities planning new transit systems.

It is not clear that conventional transit systems will attra the ridership or provide the service desired by travelers and consequently they may fail to solve the problems which they are designed to alleviate. The trend in the country is away from transit. About 100 of the nation's smaller transit lines have terminated operations over the past decade. The combined annual operating deficit for the remaining transit systems has increased from $10 million in 1965 to over $400 million in 1971, while in the past 20 years ridership has dropped from 17 million to 7 million daily. Fares have doubled since 1963 and in most systems service has been reduced. The end to increasingly massive subsidies is not in sight.

A study by Charles River Associates (3) contends that population and, particularly, employment growth in metropolitan areas seems to be concentrated in the suburban areas. They state that "transportation facilities in most metropolitan areas have been designed to provide access to the central city area. The stabilization of the population and jobs in the central city suggests that attention in transportation planning should be redirected from the central city area to the rest of the metropolitan area."

They further observe, "The economic feasibility of most public transportation systems depends upon the existence of common origin and/or destination points...Within any region there is likely to be insufficient commonality of origin-destination to justify the existence of a fixed route system due to low densities over the entire region."

If this is true, and the decline of conventional transit patronage would appear to support the contention, then it is clear that continued installation of these systems runs the risk of exaggerating the proportions of the problem rather than solving it. An alternative appears to be necessary.

1.3 POSSIBLE SOLUTIONS

In the final report of the HUD-sponsored Study in New Systems of Urban Transportation (4) which examined prospects for urban transportation development, eight objectives were established in order to reduce the problems of urban transportation:

1. Provide transportation to non-drivers: the poor, secondary workers in one-car families, the young, the old, the handicapped.
2. Provide convenience and quality of ride approximating that of a private automobile.
3. Reduce congestion at reasonable economic and social cost.
4. Optimize the use of transportation investments and systems.
5. Install transportation systems which are unobtrusive in location and design and economical in land use.
6. Develop quieter, cleaner, more attractive transportation systems, with drastic reduction in exhaust pollution and in urban street noise levels.

7. Provide transportation alternatives appropriate for a variety of urban development patterns.

8. Implement transportation improvements in an orderly fashion through reduction or removal of institutional and regulatory barriers, by permitting a creative federalism on all levels of government, and by facilitating private enterprise and financing.

Dual Mode transportation systems have been suggested (11) as candidate innovative transportation forms which potentially meet most of these objectives. A Dual Mode vehicle is one which travel under manual control on the street network for some portion of its trip, and operates under automatic control on an exclusive guideway for some other portion. Thus low density collection/distribution functions can be accommodated at low capital cost using existing street facilities, while high density routes with common origins and destinations for many travelers can be automated. Automation provides increased capacity through close headway operation while minimizing right of way (ROW) requirements, allows high speed travel with no congestion, and relieves the driver of his duties thereby providing increased free or productive time and eliminating accidents due to human driving errors. If the Dual Mode vehicles are electrically powered, the automated guideway can provide power distribution, and thus a potential for decreased air pollution exists. Further, the sides of the guideways can be designed to minimize noise transmission to adjoining areas.

Dual Mode transportation systems can provide door-to-door transportation equivalent to the automobile in convenience. They can employ small personal vehicles similar to automobiles or bus systems with various sizes of vehicles and operating philosophies Dial-a-ride, park-and-ride, and fixed route and schedule bus systems are all compatible with the Dual Mode concept and can provide effective transportation to the "transportation poor." Personal vehicles may be privately owned or rented from the system operator. Private vehicles may be specially built for Dua

Mode application or may be modified versions of existing automobiles. Thus the Dual Mode concept has considerable scope and flexibility.

A Dual Mode guideway network is the skeleton of the system. The off-guideway collection and distribution functions using existing streets and highways permit considerable flexibility in meeting changing demands and accommodating to a variety of urban development patterns. Automation of the guideway provides the capability of non-stop congestion-free travel from any entrance to any exit. The network serves the developing diverse intra-suburban as well as concentrated central business district (CBD) demand.

Thus Dual Mode transportation systems can potentially meet many of the objectives stated above and avoid many of the pitfalls of conventional transit. This leaves open the question of whether Dual Mode has the potential to attract riders and reverse the ridership and profit decline of existing transit systems.

1.4 THE ANALYSIS

The Department of Transportation, through the Systems Analysis Division of the Transportation Systems Center, has conducted an analysis of Dual Mode transportation systems. The objective of the analysis was to obtain sufficient insight into Dual Mode systems to enable the Department of Transportation to determine the potential of the Dual Mode concept as an urban transportation alternative and to determine whether further research and development was warranted. Specifically, it was to be determined whether Dual Mode might be, in itself, a viable urban transportation system, and, given the multitude of ways in which Dual Mode could be designed, an evaluation was made of all these various alternatives in order to distinguish their relative advantages and disadvantages. An objective was to determine what groups, defined by such factors as income, race, or transportation availability, gain from the implementation of Dual Mode systems and what groups are adversely affected. The distribution of benefits and impacts was investigated.

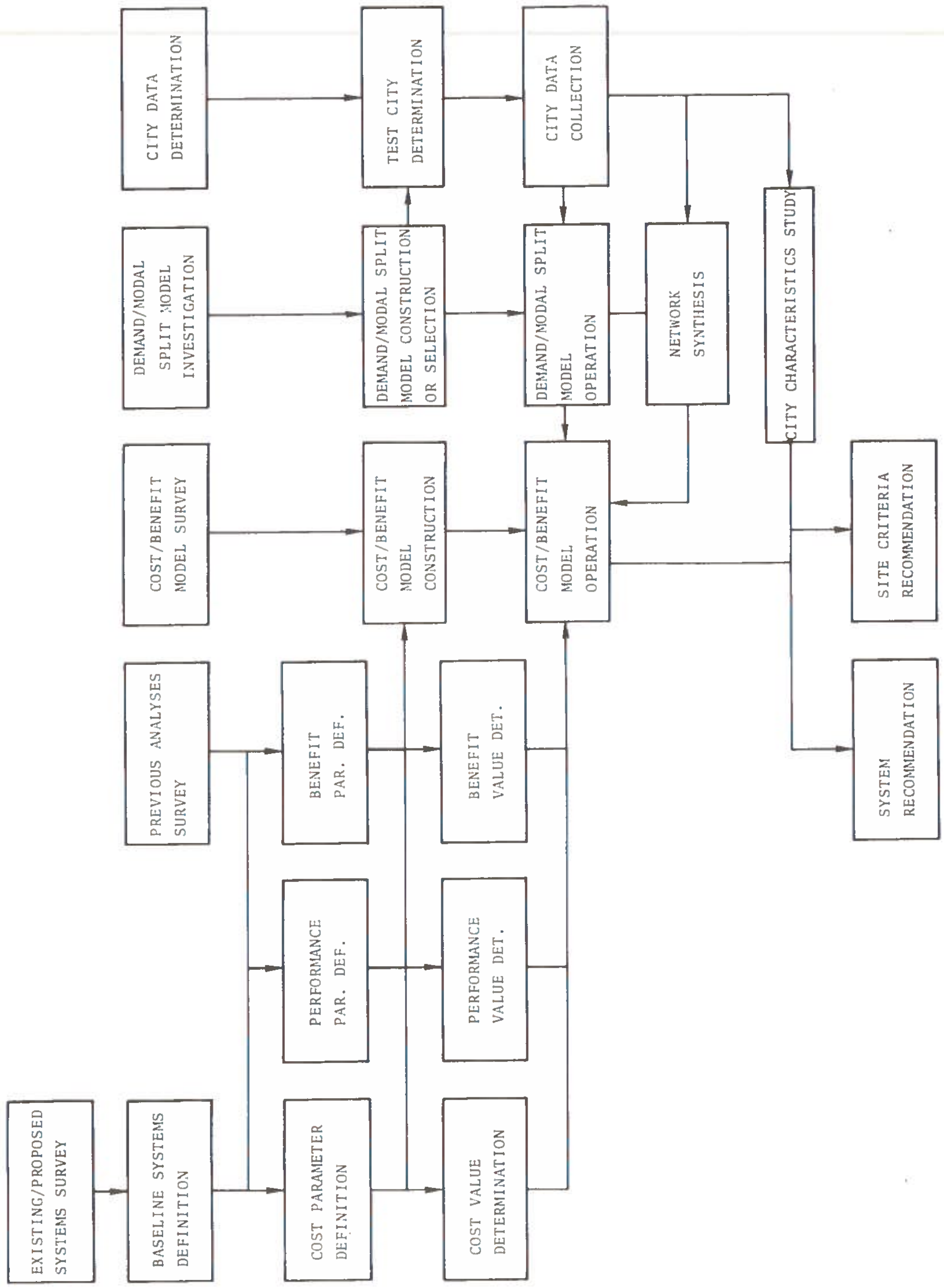
The analysis was conducted in a 1990 Boston scenario, in which an extensive Dual Mode system was presumed to exist in combination with a highway and conventional transit system. It was therefore oriented toward examining urban-wide applications of th Dual Mode concept, rather than limited service systems for specif purposes. The analysis did, however, provide insights into corridor-type applications and limited area systems. The study was not intended to be a detailed transportation planning analysi for Boston or a proposal for a Dual Mode system in Boston.

Systems that have been proposed by various institutions, companies, and developers were examined for their basic technolog ical and application elements. These basic elements were categor zed and grouped according to common characteristics, from which evolved three baselines which represent classes of proposals. Analyses of various systems indicated that for urban-wide applica tions, mixed vehicle fleets consisting of both personal vehicles and buses are more attractive than either personal Dual Mode vehicles or Dual Mode bus systems alone. In all cases examined, mixed fleets resulted in greater ridership, higher revenues, and lower cost per passenger trip than single vehicle-type systems. The bus portions provide service for the "transportation poor" while the personal vehicle portions maximize diversion of travelers from the highway onto the guideway. The mixed fleet provides a logical implementation phasing from the bus to the mo complex personal vehicles operation, as well as the flexibility meet changing patterns of transportation demand.

The three Dual Mode baselines were compared to Boston's 19 transportation plan, as projected by the Eastern Massachusetts Regional Planning Project in 1968 (9), according to the criteria of costs, expected revenues, and probable ridership (in terms of how many and what types of people are going to ride the systems) Reductions in trip times were examined as well as effects on con gestion, accessibility to employment and centers of interest, no and air pollution, and overall transportation safety. The house holds displaced by installation of this kind of system were determined by ethnic and income stratifications. The analysis was parametric, and multiple variations of the parameters being analyzed were carried out to determine first, how sensitive the Dual Mode system is to variations in these parameters, and second, how sensitive the analysis procedure is to variations in its technique.

Figure 1-1 depicts the analysis flow. The existing and proposed systems were grouped and defined as generic baselines. Previous analyses that had been performed in this area, such as the Milwaukee County analysis performed by Allis Chalmers Corporation under contract to the Urban Mass Transportation Administration, the Jet Propulsion Laboratory (JPL) study for the Office of the Assistant Secretary for Systems Development and Technology at the Department of Transportation, the Charles River Associates work for the Office of the Assistant Secretary for Policy, Plans and International Affairs at DOT and the General Research Corporation (GRC) analysis for the Department of Housing and Urban Development were examined in detail. Discussions were held with many of the contributors to the Study in New Systems of Urban Transportation (4), and an extensive literature search was undertaken to determine existing analytical techniques that might apply to the analysis. The cost parameters, performance parameters, and benefit parameters required for this analysis were defined as a result of the evaluation of previous work performed, and appropriate values for each baseline were defined for input into the cost/benefit model.

Since in general the differences in characteristics between various options of Dual Mode are less distinct than those between different modes, and since previous analyses had focused on the latter, it was necessary in this analysis to increase the depth of detail beyond that of previous studies. Existing cost/benefit models were examined to determine their applicability to the analysis. The GRC model and the TRANS model developed by the Federal Highway Administration most closely approximated the


EXISTING/PROPOSED SYSTEMS SURVEY
BASELINE SYSTEMS DEFINITION
COST PARAMETER DEFINITION
PERFORMANCE PAR. DEF.
BENEFIT PAR. DEF.
COST VALUE DETERMINATION
PERFORMANCE VALUE DET.
BENEFIT VALUE DET.
PREVIOUS ANALYSES SURVEY
COST/BENEFIT MODEL SURVEY
DEMAND/MODAL SPLIT MODEL INVESTIGATION
CITY DATA DETERMINATION
COST/BENEFIT MODEL CONSTRUCTION
DEMAND/MODAL SPLIT MODEL CONSTRUCTION OR SELECTION
TEST CITY DETERMINATION
COST/BENEFIT MODEL OPERATION
DEMAND/MODAL SPLIT MODEL OPERATION
CITY DATA COLLECTION
NETWORK SYNTHESIS
CITY CHARACTERISTICS STUDY
SITE CRITERIA RECOMMENDATION
SYSTEM RECOMMENDATION

requirements, but modifications would have been necessary in order to obtain increased sensitivity to detail. A new model, the Transportation Economic Analysis Model (TEAM) was developed.

Existing modal split models were evaluated for flexibility and the ability to distinguish the very fine characteristics which would determine the choice by riders of one type of Dual Mode versus another. The N-Dimensional Logit Model, developed by Peat, Marwick, Mitchell and Co, was chosen to fulfill this function. Various SMSA's were investigated to determine if sufficient data were available in order to perform this analysis. The data had to be both available in the projected 1990 time frame and compatible with the demand analysis technique. Boston was selected as a scenario because it met these two criteria and for other reasons discussed in Chapter 2.2.

.5 THE REPORT

The Dual Mode Systems Analysis Report consists of four volumes. Volume I is a summary of the analysis. Volume II presents the study results. In addition to this introductory chapter, it contains a brief explanation of the analysis technique used (Chapter 2), results (Chapter 3), a discussion of administrative and legal issues relevant to Dual Mode (Chapter 4), and conclusions (Chapter 5). As much as possible each chapter, and in some cases each section, has been written so that it is essentially independent of the remainder of the report. Appropriate references to other chapters or volumes are made to guide the reader to additional information.

Volume III describes the analysis technique in detail and provides much additional reference information. Detailed values used in the analysis, their sources, and methods of calculation are discussed. Assumptions basic to the development of procedures are pointed out. This volume also contains an extensive bibliography of documents which were used in the analysis.

Volume IV describes in detail the Transportation Economic Analysis Model (TEAM) developed for this analysis. This volume contains sufficient information for one unfamiliar with the model to be able to use and modify it for specific purposes. Computer tapes of TEAM can also be provided.

2. ANALYSIS TECHNIQUE ABSTRACT

2.1 BASELINE DESCRIPTIONS

The baselines examined in the analysis are generic in that they represent a confluence of various proposals. Three generic baselines were developed and are listed Figure 2-1, along with some of the organizations instrumental in their conception.

Figure 2-2 is an artist's conception of the pallet system in an urban setting, and Figure 2-3 describes this system in greater detail. The autos are conventional privately owned vehicles which are driven onto system owned pallets which ride on the guideway. Empty pallets are sent to stations to meet anticipated demand. Dual Mode buses interface directly with the guideway and do not require drivers for on-guideway operations. If a high capacity guideway were to discharge large numbers of vehicles into a congested CBD, considerable aggravation of the existing congestion might result. To prevent this, autos on pallets which arrive at the urban core are constrained in this analysis to parking at terminals where interface with the local transit is provided. Differential pricing for parking is used to induce users to leave their cars at garages built in lower land cost areas. Transfer from Dual Mode buses to transit is also required, unless one can walk conveniently from the terminal to one's destination. Multiple CBD terminals are provided, as is discussed in section 4 of this chapter. Off the guideway automobiles, using their internal combustion engines, operate as usual in the manual mode on the streets, and the Dual Mode buses with drivers operate on fixed routes and schedules.*

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*For purposes of this study, the buses use fixed routes and schedules. In reality, any of the types of buses and/or types of service could be used for any of the baselines.

PALLET SYSTEM (GM, TRW, JPL, MILWAUKEE COUNTY)

AUTO ON PALLET

DUAL MODE BUS

AUTOMATED HIGHWAY (OHIO STATE, GM, FORD/TRW, MILWAUKEE COUNTY)

DUAL MODE AUTO

DUAL MODE BUS

NEW SMALL VEHICLE SYSTEM (CORNELL AERO LAB, FORD, ALDEN, GRC)

SMALL PERSONAL VEHICLE

MINIBUS

Figure 2-1 Generic Dual Mode Baseline Systems

Figure 2-2 Pallet System

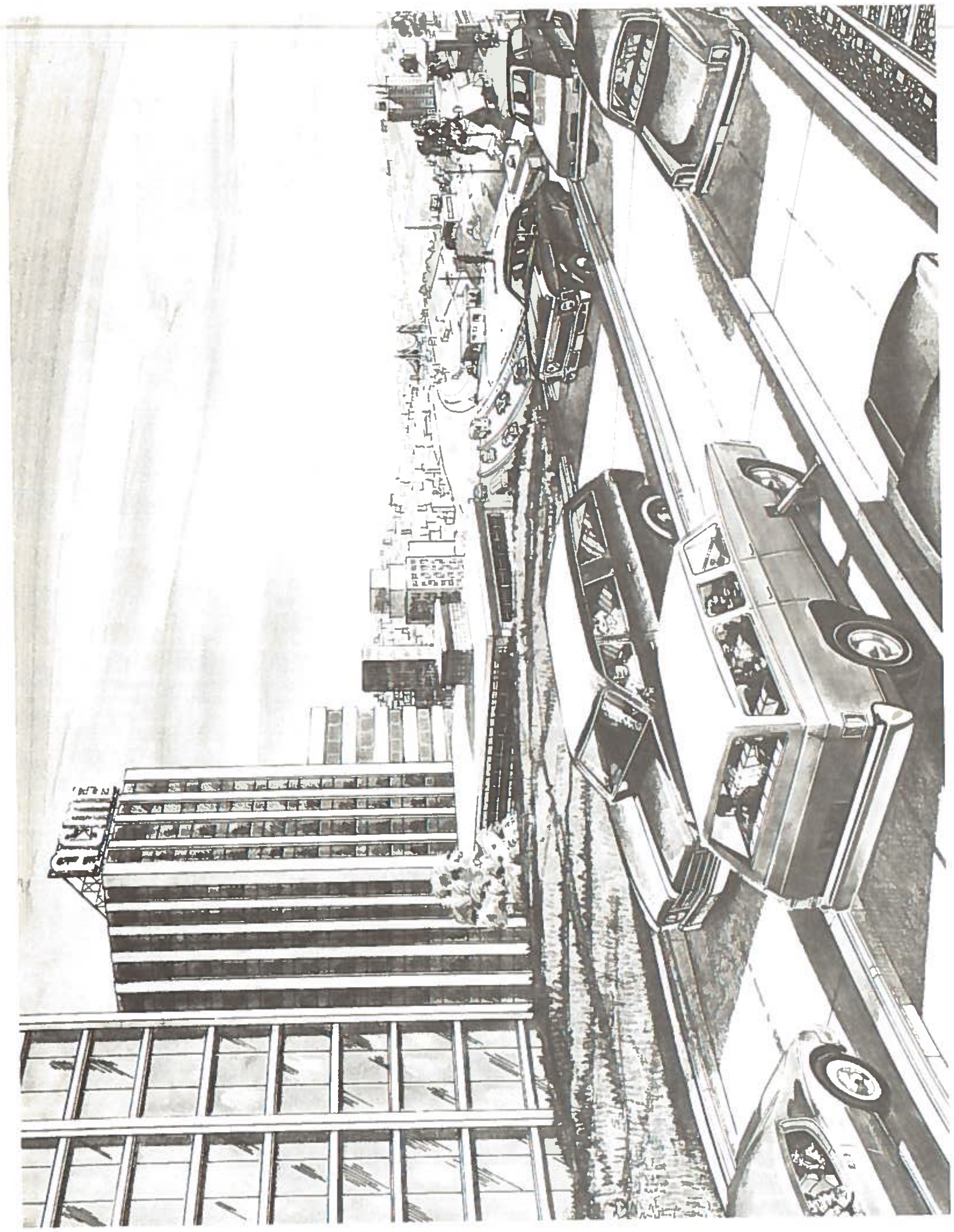
	AUTO/PALLET	BUS
SERVICE		
GUIDEWAY LINE HAUL	AUTO RIDES ON PALLET	BUS OPERATES DIRECTLY ON GUIDEWAY (NO DRIVER)
URBAN CORE COLLECTION AND DISTRIBUTION	AUTOMATIC PARKING AT TERMINALS, INTERFACE WITH LOCAL TRANSIT	INTERFACE WITH LOCAL TRANSIT AT TERMINALS
SUBURBAN COLLECTION AND DISTRIBUTION	MANUAL OPERATION OF AUTOS ON STREETS	FIXED ROUTES AND SCHEDULES
VEHICLE CHARACTERISTICS		
PASSENGER CAPACITY	6	20
OWNERSHIP	PRIVATE AUTO SYSTEM PALLET	SYSTEM
PROPULSION:		
ON GUIDEWAY	ELECTRIC PALLET, POWER TAKEN FROM GUIDEWAY	ELECTRIC, POWER TAKEN FROM GUIDEWAY
OFF GUIDEWAY	AUTO USES INTERNAL COMBUSTION ENGINE	ELECTRIC, POWER TAKEN FROM STORAGE BATTERIES (30 MILE RANGE)

Figure 2-7. Pallet System

Pallets and buses are electrically propelled: on the guideway, both draw power from the guideway; off the guideway, buses are powered by storage batteries with sufficient capacity to allow them a 30-mile range. Buses were sized for a 20-passenger capacity as a result of analyses of service requirements and patronage.

Figure 2-4 depicts and Figure 2-5 describes the automated highway. Operations are essentially the same as with the pallets except that in this case the autos operate directly on the guide-way instead of riding on a pallet. To provide the control systems, rapid response characteristics, and high reliability required for guideway operations, it seems probable that the automobiles would be built specifically as Dual Mode vehicles rather than being retrofitted for Dual Mode capability. Technical feasibility studies are required to establish this point. The vehicles perform as normal autos when off the guideway and can thus be used for all purposes one would ordinarily expect. Buses operate in the same manner as in the pallet system. Both the automobiles and buses are powered by internal combustion engines. A comparison between the buses of pallet system and the automated highway vehicle system provides the opportunity of analyzing the relative effects upon Dual Mode systems of electrical and internal combustion propulsion.

The final baseline, illustrated in Figure 2-6 and described in Figure 2-7, uses totally innovative small vehicles specifically designed for a Dual Mode system. In this case a dense network of stations easily accessible by walking is provided in the central business district, and all vehicles are restricted to the guideway in the CBD. It is possible to pick up a vehicle at any station in the CBD and take it to another station also in the CBD without ever driving the vehicle at all. The small personal vehicle is designed for individual use, but is rented from the system by the user. For a trip between a suburban origin and a downtown destination, the small personal vehicle is driven manually on local streets to the nearest guideway entrance. From there, the vehicle proceeds



	AUTO	BUS
<u>SERVICE</u>		
GUIDEWAY LINE HAUL	AUTO OPERATES DIRECTLY ON GUIDEWAY	BUS OPERATES DIRECTLY ON GUIDEWAY (NO DRIVER)
URBAN CORE COLLECTION AND DISTRIBUTION	AUTOMATIC PARKING AT TERMINALS, INTERFACE WITH LOCAL TRANSIT	INTERFACE WITH LOCAL TRANSIT AT TERMINALS
SUBURBAN COLLECTION AND DISTRIBUTION	MANUAL OPERATION OF AUTOS ON STREETS	FIXED ROUTES AND SCHEDULES
<u>VEHICLE CHARACTERISTICS</u>		
PASSENGER CAPACITY	6	20
OWNERSHIP	PRIVATE	SYSTEM
PROPULSION:		
ON GUIDEWAY	INTERNAL COMBUSTION ENGINE	
OFF GUIDEWAY	INTERNAL COMBUSTION ENGINE	

Figure 2-5 Automated Highway Vehicle System

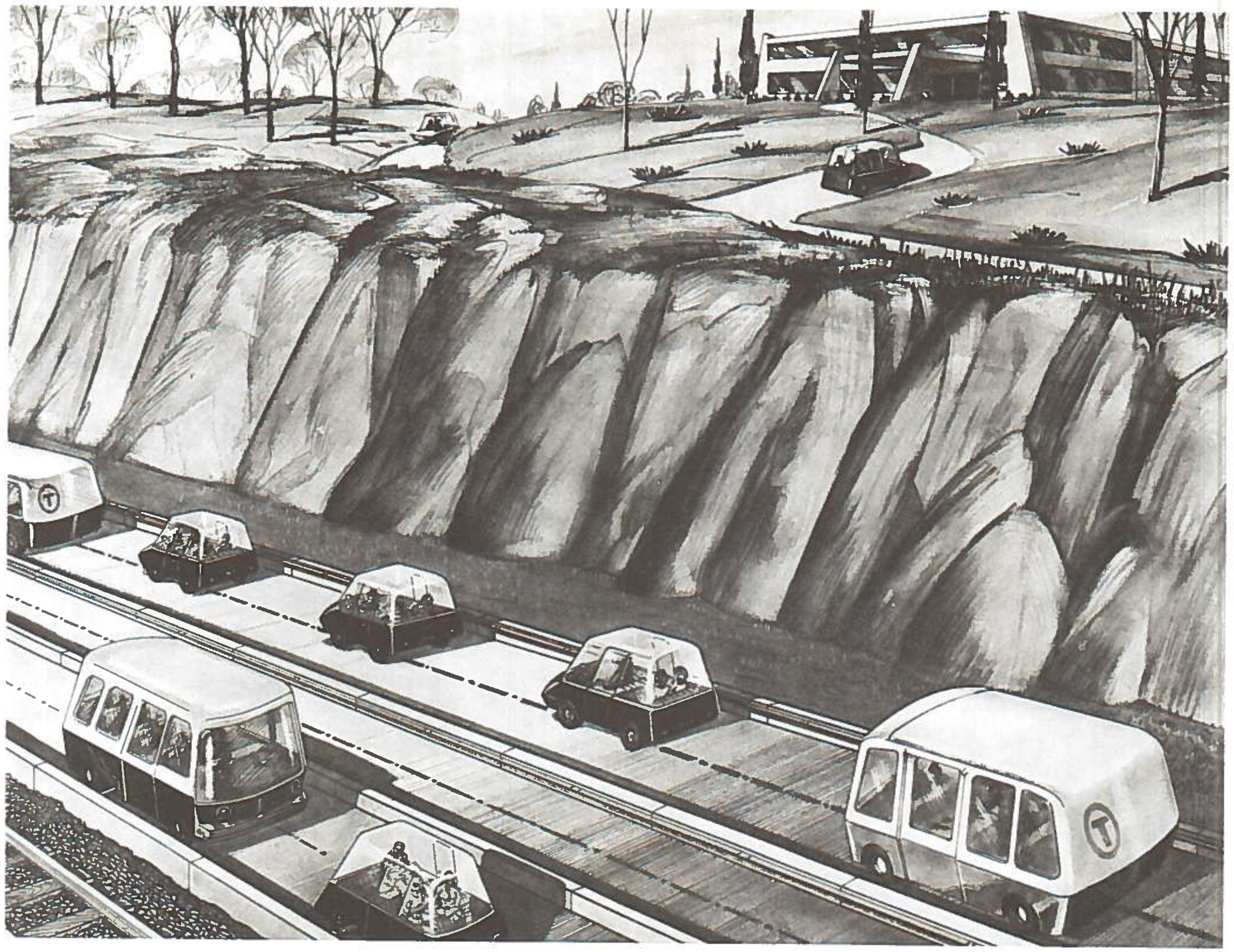


Figure 2-6 New Small Vehicle System

	SMALL PERSONAL VEHICLE	MINIBUS
SERVICE		
GUIDEWAY LINE HAUL	VEHICLE OPERATES DIRECTLY ON GUIDEWAY	BUS OPERATES DIRECTLY ON GUIDEWAY (NO DRIVER)
URBAN CORE COLLECTION AND DISTRIBUTION	DENSE NETWORK OF CBD STATIONS ACCESSIBLE BY WALKING.	
	SMALL PERSONAL VEHICLE PROVIDES PRT SERVICE WITHIN CBD.	
SUBURBAN COLLECTION AND DISTRIBUTION	MANUAL OPERATION OF VEHICLES ON STREETS	DIAL-A-RIDE WITH PARK-AND-RIDE FACILITIES PROVIDED AT STATIONS
VEHICLE CHARACTERISTICS		
PASSENGER CAPACITY	4	12
OWNERSHIP	SYSTEM	SYSTEM
PROPULSION:		
ON GUIDEWAY	ELECTRIC, POWER TAKEN FROM GUIDEWAY	
OFF GUIDEWAY	ELECTRIC, POWER TAKEN FROM STORAGE BATTERIES (30 MILE RANGE)	

Figure 2-7 New Small Vehicle System

along the guideway under automatic control to the station nearest the user's destination. The user leaves the vehicle at this station. The vehicle is either allotted to another user in the area or is sent to a remote storage facility, from which it can be recalled when needed. For the return trip, a vehicle, but not necessarily the same one driven into the CBD, is provided at whichever CBD station the user chooses. Thus one is always guaranteed a vehicle at a CBD station, but no permanent correlation between particular individuals and vehicles exists. The minibus operates as a dial-a-ride vehicle in the suburbs, permitting minimized wait time to be analyzed.

Although batteries were assumed to provide the energy for the electrically powered vehicles operating off the guideway, there are alternatives should the high performance batteries envisioned fail to materialize. Hybrid propulsion systems on the vehicles, involving internal combustion engines driving generators, are an alternative. The vehicle's electric motors would thus be powered directly from the guideway when on it and from the engine-generator combination when on local streets. Indeed, such a combination may provide the small personal vehicle with considerably more flexibility and independence than the battery powered version described here, although at the expense of its simplicity. Throughout the analysis and for all baselines the Dual Mode system was sized to meet all reasonable demands, which means that a vehicle and appropriate guideway space were always provided when required (bus service was provided wherever demand exceeded a specified minimum level).

2.2 CHOICE OF SCENARIO

It was not the purpose of the analysis to design a Dual Mode system for a particular city, but rather to analyze Dual Mode in a representative type of city. This permits city characteristics to be related to baseline characteristics. In order to select a scenario, the criteria of size, demographic characteristics, transportation supply and transportation data availability were applied to the SMSA's.

Both GRC and General Motors have performed similar city characteristics analyses previous to this one. GRC conducted a factor analysis on the 24 SMSA's with a 1960 population of one million or more. A ranking of the areas by their "transportation trait" factor distinguished the auto-oriented cities from the relatively transit-oriented.

General Motors chose 80 U.S. SMSA's as likely to require extensive limited access arterial transportation facilities. Each area was characterized by the 53 variables shown in Figure 2-8. Several multivariate statistical techniques were utilized to cluster the cities into internally homogeneous but distinct groups. For each application of the clustering process, the desired number groups (called the "group level") was specified. Results were published for group levels 6 through 10.

For the Dual Mode scenario selection, one city was to be chosen. The 9-group clustering level from the General Motors analysis was used since it contained a wide range of SMSA types, the statistical index measuring homogeneity within the groups was optimal at this level, and this was the highest level at which representative ranking for the cities was available. Figure 2-9 shows the ranking for clustering at the 9-group level. The various groups at this level are characterized by the authors as follows:

- Groups 1 and 2 are self-explanatory and reflect the uniqueness and dominance in the urban hierarchy of first, New York and secondly, Chicago and Los Angeles.
- Group 3 consists of large northeastern cities which are characterized by high residential density and transit orientation.
- Group 4 consists of southern cities which have high residential density, young families and low personal wealth.

VARIABLE TITLE
1. LAND AREA OF URBANIZED AREA, 1970
2. APPROXIMATE NUMBER 45° SECTORS OF URBAN DEVELOPMENT AROUND CBD
3. NUMBER OF INCORPORTATED CITIES WITHIN URBANIZED AREA, 1960
4. NUMBER OF CENTRAL CITIES DEFINED FOR SMSA, 1970
5. TOTAL POPULATION OF URBANIZED AREA, 1970
6. APPROXIMATE YEAR IN WHICH CENTRAL CITY EXCEEDED 50,000 POPULATION
7. POPULATION GROWTH FACTOR FOR SMSA, 1965-1985
8. PERCENT OF URBANIZED AREA POPULATION LOCATED IN CENTRAL CITY, 1970
9. POPULATION PER SQUARE MILE IN CENTRAL CITY, 1960
10. POPULATION PER SQUARE MILE IN URBAN FRINGE, 1960
11. PERCENT OF SMSA POPULATION NON-WHITE
12. PERCENT OF SMSA POPULATION LESS THAN 18 YEARS OLD, 1970
13. PERCENT OF SMSA POPULATION GREATER THAN 64 YEARS OLD, 1970
14. MEAN NUMBER OF PERSONS IN HOUSEHOLD IN SMSA, 1960
15. PERCENT OF SMSA HOUSING WHICH IS SOUND WITH ALL FACILITIES, 1960
16. PERCENT OF SMSA HOUSEHOLD IN ONE-UNIT STRUCTURES, 1960
17. PERCENT OF SMSA POPULATION IN GROUP QUARTERS, 1960
18. MEDIAN VALUE OF ALL OWNER-OCCUPIED HOUSING IN SMSA, 1960
19. PER CAPITA INCOME, 1970
20. PROJECTED PER CAPITA INCOME GROWTH, 1970-1990
21. PROJECTED MEAN HOUSEHOLD INCOME IN SMSA, 1985
22. PROJECTED PERCENT OF SMSA HOUSEHOLDS WITH LESS THAN $4,000 INCOME, 1985
23. PROJECTED PERCENT OF SMSA HOUSEHOLDS WITH GREATER THAN $15,000 INCOME, 1985
24. RATIO OF NUMBER OF FAMILIES WITH LESS THAN $3,000 INCOME IN CENTRAL CITY TO THOSE IN URBANIZED, 1960
25. RATIO OF NONWORKER TO WORKER POPULATIONS IN URBANIZED AREA, 1960
26. PERCENT MARRIED WOMEN WITH HUSBAND PRESENT IN LABOR FORCE IN URBANIZED AREA, 1960
27. PERCENT WHITE COLLAR EMPLOYMENT IN SMSA, 1960
28. MEAN NUMBER OF AUTOMOBILES AVAILABLE PER FAMILY IN SMSA, 1960

VARIABLE TITLE
29. PROPORTION OF HOUSEHOLDS IN CENTRAL CITY WITH NO AUTOMOBILE AVAILABLE, 1960
30. PROPORTION OF HOUSEHOLDS IN URBAN FRINGE WITH NO AUTOMOBILE AVAILABLE, 1960
31. PERCENT OF WORKERS COMMUTING CENTRAL CITY TO URBAN FRINGE, 1960
32. PERCENT OF WORKERS COMMUTING SMSA FRINGE TO CENTRAL CITY, 1960
33. PERCENT OF WORKERS COMMUTING TOTALLY WITHIN SMSA FRINGE, 1960
34. PERCENT CENTRAL CITY WORKERS USING PUBLIC TRANSIT, 1960
35. PERCENT URBAN FRINGE WORKERS USING PUBLIC TRANSIT, 1960
36. PROPORTION OF WORKERS WALKING TO WORK IN SMSA, 1960
37. PROPORTION OF WORKERS USING RAIL TRANSIT IN SMSA, 1960
38. TOTAL OF ALL PUBLIC TRANSIT VEHICLES IN SMSA, 1966
39. PERCENT OF SMSA RETAIL SALES IN CENTRAL BUSINESS DISTRICT, 1967
40. PERCENT CHANGE IN CBD RETAIL SALES, 1963-1967
41. NUMBER OF SMSA RETAIL ESTABLISHMENTS PER 1000 POPULATION, 1967
42. AVERAGE NUMBER OF EMPLOYEES PER MANUFACTURING ESTABLISHMENT IN SMSA, 1967
43. RECEIPTS OF SMSA SELECTED SERVICE ESTABLISHMENTS PER CAPITA, 1967
44. MEAN JANUARY TEMPERATURE IN DEGREES FAHRENHEIT
45. TOTAL DAILY VEHICLE MILES OF TRAVEL ON PRINCIPLE ARTERIAL ROADWAYS IN URBAN AREA, PROJECTED 1990
46. PERCENT CHANGE IN PRINCIPAL ARTERIAL DAILY VEHICLE MILES OF TRAVEL, 1968-1990
47. PERCENT OF TOTAL ALL ROADWAY DAILY VEHICLE MILES OF TRAVEL ON PRINCIPAL ARTERIALS, PROJECTED 1990
48. PERCENT OF TOTAL ALL ROADWAY DAILY VEHICLE MILES OF TRAVEL ON FREEWAYS, PROJECTED 1990
49. PRINCIPAL ARTERIAL DAILY VEHICLE MILES OF TRAVEL PER CAPITA, PROJECTED 1990
50. TOTAL ROUTE MILES OF FREEWAYS PROPOSED FOR 1990
51. TOTAL INCREASE IN PRINCIPAL ARTERIAL ROUTE MILES PROPOSED FOR 1968-1990.
52. RATIO OF PROJECTED 1990 PRINCIPAL ARTERIAL DVMT PER ROUTE MILE TO 1968 PRINCIPAL ARTERIAL DVMT PER ROUTE MILE
53. PRINCIPAL ARTERIAL DAILY VEHICLE MILES OF TRAVEL PER ROUTE MILE, PROJECTED 1990

Figure 2-8 General Motors Variables Selected for Principal Components Analysis

GROUP 1

(1) NEW YORK

GROUP 2

(1) CHICAGO
(1) LOS ANGELES

GROUP 3

1. ST. LOUIS
2. BOSTON
3. DETROIT
4. PHILADELPHIA
5. PITTSBURGH
6. BALTIMORE
7. WASHINGTON

GROUP 4

1. NASHVILLE
2. MEMPHIS
3. BIRMINGHAM
4. JACKSONVILLE
5. ATLANTA
6. CHARLOTTE
7. MOBILE
8. NEW ORLEANS
9. KNOXVILLE
10. LOUISVILLE
11. NORFOLK
12. HONOLULU

GROUP 5

1. KANSAS CITY
2. OKLAHOMA CITY
3. DENVER
4. PORTLAND
5. SEATTLE
6. SPRINGFIELD
7. INDIANAPOLIS
8. PROVIDENCE
9. TULSA
10. TACOMA

GROUP 6

1. MILWAUKEE
2. GRAND RAPIDS
3. CINCINNATI
4. SYRACUSE
5. COLUMBUS
6. AKRON
7. TOLEDO
8. ROCHESTER
9. CLEVELAND
10. HARTFORD
11. ALBANY
12. BRIDGEPORT
13. SALT LAKE CITY
14. WILMINGTON
15. SACRAMENTO
16. BUFFALO
17. WORCESTER
18. RICHMOND

GROUP 7

1. SAN JOSE
2. FORT WORTH
3. HOUSTON
4. PHOENIX
5. SAN ANTONIO
6. SAN BERNARDINO
7. SAN DIEGO
8. BEAUMONT
9. DALLAS
10. EL PASO
11. SAN FRANCISCO

GROUP 8

1. FORT LAUDERDALE
2. WEST PALM BEACH
3. MIAMI
4. TAMPA
5. ORLANDO

GROUP 9

1. OMAHA
2. DAVENPORT
3. UTICA
4. DULUTH
5. LANSING
6. DAYTON
7. YOUNGSTOWN
8. MINNEAPOLIS
9. TUCSON
10. WICHITA
11. MADISON
12. FLINT
13. ALBUQUERQUE
14. NEWPORT NEWS

Figure 2-9 Standard Metropolitan Statistical Areas Ranked by Representativeness in each Group (9-Group Level)

- Group 5 contains cities not highly industrial, of average personal wealth, and with older families.
- Group 6 is located in the mideastern section of the U.S. and are the older northern industrial areas characterized by high personal wealth, high residential density and public transit orientation.
- Group 7 consists of the "young southwestern" areas with the lowest residential density and public transit orientation, young families and the highest projected growth in roadway usage.
- Group 8 consists of the "Florida" areas with significant retired populations and low residential densities.
- Group 9 consists of the young northern industrial areas located further west than the older northern industrial (group 6). Group 9 is characterized by high personal wealth, low density and high manufacturing employment (5).

Groups 1, 2 and 8 were dropped from consideration because they are very special cases, not typical of many urban areas. Of the remaining 6 clusters, groups 3, 5, 6 and 7 were selected as the most appropriate for study on the basis of:

a. The number of cities in the group

b. The size of the cities in the group

c. The expected growth of the cities in the group

d. The homogeneity of the group

Boston was eventually chosen as the city to be studied. This choice came from the fact that it is a good representative of its group (group 3), has the appropriate data in available form, is a good representative of a class of cities determined by the GRC analysis and has an extensive transit system (enabling a comparison of Dual Mode with conventional transit). Thus the scenario selection conforms to the relevant portions of both the GRC and General Motors studies.

2.3 ANALYSIS PROCEDURE

Figure 2-10 is a simplified description of the analysis flow for a baseline. Using the total 1990 origin/destination demand as projected by the local planning agency, the modal split model was applied to determine the ridership on the Dual Mode system and the coexisting highway and transit systems. Ridership levels were based upon the fare charged or perceived cost, the time components of a trip, and various operating policies (e.g., regarding transfers to conventional transit). Costs and impacts were defined as a function of various parameters, and these data were aggregated and organized in the TEAM cost/benefit model. Parametric analyses were carried out to determine sensitivity to variations in the input data. The results were analyzed, evaluated, and summarized as costs and benefits. For each Dual Mode system, statistics for Dual Mode, for the complementary highway network, and for transit were calculated.

2.4 NETWORK SYNTHESIS

Since the transportation planners of Boston have spent more time and have more knowledge of that city than the analysis team, it was decided to allow the network to conform to the local 1990 transportation plan* philosophy in terms of general orientation.

*For the 1990 case being considered, which is the recommendation of the Eastern Massachusetts Regional Planning Project. Boston is conducting a transportation plan restudy which is expected to have considerably different recommendations. For analysis purposes, however, the EMRPP plan provided an adequate base for comparison.

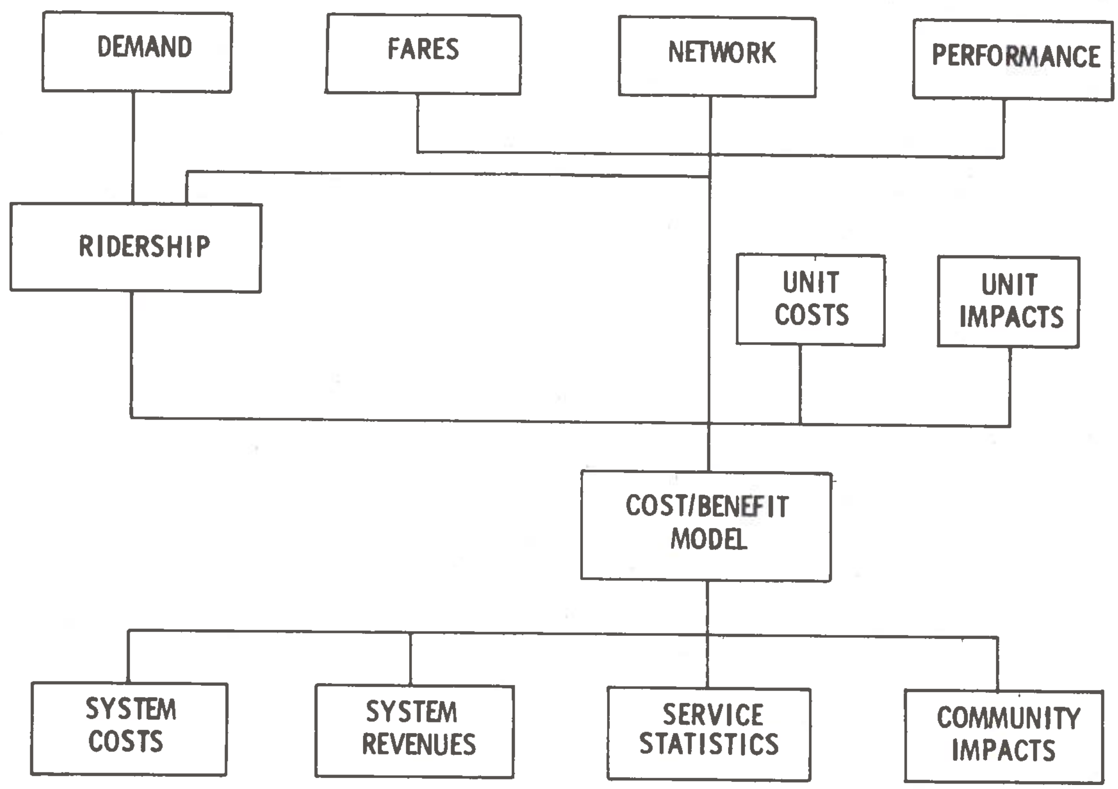


Figure 2-10 Dual Mode Analysis Functional Flow

The proposed highway and rapid transit construction for Boston is shown in Figure 2-11. In designing the Dual Mode network, portions of the conventional facilities planned for 1990 were assumed not to be built (114 miles of highways and 29 miles of rapid transit), because the capacity and connectivity these would provide would not be necessary with Dual Mode present.

A basic Dual Mode network was designed for all baselines, with some adjustments required to meet the peculiarities of specific systems. The Dual Mode network designed for Boston is depicted in Figure 2-12. Most of the stations, shown as circles, provide for entry to and exit from the system. For the pallet and automated highway vehicle systems, stations in and near the CBD are indicated in Figure 2-13 as three different types. At the stations indicated by diamonds, Dual Mode users can transfer to the existing rapid transit system. Vehicle access to and from the local street network is forbidden at these stations, and automobile parking is provided. The one CBD station indicated by a triangle has no direct transit interface since it is within walking distance of the main financial district. As with the other CBD stations, vehicles are not permitted access to local streets and parking is provided. The stations denoted by squares lie on the periphery of the CBD and vehicles are permitted access to local streets. Transfer to rapid transit and parking are provided, and CBD-bound travelers are encouraged to park at these lower land cost stations through reduced parking charges.

For the new small vehicle baseline, the network in the downtown area was structured to provide walking access from the system to all CBD points. The dense CBD collection/distribution network for this system is shown in Figure 2-14. A large portion of the network is tunneled, and all vehicles are confined to the guideway in this area.

Right of way acquisition was minimized in order to reduce both dollar costs and community impact. Whereas all of the planned highway additions would require the taking of new land, the Dual Mode network, due to its narrow guideway, could make extensive use

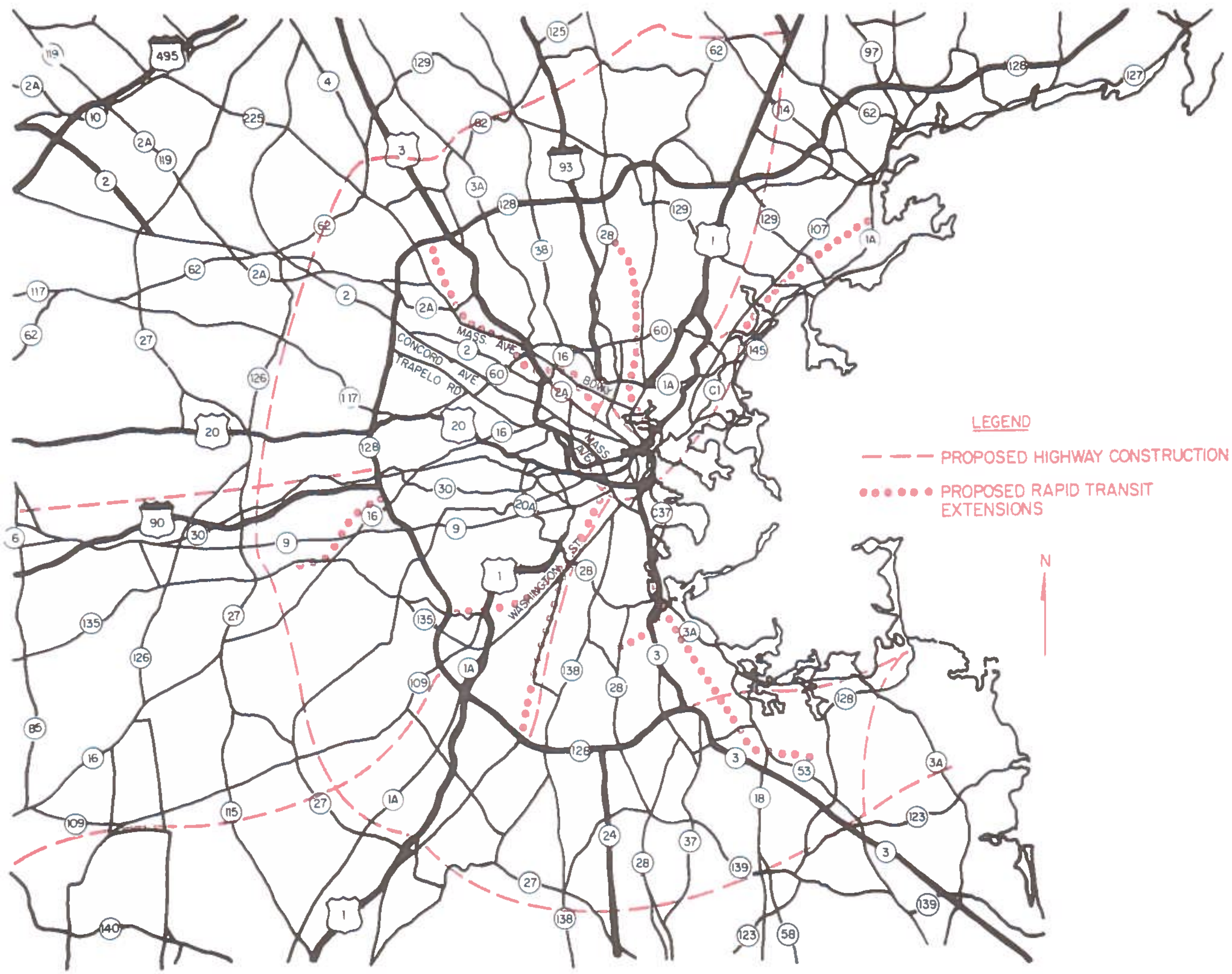


Figure 2-11 Boston Proposed Highway and Rapid Transit Construction

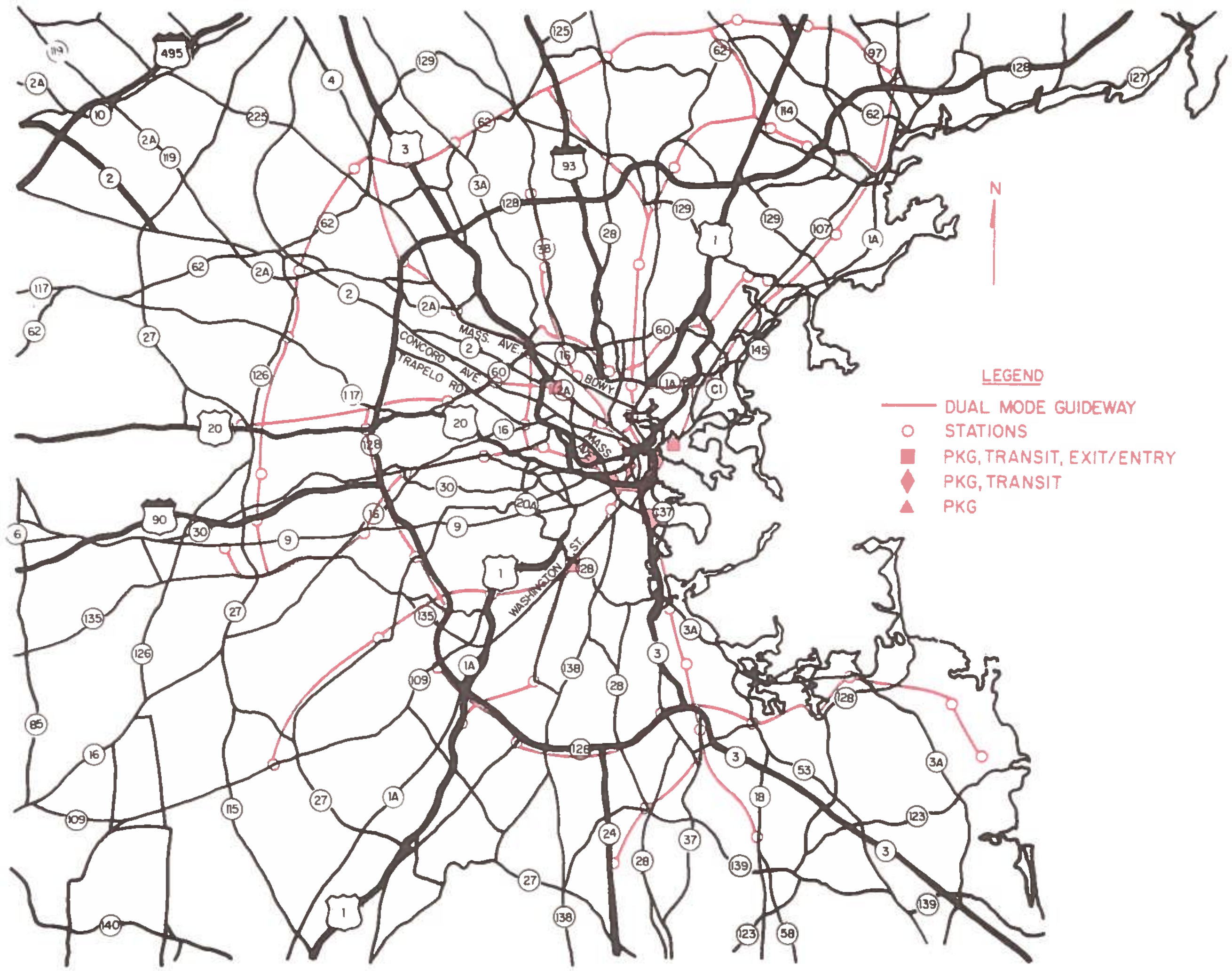


Figure 2-12 Boston Dual Mode System Guideway

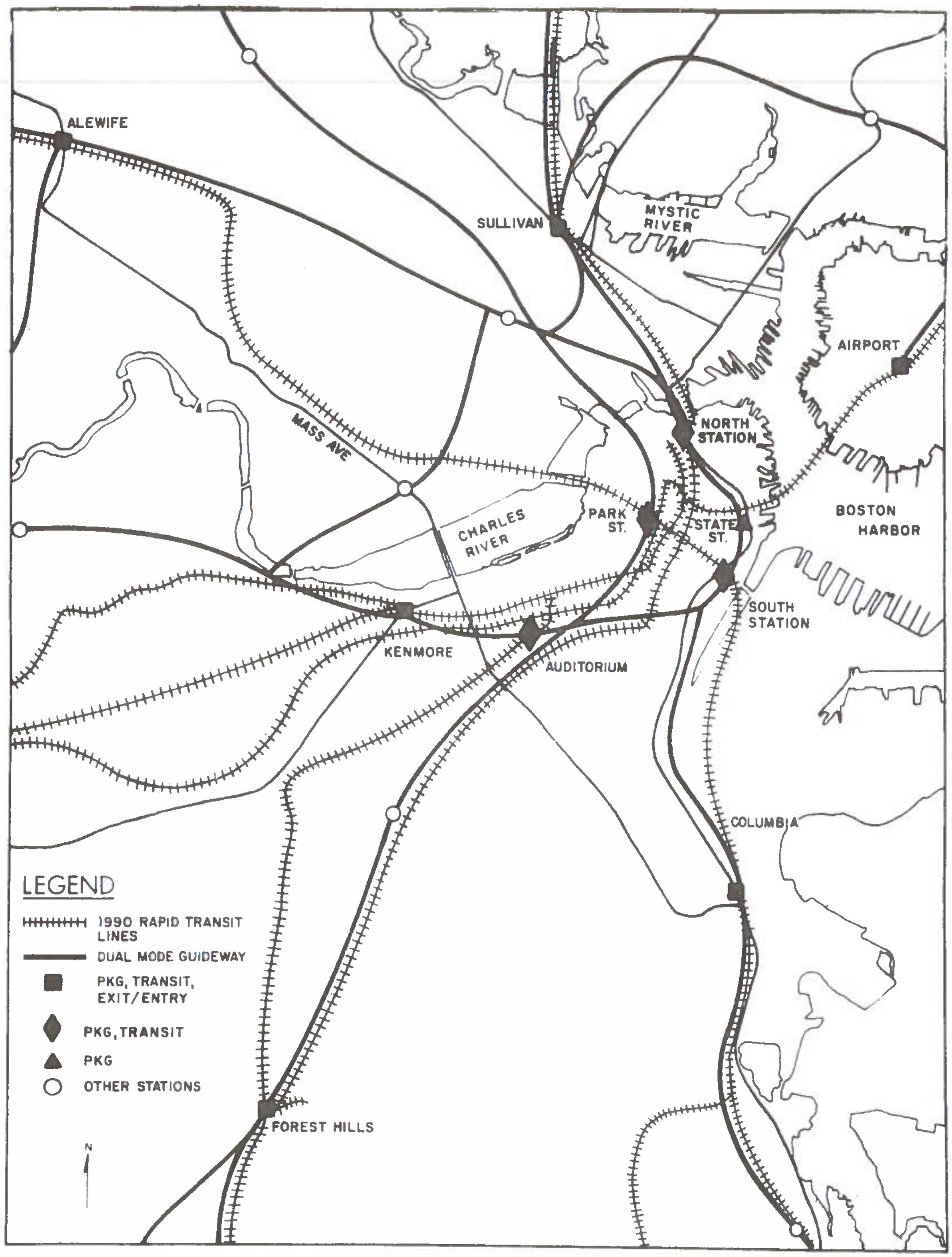


Figure 2-13 Dual Mode CBD Network

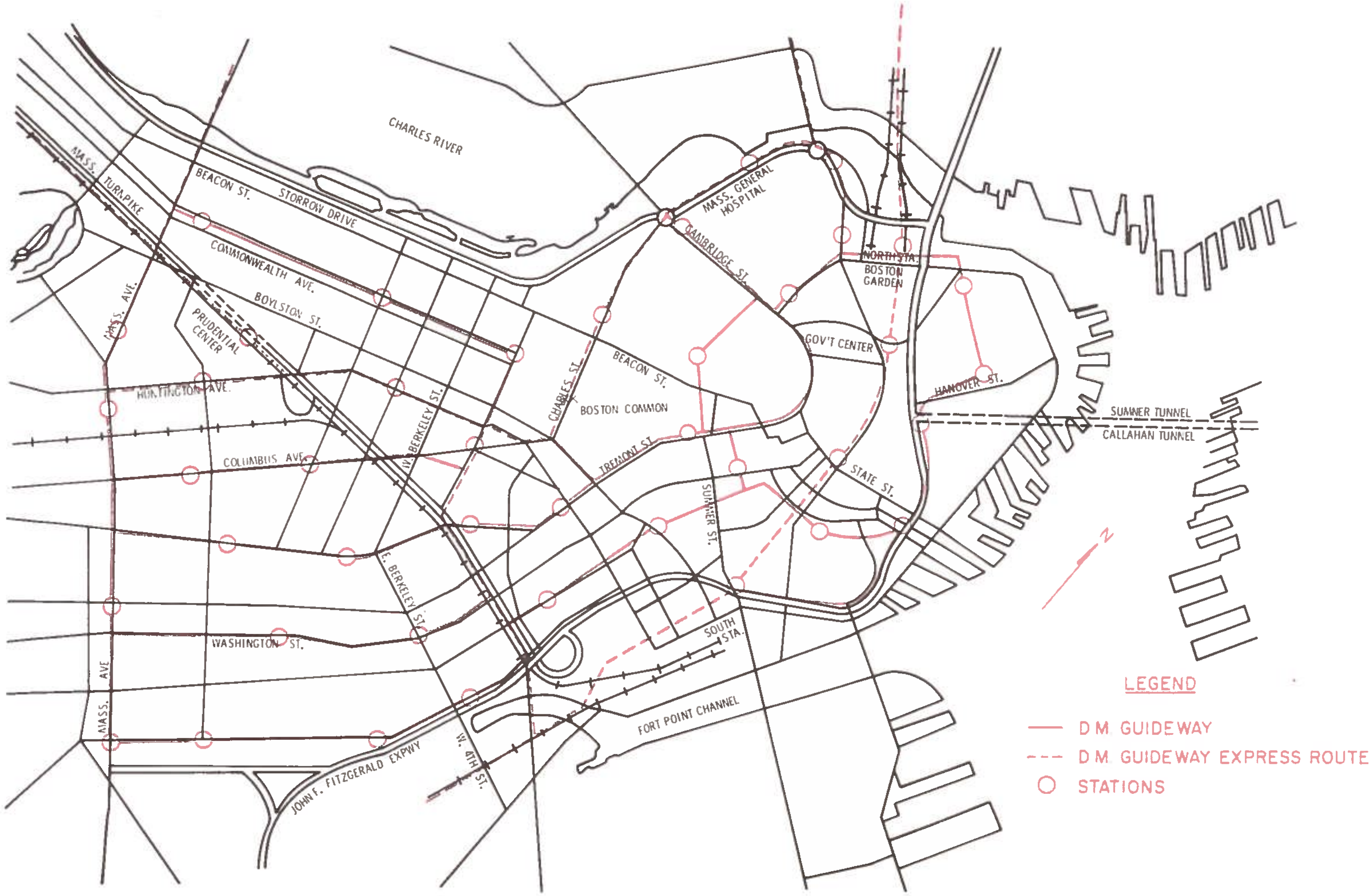


Figure 2-14 Boston New Small Vehicle CBD Network

of existing right-of-way. A majority of the Dual Mode guideway was tunneled, located on existing highway right-of-way, or laid out on existing rail right-of-way, as is apparent from a comparison of the guideway network with the highway and rail network shown in Figure 2-15. As a result, only about 20% of the Dual Mode guideway required the acquisition of new land.

2.5 SYSTEM CAPACITY

Speeds of 60 mph were assumed over a majority of the network. In the vicinity of the CBD speeds were reduced to 30 mph, and for the new small vehicle baseline speeds were 15 mph on the dense CBD network, except on through routes. For standard 20-foot auto lengths, this is equivalent to 8,000 vehicles per hour, bumper to bumper, on 30 mph segments, and for 10-foot small personal vehicles at 15 mph a similar bumper to bumper capacity results. The maximum probable deceleration of a disabled vehicle was estimated to be 0.7g, and the standard emergency deceleration was defined to be 0.6g for reasons of comfort and capacity. A vehicle spacing sufficient to allow one vehicle to decelerate at the standard emergency deceleration behind another decelerating at the maximum probable level for a disabled vehicle, without the vehicles colliding, results in a guideway capacity of 6,000 vehicles per hour for vehicles of automobile size and smaller. Unbelted passengers in large buses reduce the permissible emergency deceleration to 0.2g, resulting in a maximum capacity of 400 buses per hour. These capacity figures permit leeway from the physical limits of the bumper to bumper case, and were used in this analysis. Buses and automobile-size vehicles were mixed on the guideway and the resultant vehicle capacity was dependent upon the ratio of one type of vehicle to the other. The various aspects of this very complex subject are discussed in considerably more detail in Chapter 4.2 of Volume III.

Provisions were made to handle emergency rerouting should a breakdown occur. As a design requirement, in no case would any

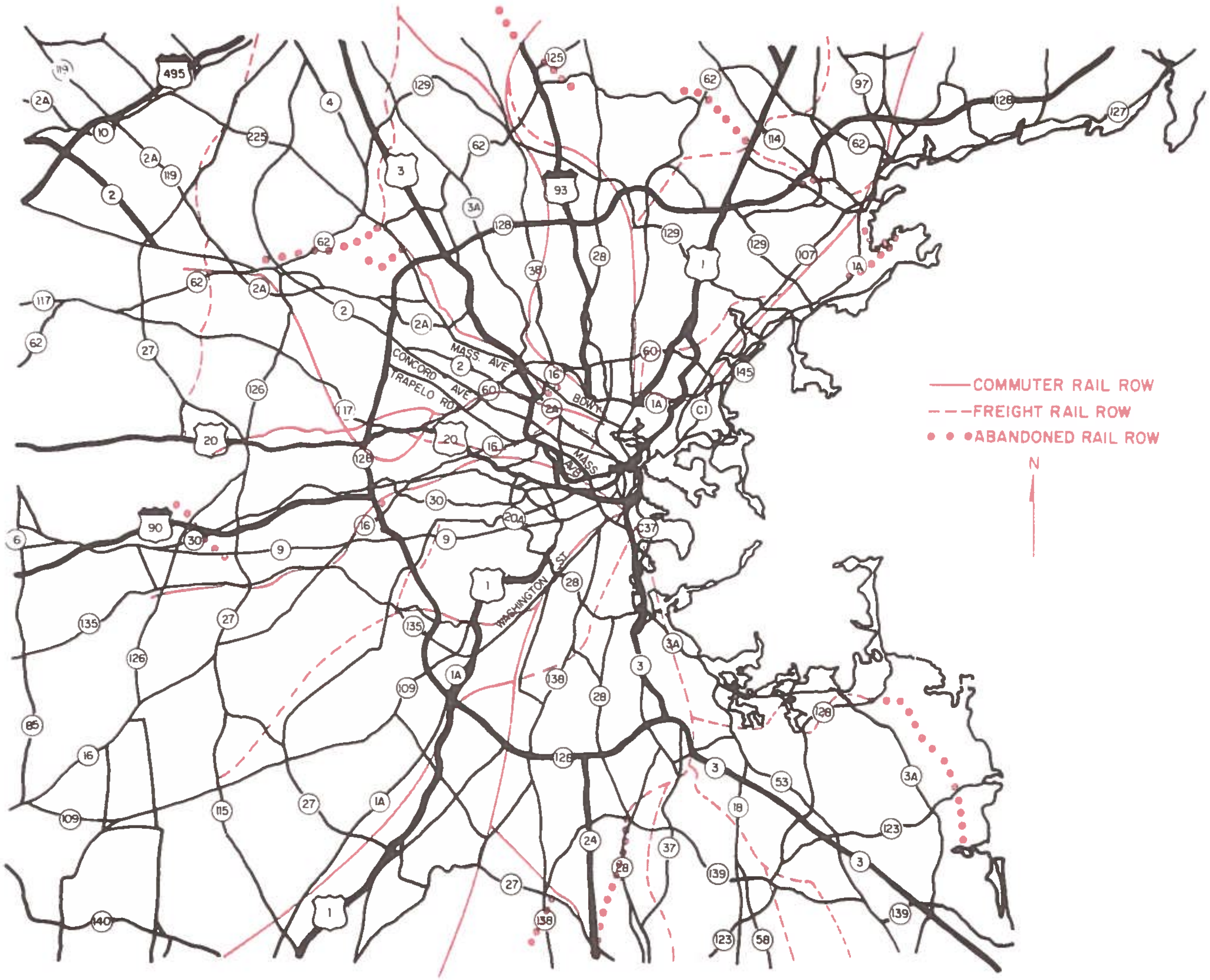


Figure 2-15 Boston Highway and Rail Rights of Way

significant delays be encountered when a portion of guideway was temporarily inoperative. Where sufficient connectivity existed, closing of lanes was accommodated by routing vehicles to alternate paths with negligible delay. Where this level of connectivity did not exist, there were two options. For portions of guideway in which all traffic lanes were required to handle expected flows in both directions, an additional lane was inserted for emergencies and overflow conditions. For portions where the flow in one direction was very light even during the peak hour, no additional lane was required, since the off-peak direction lane could provide the emergency capability.

2.6 TRAVEL PATTERNS AND RIDERSHIP DETERMINATION

The Eastern Massachusetts Regional Planning Project (EMRPP) performed an analysis of population land use, economic activities and transportation facilities based on 1963 data (9). Land use planning based on area growth goals and objectives was carried out and 1990 regional population statistics were projected, including estimates of individual travel patterns. For Dual Mode study purposes the results of the EMRPP generated and distributed trips were accepted as valid and considered appropriate for obtaining a relative performance comparison among the various Dual Mode baselines.

The EMRPP Recommended Transportation Plan (9) was based on a dispersed growth pattern employing radial and circumferential traffic flows. Trip generation patterns for the various 1990 regional population centers are seen in Figure 2-16. Travel densities between these centers are shown in Figure 2-17. Figure 2-18 reflects significant trip making statistics for the 1990 time frame. The EMRPP study produced the following additional regional statistics:

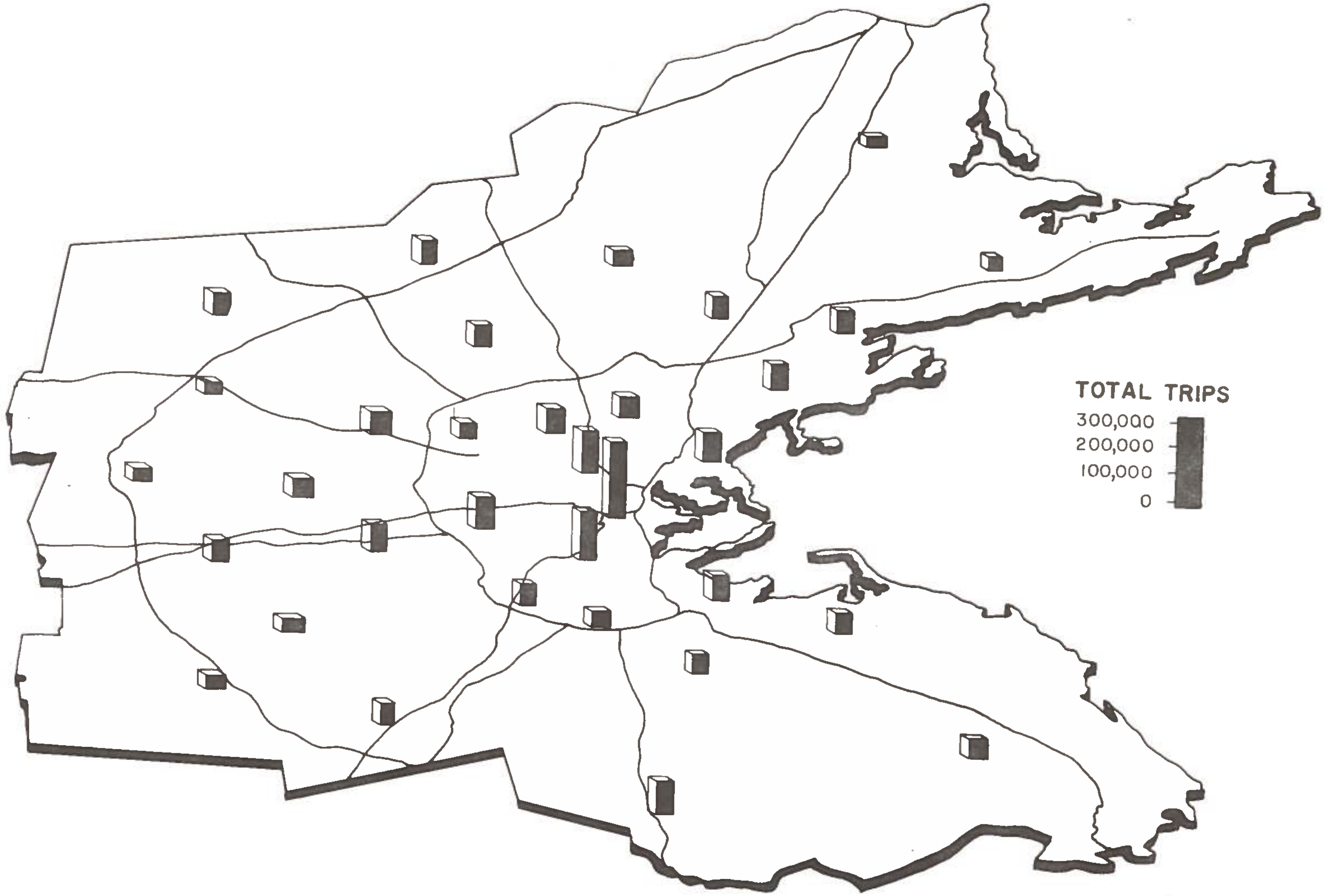


Figure 2-16 Total Trips Flowing in and Out of Boston Areas for The AM Peak Three Hours in 1990

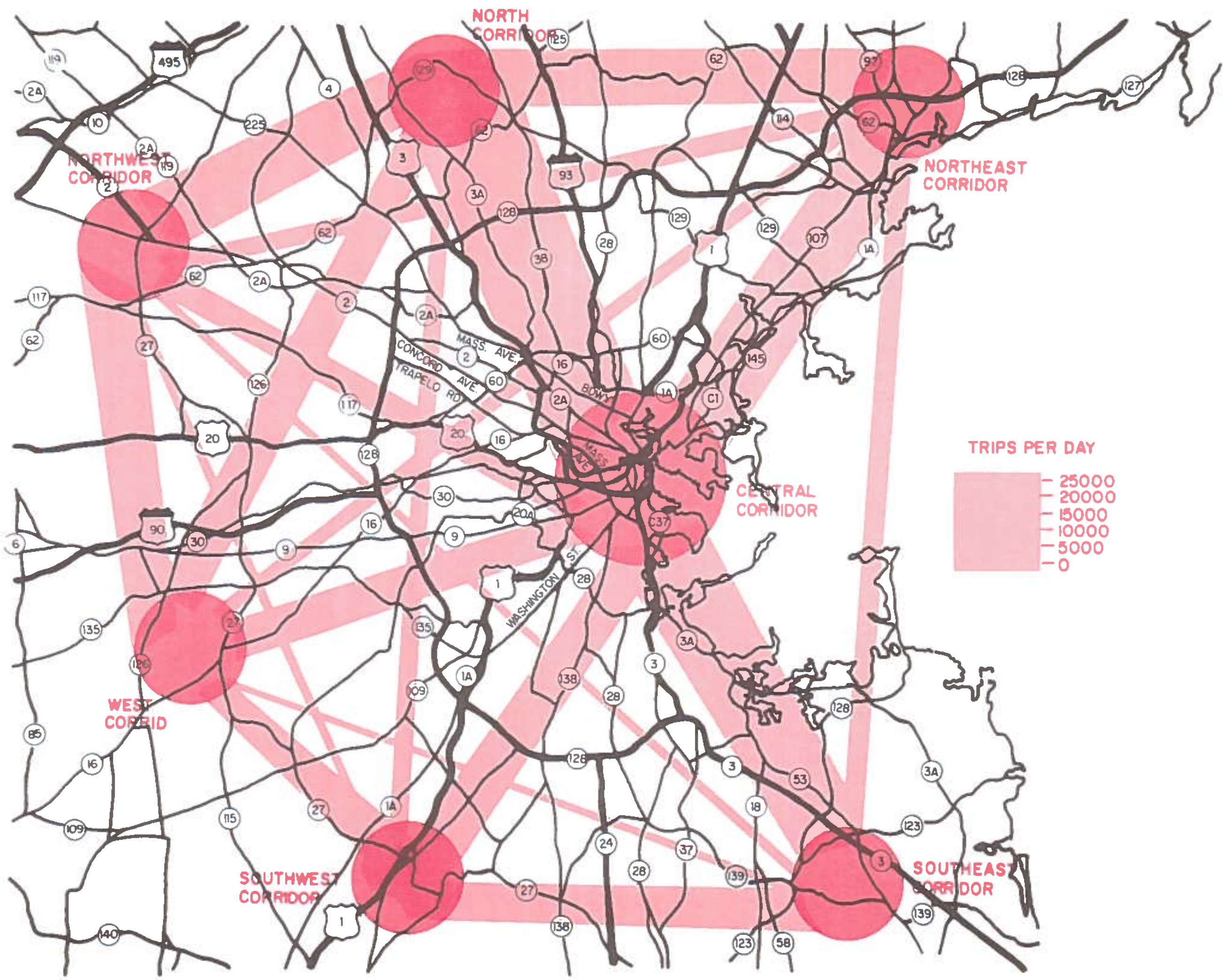


Figure 2-17 Boston Traffic Flow
(by Corridors)

TOTAL DAILY TRIPS	10,700,000
PEAK	36%
OFF PEAK	64%
TRIP ORIENTATION	
INTRA-CBD	1%
TO/FROM CBD	9%
INTRA-SUBURBAN RADIAL	48%
INTRA-SUBURBAN CIRCUMFERENTIAL	42%
POTENTIAL RIDERS	
TOO SHORT FOR DUAL MODE	48%
BEYOND DUAL MODE SERVICE AREA	8%
POTENTIAL DUAL MODE TRIPS	44%

Figure 2-18 Boston 1990 Demand Characteristics

	1963	1990	% Increase
Population	3,540,000	4,730,000	34
Employment	1,300,000	1,800,000	39
Median Family Income*	$6,520	$13,300	103
Car Ownership (Persons/Car)	3.3	2.1	-36
Total Cars	1,070,000	2,220,000	108

Also, vehicle miles traveled each day is projected to double from 1963 to 1990 (assuming implementation of the 1990 Recommended Plan).

The technique adopted to determine the expected level of ridership of each Dual Mode baseline (and on complementary transit and highways) was basically a modification of the method used by transportation planners. Modifications were required for cost/benefit analysis because the method developed for planners is used to determine detailed transportation systems location for a city, whereas this analysis was designed to trade off costs and benefits, to perform parametric analyses, to project for innovative modes, and to make finer distinctions between the characteristics of various alternatives than would be required in the traditional planning process. Extensive use of the FHWA battery of programs, development of several special-purpose computer programs and the use of the N-Dimensional Logit Model provided this flexibility. A detailed description of the techniques applied and of the programs developed for ridership analysis are included in Chapter 3 and Appendices A through D of Volume III.

*Measured in 1968 dollars.

The demand analysis flow is shown in Figure 2-19. Base year 1963 data were used to calibrate the modal split model. The model was specifically chosen to provide a large number of variables which would allow investigation of the characteristics of riders relative to the various characteristics of different systems. Calibration was performed in order to determine how riders react to such items as transfer time, wait time, riding time, walk distance, fares, parking costs, and a number of other variables. The calibrated parameters were organized into equations which described the characteristics of each Dual Mode alternative, of the highway option, and of transit available relative to ridership classes.

The local planning agency in Boston has defined 894 traffic analysis zones, which results in 810,000 possible trip combinations. To make the problem more tractable, 136 superzones were created resulting in only 18,000 trip combinations. These superzones, each one corresponding roughly to one Dual Mode station, were used for application of the modal split model.

An abstract representation of the Dual Mode network was constructed to reflect travel in all areas where service was provided. Skims of this network (showing interzonal travel times by Dual Mode), as well as skims of the projected 1990 highway and transit networks, were input to the modal split model. These skims also provided trip times for the accessibility analysis.

Extensive parametric studies were conducted to determine the sensitivity of modal split to changes in fare policies, system delays, headways and model parameters, and to determine the correct system parameters for use in the assignment process. Based upon the demographic characteristics of each superzone, temporal factors, and the modal split results, ridership levels were determined for travel between each superzone and every other superzone. The 1990 total person trip tables were applied to these results, which generated actual tables of person trips by origin,

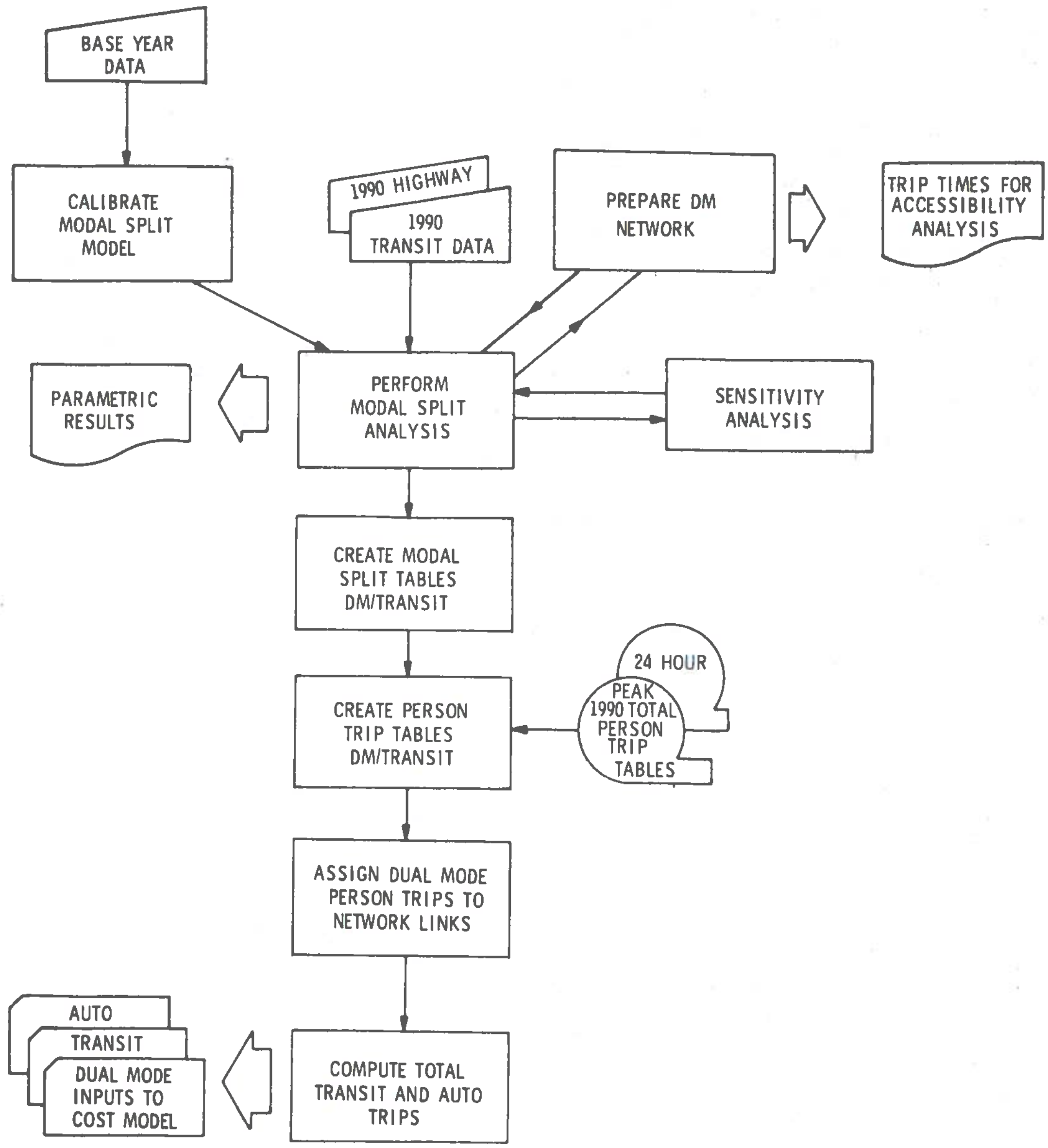


Figure 2-19 Demand Analysis Flow

destination, temporal period, and mode. These persons were then assigned to the appropriate links of the Dual Mode network, computations of how many people were using transit and auto were performed, and the data were reorganized to become input for the cost/benefit model.

To give some indication of the size of the problem, in the calibration 40 independent variables were reduced to 12 significant ones representing 12 different characteristics of people and systems. The analysis considered 10 levels of service variables, and was stratified by peak and off-peak temporal periods; high, middle, and low income levels; and work and other trip purposes. The demand analysis representation of the Boston Dual Mode network had 154 on-guideway links, 272 off-guideway links, 544 walk/wait links, and 36 intersections, for a total of 1,006 links. A link was defined between the center of a demand analysis superzone and a station, between a station and an intersection, between two intersections or two stations, or to represent an action such as waiting. 19,000 highway miles, 81 rapid transit route miles, and 600 bus route miles were also considered. Three major models, represented basically by the top, middle and bottom portions of Figure 2-19, were used with a total of between 19 and 22 supporting computer programs, depending on which baseline was being analyzed.

2.7 COSTS

The cost projections used were based on previous Dual Mode and PRT cost studies, current project costs such as the Morgantown Project, and current transportation system costs. Dual Mode cost estimates were made in the UMTA Milwaukee County Dual Mode study by Allis Chalmers (6) and the Northeast Corridor Project by TRW (13,14,15,16,17). A number of estimates of Dual Mode costs were developed by contractors working on the HUD-sponsored Study of New Systems in Urban Transportation (4). Recently JPL prepared a

Dual Mode study for the DOT Office of the Secretary (8) which contained additional Dual Mode cost estimates. The data from these sources were analyzed and utilized extensively.

The costs of the highway and transit additions were based on traditional sources: the Federal Highway Administration (21, 22,23,24,25), from the Urban Mass Transit Administration (19) and the American Transit Association (1). Experience with the Bay Area Rapid Transit (BART) system provided valuable insight into how cost estimates may be related to actual experienced costs. TSC itself is involved with development of several new ground systems, and cost estimates were available from these projects and applied in the analysis.

The detailed costs, estimating techniques and values assumed for this analysis are documented in Volume III, chapter 5. Right of way cost was determined as a function of network location and land use. Guideway structural cost was determined by the type of construction required in each link or segment (subset of a link). Track, electrification, and guideway command and control costs were itemized separately. Each interchange was costed by type and individually tabulated. Terminals were costed using the appropriate cost for each individual terminal location and type.

System revenues were calculated from user fares and from parking charges. Fares were assessed as a fee per vehicle trip or a fee per vehicle mile for the personal vehicles and as a fee per passenger mile or fee per passenger trip for buses.

The appropriate fare structures and fare levels for each baseline were selected after parametric analysis of fares and demand levels had been conducted. Results of these analyses are reported in Chapter 4. From the revenue and cost information the Dual Mode system operator cash flow and profit or loss were calculated.

2.8 IMPACT EVALUATION

A detailed quantitative assessment of the impact of the Dual Mode baselines upon users and the community was carried out. The relative safety of the system was determined by projections of traffic accidents and fatalities for each Dual Mode system and its complementary highway and transit systems, as well as for the 1990 plan. Increased accessibility to commercial, educational, recreational, and medical facilities was quantified in terms of the number of persons residing within 20 minutes and 40 minutes travel time of several major activity centers during peak and off-peak periods. An analysis was also performed of changes in low-income people's access to job opportunities and changes in elderly and teen-age people's access to nonwork activities by alternative public modes of transportation. Figure 2-20 depicts typical accessibility contours around a major activity center for the 1990 Boston transportation plan and a Dual Mode baseline. Increased accessibility to the CBD via Dual Mode is expressed as the population of the area between the solid and dashed lines.

Travel time was not only considered as an implicit variable in the accessibility analysis, but was also calculated for all systems to determine changes in travel time due to the introduction of the Dual Mode system. Changes in speeds for Dual Mode and for the complementary highway and transit networks were accounted for.

Air pollution was calculated by pollutant type (SO_2, NO_x, particulates, etc.) for the 1990 plan and for the highway, transit, and Dual Mode components of each alternative. Currently effective or anticipated Environmental Protection Agency standards applicable to diesel and gasoline engines and electrical generating plants were assumed. To determine the effect of the various systems upon limited power resources, the power consumption of each mode was calculated.

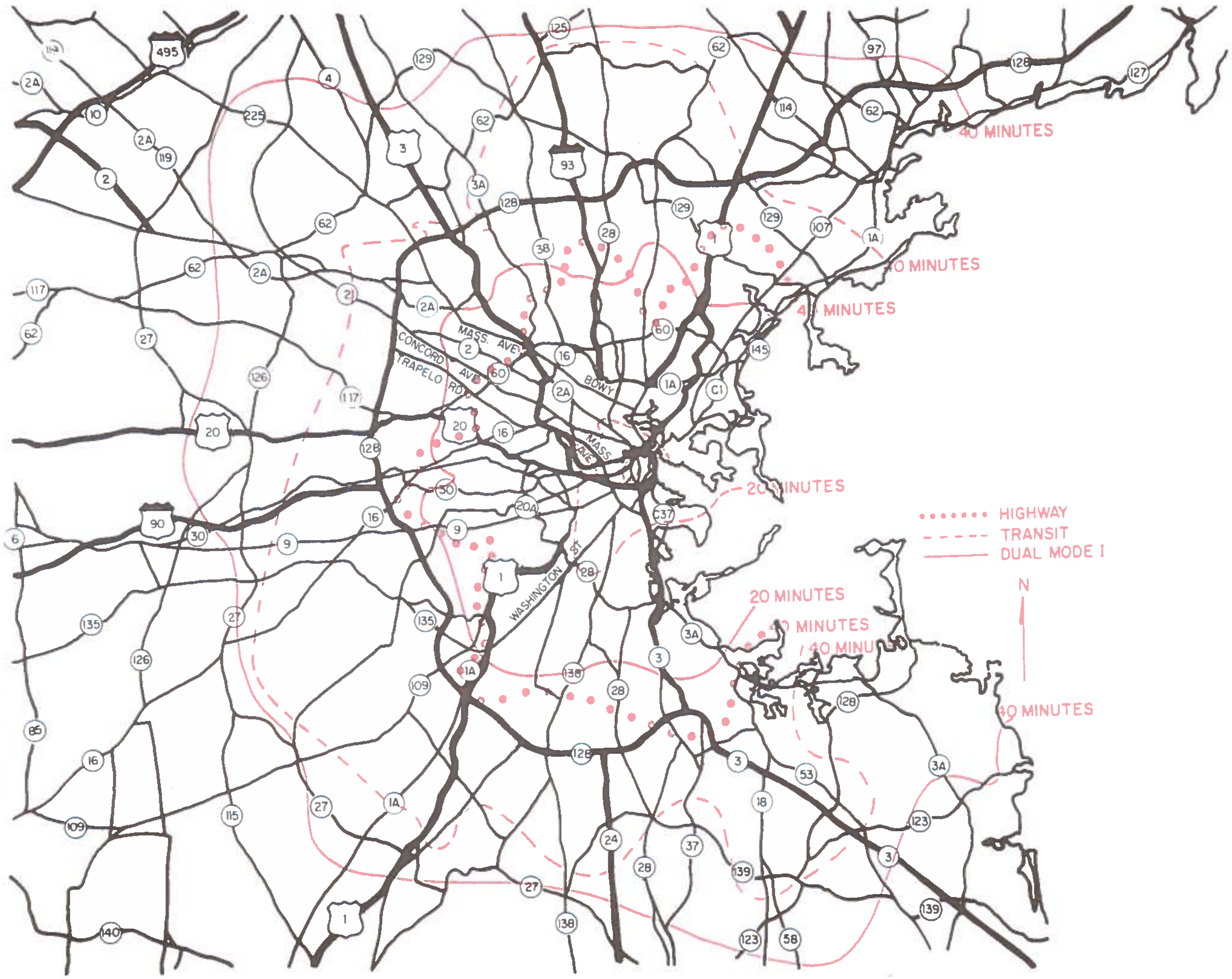


Figure 2-20 Peak Period Travel Time Contours from CBD

Other impacts examined in a quantitive manner were household and business displacements due to right of way acquisition and the number of households affected by noise pollution. Figure 2-21 illustrates the method used to determine the number of noise impacted households associated with a Dual Mode system. Possible combinations of vehicle and roadway characteristics (e.g., engine type, speed, number of lanes, guideway location with respect to conventional modes) were used in the TSC Highway Noise Prediction Model (27) to generate the noise level of each system configuration at various distances from the noise source. Using the right of way characteristics, land categories, construction types, and speeds defined for the Dual Mode network, as well as residential noise criteria for day and nighttime operation, a noise pollution envelope was generated for each network link or segment. From the noise pollution envelopes and 1990 demographic data, the total number of impacted dwelling units was determined.

Where meaningful, quantitative benefits and disbenefits arising from Dual Mode were converted into monetary terms so that they could be included in the cost-benefit ratio calculated for each alternative. These costed items included changes in travel time (including a special factor for driver relief), accidents, air pollution, household/business displacements, land value, and tax revenues. The dollar value of annual travel time savings was computed by multiplying the difference in regionwide passenger hours traveled for Dual Mode vs. the 1990 plan by $3.00 per hour and multiplying the truck driver time savings by $6.00 per hour. Driver relief benefits were arrived at by valuing the vehicle driver hours traveled on the guideway at $1.50 per hour. Accident cost savings were calculated using an average cost for all accident types of $1,110 per accident. The cost to society of air pollution (in the form of damage to property, vegetation, and health, and decrease in human lifespan) was computed on the basis of the following rates per ton for the various constituents:

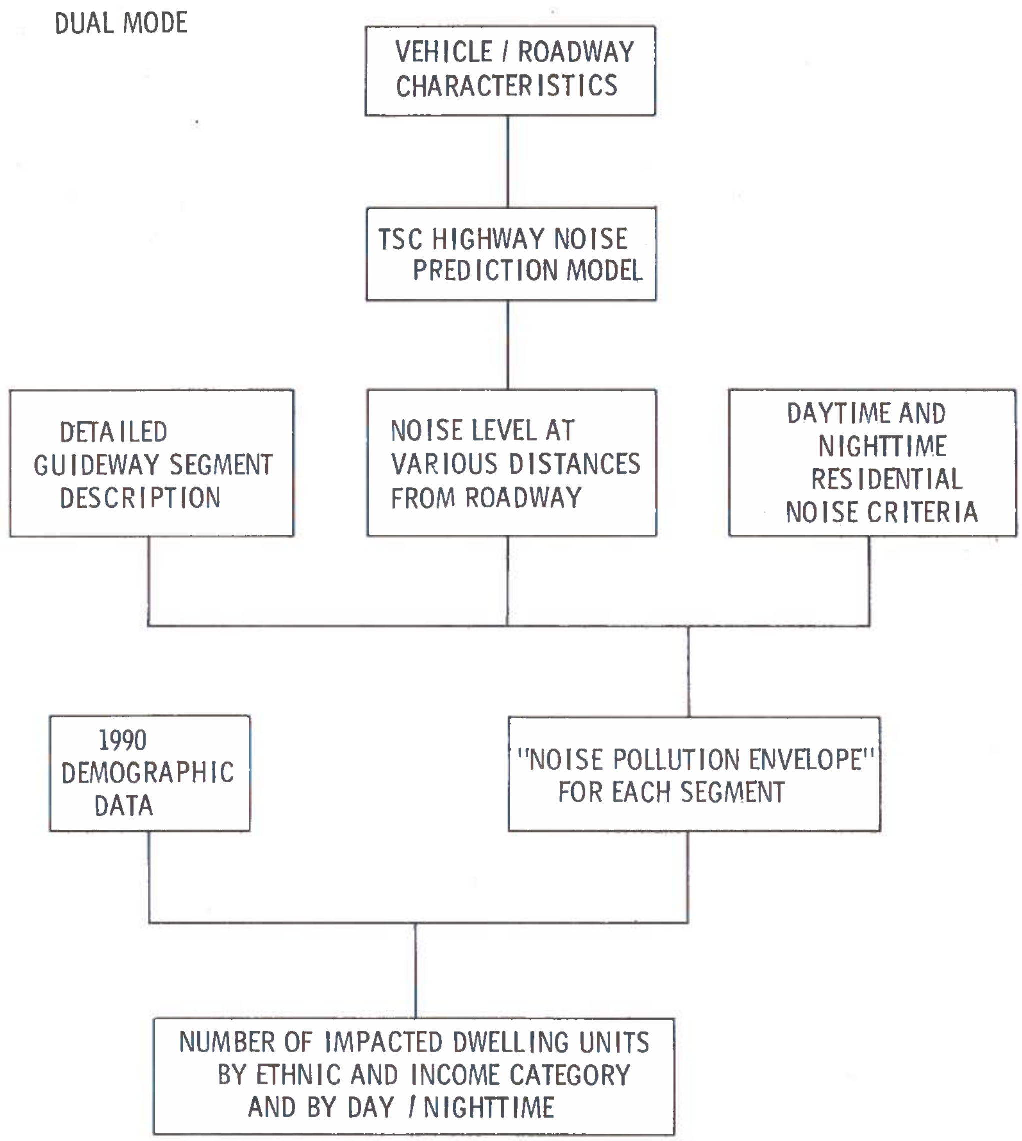


Figure 2-21 Noise Impact Analysis Flow

Constituent	Cost Per Ton
Carbon monoxide	$ 1.65
Particulates	205.00
Sulfur dioxide	250.00
Hydrocarbons	130.00
Nitrous oxides	50.90

Household/business displacement savings for Dual Mode vs. the 1990 plan consisted of relocation costs not incurred by the system owner ($1,600 per dwelling unit, $3,080 per business) as well as "aggravation" costs not borne by the displacees ($20,000 per dwelling unit). The increase in land values due to Dual Mode likewise reflected two factors: improved accessibility to the CBD and a reduction in the number of noise impacted households. The accessibility-related change in land value was computed by plotting the full market value per acre of land in various communities in the Boston area against the distance from the CBD, determining from this graph the percentage increase in land value in response to a given baseline-specific increase in regionwide travel speed (which effectively reduces distance from the CBD), and then applying this percent increase in value to the market value of all land within the affected area. The noise-related change in land value actually consisted of a savings in land value losses and was calculated by multiplying the reduction in noise impacted households (realized by building Dual Mode rather than the 1990 plan) by 20% of the average value of a dwelling unit. Tax revenue increases attributable to Dual Mode were computed on the basis of savings in right of way acquisition as well as increases in land value. A more detailed description of the methodology for determining quantitative impacts is presented in Chapter 6 of Volume III.

It is recognized that the quantifying and monetizing of benefits is an area which elicits considerable debate. Consequently, the unit values of the individual elements of the benefit calculation are preserved and displayed in the baseline discussions in Chapter 3. A more detailed description of the methodology for determining quantitative impacts and the assumptions underlying the monetary evaluation of impacts is presented in Chapter 6 of Volume III.

In addition to these quantitative, monetary assessments of Dual Mode's impact, the overall effect of the system on land values and retail sales was examined, and industries that would be affected in terms of employment due to this new technology were identified. To the extent possible, qualitative evaluation of driver convenience, neighborhood appearance and character changes, and future metropolitian development trends was carried out.

In an examination of legal and administrative issues relative to Dual Mode, potential difficulties in the establishment and operation of a Dual Mode system were identified and alternative solutions were suggested. The legal liability and accident cost allocation problem was considered in detail, including evaluation of the fault system, the enterprise liability system, and social insurance compensation plans. National regulation versus local control of Dual Mode systems was examined, and the implications of centralized control and precedents for various extents of national regulation were considered.

2.9 COST/BENEFIT MODEL

The data generated in the processes described above were aggregated, manipulated, organized, and displayed by the specially developed cost/benefit model, Transportation Economic Analysis Model (TEAM). Volume IV of this report is entirely devoted to a detailed documentation of this model. The model is comprised of two independently executable programs. The New System Cost Program was used to compute and display the costs and some of the impacts related to the Dual Mode transportation systems and complementary highway and transit systems. The cost calculations and associated operational statistics for the 1990 plan were performed by the Highway-Transit Cost Program. These computer programs are written in Fortran for execution on a CDC-6000 computer. The New System Cost Program utilizes, through a number of overlays, 243,000 of the computer's 300,000 words of core and executes in approximately 30 seconds for the size networks analyzed in this study. The Highway-Transit Cost Program executes in 15 seconds within a core range of 125,000 words.

The overall structure of the TEAM model is illustrated in Figure 2-22. In each run of the model, analysis data for highways, transit and for one Dual Mode baseline were produced. Parametric runs were accomplished through multiple runs of the model, which may be cycled automatically.

Plots of the parametric run output data can also be generated directly by the model. These outputs form the data base for the analysis. Data were stratified by temporal period (peak, off-peak, daily and annual), by operations on and off the guideway, by multiple transit modes (bus, rapid rail and streetcar), and by multiple vehicle fleets (e.g., small personal vehicles and mini-buses) within a Dual Mode baseline. Highway travel was analyzed separately for freeways and for surface arterials. Both person and vehicle travel statistics were identified, and costs were assigned depending upon individual or system ownership. Land costs were computed with respect to four construction types (elevated, at grade, cut and cover, tunneled), three geographic areas (CBD, urban, suburban) and ten land use categories (residential, park, abandoned, etc.). Various elements of the Dual Mode system were sized automatically by the model for the specified demand. That is, the amount of land required, the number of guideway lanes, and sizes of terminals were calculated as a function of the number of riders passing through each portion of the system.

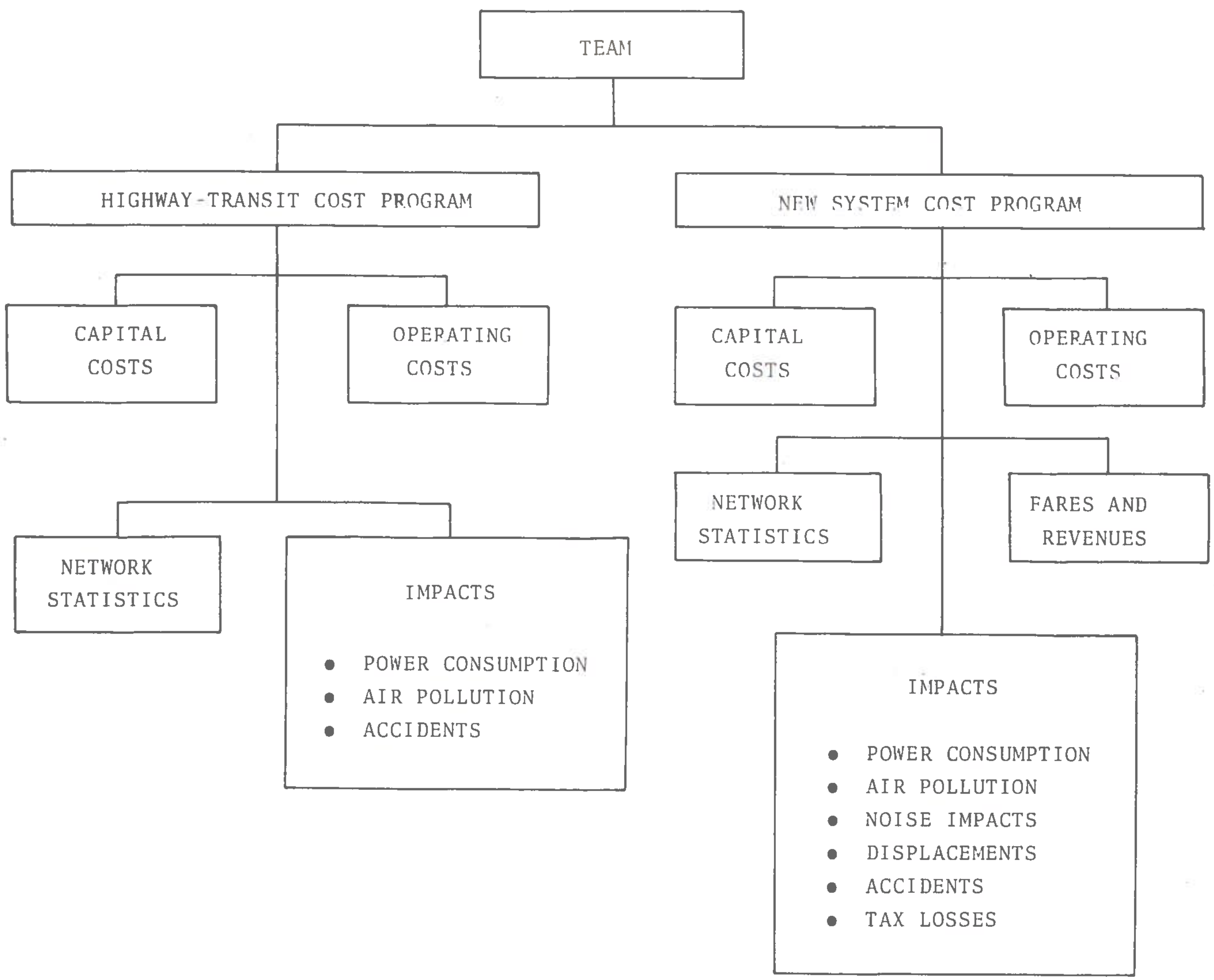


Figure 2-22 Transportation Economic Analysis Model Structure

3. BASELINE ANALYSIS AND COMPARISONS

3.1 PALLET SYSTEM

Figure 3-1 presents data on network and ridership characteristics, costs, and impacts for the pallet system (combination of cars on pallets and Dual Mode busses). Unless otherwise indicated, the following discussion is based on results shown in this table.

3.1.1 Service

The Dual Mode pallet baseline attracts 1.3 million daily riders, or 12% of the regionwide daily trips. This represents 23% of the trips for which it is a possible option.

The pallet combination attracts a total of 22.3% of all travelers to the CBD. The use of pallets themselves for trips to the CBD is proportionally no higher than its use for other trips it could service in the region. This results primarily from the parking charges levied in the CBD. The Dual Mode bus portion of this baseline captures 17.2% of all CBD travelers as compared to only 3.2% overall in that portion of the Boston region where it is considered a transportation alternative. The CBD-related trips represent over 90% of all Dual Mode bus ridership.

Throughout the region, Dual Mode patronage reduces highway usage by about 10% and transit by 33%, with the ex-highway travelers amounting to 70% of the Dual Mode ridership. Ninety percent of the CBD-bound Dual Mode patrons utilize rapid rail transit for final CBD distribution (the remainder are within walking distance of their destinations). This induced traffic gives rapid transit an overall ridership (number of person trips) 13% greater than with the 1990 plan; in the CBD itself where this induced ridership is concentrated, the ridership is 60% greater than with the 1990 plan. The overall rapid rail patronage would have dropped to 46% of the 1990 plan value without this induced traffic.

	1990 Plan (1)	Dual Mode
System Extent:		
Route Miles Constructed	144	249
New Construction Acreage	19,100	3,290
DM Lane Miles		1,140
Costs:		
Capital Cost	$\$1,020 \times 10^6$	$\$2,630 \times 10^6$
DM Annual Capital Cost		$\$308 \times 10^6$
DM Total Annual Operating Cost		$\$416 \times 10^6$ (2)
Total Region Annual Operating Cost (3)	$\$2,050 \times 10^6$	$\$2,170 \times 10^6$
Total Region Annual Oper. & Cap. Cost (3)	$\$2,160 \times 10^6$	$\$2,480 \times 10^6$
DM Revenue		$\$250 \times 10^6$
DM System Operation Profit		
a. revenues less system operating cost		$-\$4 \times 10^6$
b. revenues less system operating & capital cost		$-\$312 \times 10^6$
Network Statistics:		
Daily DM Person Trips		
Pallet		1.13×10^6
DM Bus		0.18×10^6
DM Modal Split		
Daily		12%
Peak Period CBD Round Trips		22%
DM Average Trip Length		
Pallet		15.0 mi.
DM Bus		8.9 mi.
Region Average Trip Length (3)	5.3 mi.	5.7 mi.
DM Average Trip Speed		24.0 mph
Region Average Trip Speed (3)	16.1 mph	18.4 mph

Figure 3-1 Pallet System Characteristics

Network Statistics (Cont.)	1990 Plan[1]	Dual Mode
Peak Period Surface Arterial Speed	15.8 mph	17.7 mph
Region Daily Time Savings [3]		19.4 yrs.
DM Annual Passenger Miles Traveled (on & off guideway)		5.60×10^9
% on guideway		56.6
Region Annual Passenger Miles Traveled[3]	17.1×10^9	18.5×10^9
DM Annual Vehicle Miles Traveled (on & off guideway)		3.73×10^9
% on guideway		59.6
Region Annual Vehicle Miles (Without trucks)[3]	11.1×10^9	12.2×10^9
DM Fleet Size		
Pallet		20,000
DM Bus		2,300
Impacts		
Total Region Annual Traffic Accidents[3]	62,100	56,300
Total Region Annual Traffic Accidents per Pass. Mile[3]	3.63×10^{-6}	3.04×10^{-6}
Total Region Annual Fatalities[3]	320	294
Total Region Annual Fatalities per Pass. Mile[3]	0.02×10^{-6}	0.02×10^{-6}
Total Region Daily Transportation Energy Consumption (BTU's)[3]	22.2×10^{10}	28.9×10^{10}
Total Region Daily Pollutant Output (LBS)[3]	994,000	1,110,000
NO_x	396,000	443,000
Particulates	13	7,830
SO_2	161	93,800
CO	549,000	518,000
HC	48,700	45,200

Figure 3-1 Pallet System Characteristics - Continued

Impacts (Cont.)	1990 Plan[1]	Dual Mode
Household Displacements	58,000	6,060
Household Displacements per Route Mile	402	24
Household Displacement Acres	8,680	836
Business Displacements	355	27
Tax Revenue Losses	$ 21.9 x 10^6	$ 4.5 x 10^6
Tax Revenue Losses per Route Mile	$151 x 10^3	$18 x 10^3
Tax Revenue Loss Acres	8,720	2,000
Noise Impacted Households Daytime	41,000	431
Noise Impacted Households Nighttime	152,000	1,090
Noise Impacted Households per Route Mile - Daytime	284	2
Noise Impacted Households per Route Mile - Nighttime	1,050	4

(1) Data for the 1990 plan on system extent, capital cost, displacements, tax revenue losses and noise impacts refer to new highway and transit facilities that would be built if Dual Mode were not implemented.

(2) Includes operating and depreciation costs for private automobiles during the off-guideway portion of a Dual Mode trip.

(3) Regional data reflect all transportation modes throughout the entire study area.

Figure 3-1 Pallet System Characteristics - Continued

The use of such a Dual Mode system in Boston would result in a sizeable travel time savings for the region as a whole, compared to the 1990 plan, as indicated in Figure 3-1. These savings result both from shorter trip times on the Dual Mode system and the increased speeds on highways resulting from reduced congestion, another contribution of Dual Mode. Although the total number of person trips in the region remains the same, the person miles and vehicle miles traveled both increase with the introduction of the Dual Mode pallet system. The annual person-miles increase by approximately 8% over the 1990 plan results, and vehicle miles are up by about 10%. These values increase because of the circuitous routing in the Dual Mode trips. The guideway itself does not always provide the most direct route between origin and destination stations, and extra distance is involved in getting to and from the stations via local streets. The backhauling of empty pallets contributes to a further increase in vehicle miles. A more densely laid-out network would relieve the circuitousness of the situation, with an added capital expense and some beneficial effect on patronage of the Dual Mode system. In spite of the somewhat longer distances involved in Dual Mode trips, though, speeds on it are sufficiently high to provide significantly shorter travel times than could be achieved with the other modes of transportation for many origin-destination pairs.

Automobiles riding on the pallets are not allowed to exit the system and enter local streets in the CBD area. Instead, special parking is provided for them in and adjacent to the CBD, as shown in Figure 2-12. This provision for parking affects costs and time delays experienced by the users. In order to reduce land costs, it is desirable to concentrate as much of the parking as possible in sites adjacent to rather than within the CBD. With parking charges as a policy lever to guide CBD-bound pallet users from the downtown garages to those on the periphery, a mix of one CBD to three peripheral parkers is obtained. Charges of $1.50 in the CBD and $.55 in the peripheral locations were selected. These charges bracket the $1.10 average CBD fee faced by the conventional auto driver. Pallet users require 7,500 parking spaces, of which 1,900 are located in the CBD. Since most pallet users in the CBD are diverted from automobiles, nearly the same total number of automobiles have to be supplied with parking as in the 1990 plan. However, the movement of most of the Dual Mode automobile parking to the periphery of the CBD makes it necessary to provide only a total of 70,000 CBD parking spaces (including Dual Mode and conventional automobiles), as opposed to the 1990 plan figure of 80,000.

The bus operational scenario off the guideway is similar to that of conventional buses--that is, a pseudo door-to-door mode where users walk to a bus stop and wait for the bus which is following some predefined route. Though travelers could use the Dual Mode bus for local off-guideway service, the primary service and route structuring is designed to provide point-to-point service between high demand activity centers for trip lengths requiring use of the guideway.

The bus system is designed for point-to-point service with no transfers. As such, the off-guideway origin route structuring is destination sensitive and services only demand generated for that ultimate destination. To provide good service at acceptable load factors requires larger fleets of smaller buses than would be necessary with transfers allowed. Since the system has been designed with a "no-transfer" policy, a few side effects are noteworthy.

Assuming no other service level changes, the inclusion of transfers at guideway stations results in a 10 to 20% loss of the clientele who would originally use the system. This is caused by the newly experienced transfer delays. However, to counter the transfer delays, off-guideway service can be improved considerably, maintaining the "no transfer" load factor without proportional fleet size impacts. More stations, hence riders, can be served and off-guideway operations will become more efficient, even though system scheduling becomes more difficult. An increase in ridership of 100 to 300% seems feasible, compared to the no-transfer policy.

Walking distances and frequency of service were examined to determine their effect on ridership. Once trends were established the off-guideway route lengths were designed to provide total trip times generally much better than competing transit options and, as expected, not as good as pallet or, in general, the conventional automobile. As with the pallet, the Dual Mode bus is complementary with existing rapid transit in the CBD.

Walk distances were increased with an attendant reduction in off-guideway route extent. Investigation revealed that ridership does not significantly decrease by increasing walk time to the pickup point from an initial value of two to five minutes. Off-guideway bus route time was thus reduced by an average of one half the value required for a two-minute walk. This results in a lower average door-to-door time for bus passengers and reduced bus fleet requirements.

By reducing frequency of service to half its design value and increasing wait times from an average of five minutes to an average of ten minutes, the ridership decreased between 25 and 35 percent. An undesirable side effect was a reduction in bus load factors even though the bus fleet size could be substantially reduced. Final off-guideway service data for an average bus user are summarized in Figure 3-2.

Based on the above analysis, walk distances, bus headways (a function of scheduled frequency), and off-guideway tour lengths were selected to provide reasonable levels of service to the users. Often, several off-guideway routes were required from the same guideway station.

The Dual Mode bus was originally visualized as being a standard-sized, 50-passenger bus. The ridership was sufficiently small, however, that the average load factor was only 16%. Therefore, an analysis was done to determine the effects of adopting a smaller bus, and a bus sized to carry 20 passengers was chosen. Figure 3-3 shows the changes in a number of parameters that occurred when the bus size was reduced.

	Walk n' Ride Stops	Park n' Ride Stations
Travel Time (minutes)[1]	10.3	2
Tour Length (miles)	2.6	1
Tour Speed (mph)	15.1	30
Auto Access Time (minutes)	N.A.	21
Auto Access Distance (miles)	N.A.	7
Auto Access Speed (mph)	N.A.	20
Wait Time (minutes)	5	5
Walk Time (minutes)	5	N.A.

(1) From bus stop to guideway terminal.

Figure 3-2 Average Dual Mode Bus Off-Guideway Service Data

	% Change Due to Reduction
Average load factor	+156
Annual Bus Capital + Interest Cost	-35
Annual DM Capital + Interest Cost	-2
Annual DM Operating Cost	-0.3
Annual DM Total Cost	-1.3
Profit	
a. Revenue less oper. cost	+13
b. Revenue less oper. + cap. cost	+22

Figure 3-3 Effect of Reducing Dual Mode Bus Size From 50 to 20 Passengers

The reduction in size has a significant effect on the annual capital and interest costs for the bus, but has little impact on the overall system costs. The profit picture improves, especially if only operating costs are considered, but the system still operates on a deficit.

As shown in the table, reduced size permits a significant increase in load factor and a reduction in bus annuities. These changes are, though, relatively insignificant compared to total system costs, which are dominated by items such as the guideway cost (38% of capital) and the pallet cost (23% of capital). Profits do, however, improve somewhat.

An on-guideway fare rate of $.10/mile was assessed the pallet users with $.50 as a minimum charge. This fare rate structure attracts a good overall mix of different length trips, since the lower cost per trip appeals to the short distance travelers and the significant time savings attracts those making longer trips. Figure 3-4 illustrates the effect of fare variations on pallet ridership. Shown are modal splits over the entire region plus those for CBD-oriented trips. The pallet travelers to the CBD are less sensitive to fare change than are the average regionwide travelers. This is primarily due to the other fixed fee requirements for each CBD trip, i.e., parking and transit fees. Regionwide pallet ridership totals would exhibit twice the response to a fare rate change as would the CBD-related ridership.

A fare of $.50 per trip was charged to transit and to Dual Mode bus riders, and ridership sensitivity to bus fare is reflected in Figure 3-5. Most travelers using the Dual Mode bus have short average trip lengths and are more sensitive to fare than are pallet users. As bus fare is increased pallet and transit capture the largest portion of travelers to the CBD. Elsewhere in the region, pallet and auto equally share the bus losses.

Figure 3-6 reflects combined effects of varying both pallet and Dual Mode bus fare. The fare structure for both was increased and decreased at percentage levels about the nominal rate. As

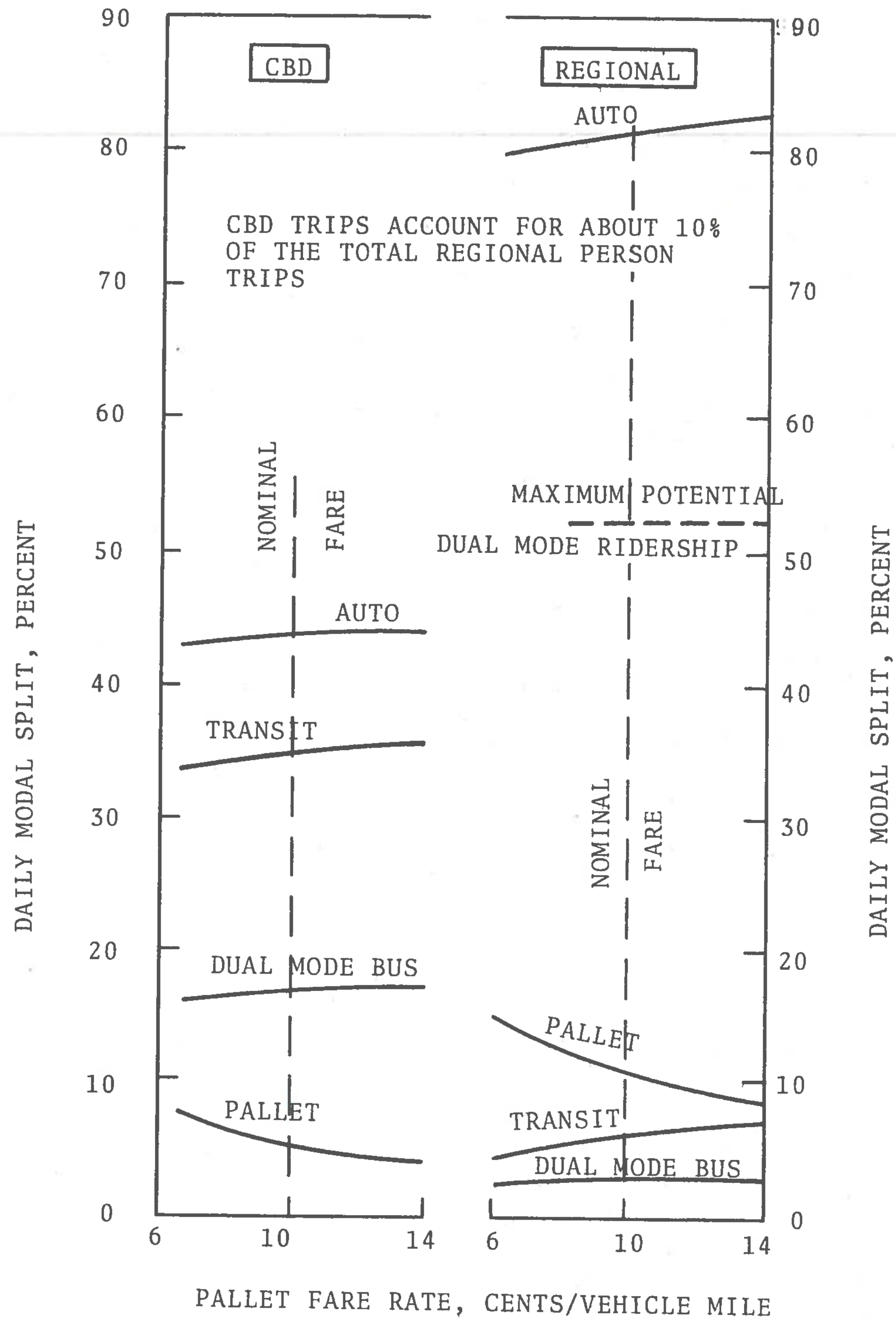


Figure 3-4 Pallet CBD and Regional Modal Split vs. Pallet Fare Rate

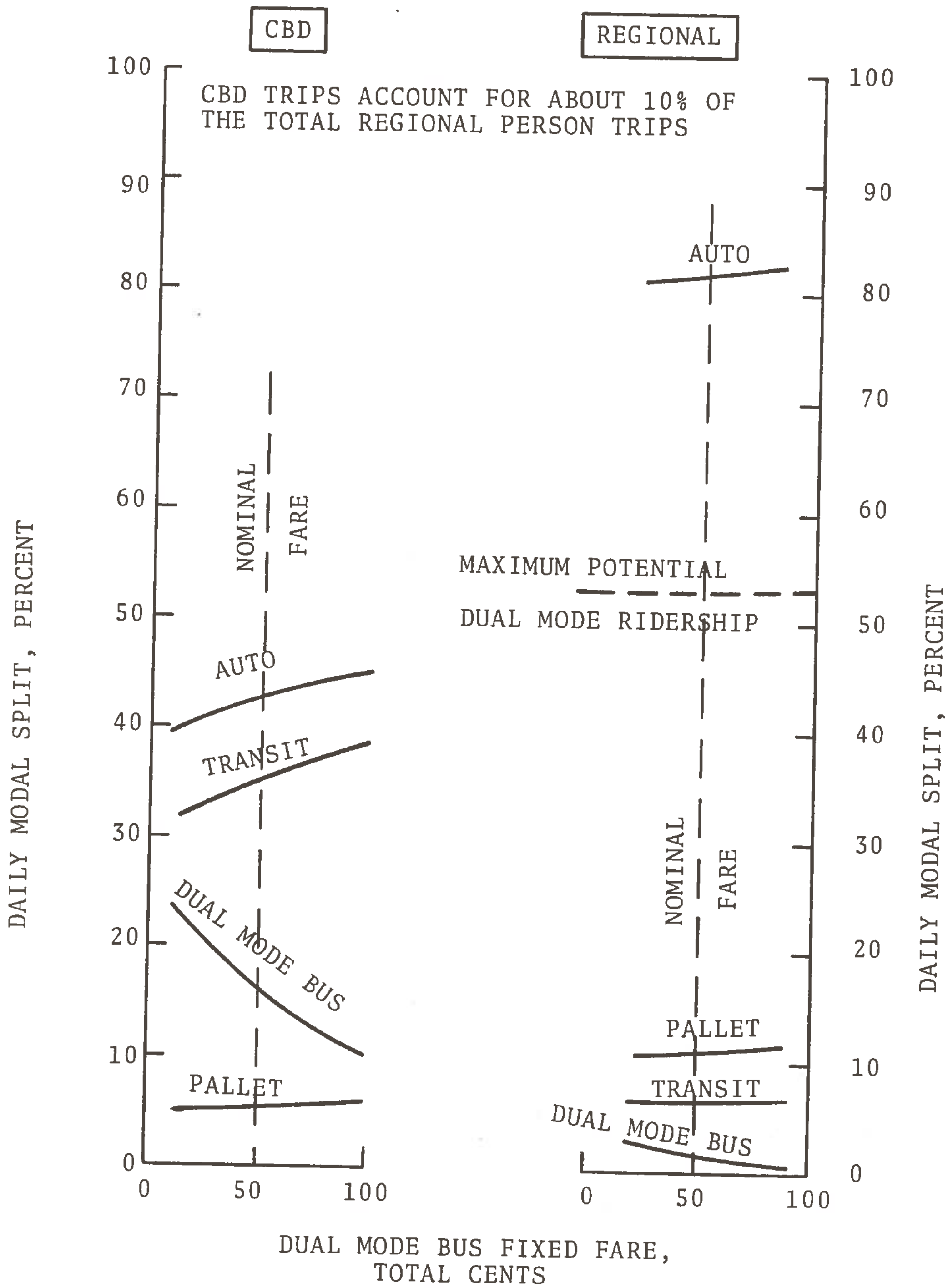


Figure 3-5 Pallet System CBD and Regional Modal Split vs. Dual Mode Bus Fare

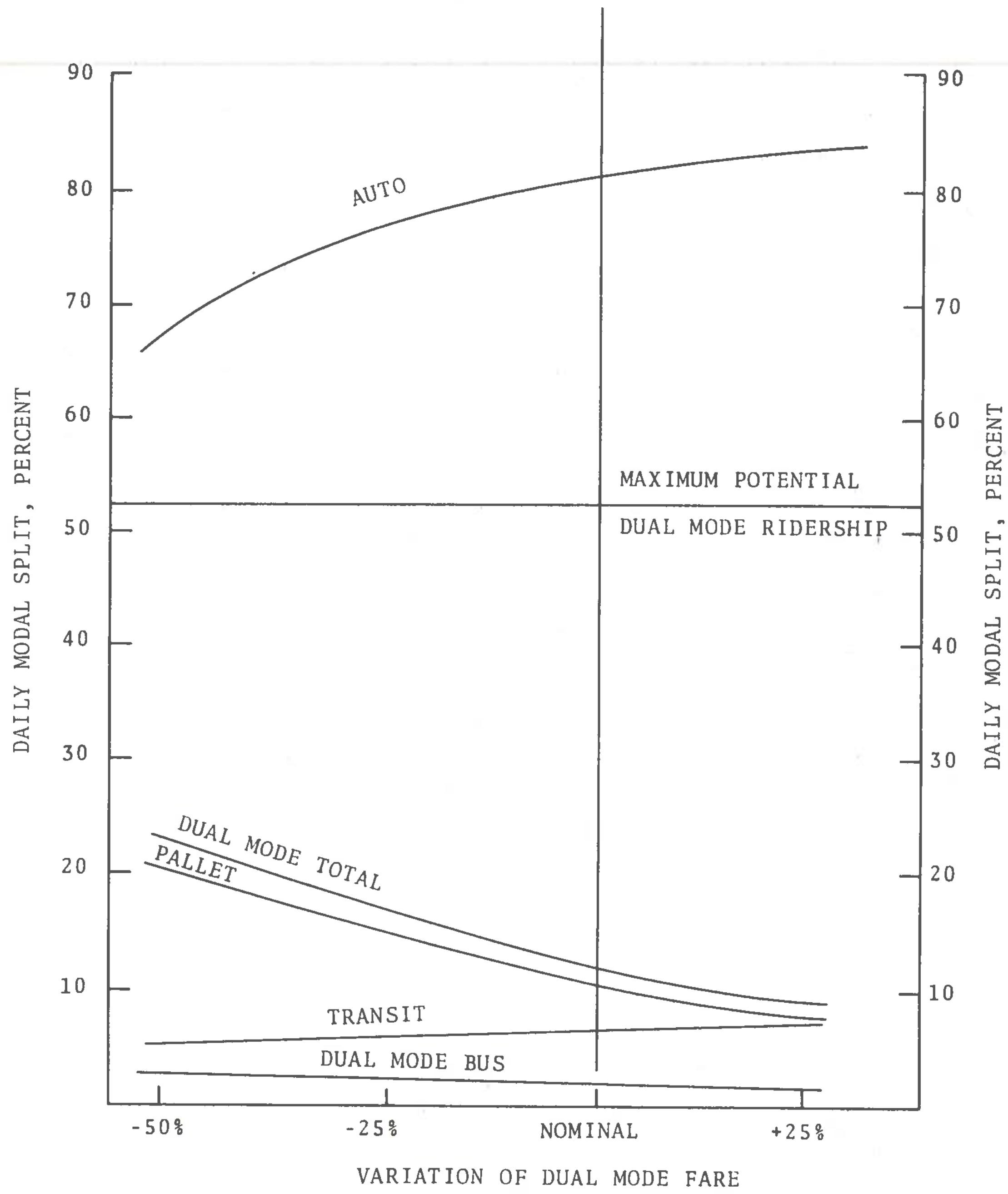


Figure 3-6 Pallet System Regional Modal Split vs. Simultaneous Dual Mode Fare Changes

seen, the automobile reflects the overwhelming ridership change when Dual Mode fare variations occur.

It was found that little ridership shifts to the Dual Mode bus as a result of increased pallet parking charges in the CBD. Transit and auto typically share 85% of the pallet loss and the Dual Mode bus receives the remaining 15%. The base pallet parking charges are $.55 and $1.50 in the peripheral and CBD garages, respectively.

3.1.2 Impacts

For the pallet system as well as other Dual Mode baselines, accidents and fatalities were computed separately for on-guideway and for off-guideway travel. Off-guideway calculations were based on current accident and fatality rates for automobiles and buses, depending on the nature of the Dual Mode vehicle. The safety of on-guideway operations was determined parametrically, varying rates through a range that included those of air carrier, rapid transit, highway, and bus systems and the idealized accident-free (zero rate) case. The reason for this is that the guideway portion of a Dual Mode trip encompasses several novel transportation features such as close vehicle headways and automatic command and control for which there is no experience upon which to base a determination of accident rates.

Figure 3-7 shows total regional accidents and fatalities (for all modes) for the pallet baseline and for the 1990 plan as a function of the on-guideway accident/fatality rate.* It can be seen that if on-guideway travel is as safe as current-day travel by air carrier and rapid transit systems, the pallet system results in significantly fewer traffic accidents than the 1990 plan,

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* The traffic accident rate for buses was too far out of line with the rates for other modes to be included in the sensitivity analysis. The explanation of the unusually high bus rate (71 accidents per million VMT) is given in Volume II, Chapter 6.4.

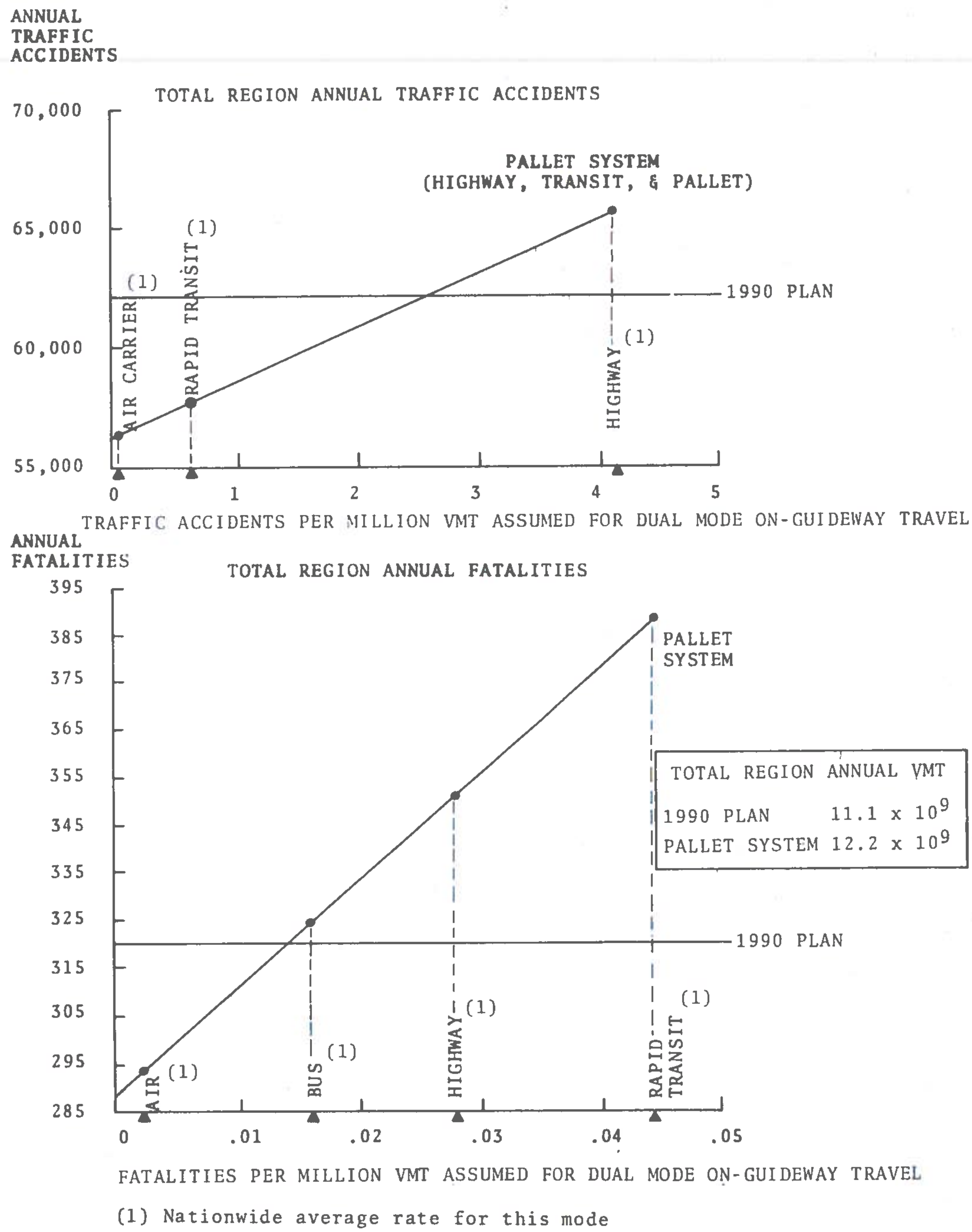

Figure 3-7 Effect of Varying On-Guideway Accident/ Fatality Rate - Pallet System

in spite of the higher associated vehicle miles traveled (VMT). Moreover, if the on-guideway combined fatality rate for pallets and buses is as low as that achieved by the airlines, the total number of fatalities is less than for the 1990 plan.

The discussion of legal issues related to Dual Mode safety (see Chapter 5.4) suggests that for a Dual Mode system to be practicable and acceptable to the public a high level of safety and reliability will be required for guideway operations. This means that system operators will have a strong incentive to make sure that vehicles and the guideway are well maintained. Since certificated air carriers are currently able to achieve relatively low accident and fatality rates by applying stringent check-out and maintenance procedures to their technologically advanced vehicles and equipment, it seems reasonable to assume that Dual Mode systems can likewise achieve (or may be required to achieve) equivalent rates with their advanced technology. If it is assumed that accident rates on the guideway would be the same as those experienced by airlines, the introduction of the pallet system results in a 9.4% decrease in total region annual traffic accidents and an 8.1% decrease in fatalities over the 1990 plan. These percentage decreases reflect the fact that 12% of the travel that would otherwise take place on highway and transit facilities is being diverted to the pallet system, which has an on-guideway component that is assumed to be safer than highway and transit travel.

The pallet system causes a significant increase in both energy consumption and total pollutant emission for the regional transportation system, although on a constituent basis it does provide some specific improvement. Energy consumption for the pallets themselves suffers from the fact that they are heavy when loaded, have a large frontal area, spend a good deal of their time at relatively high speeds and carry relatively few passengers at a time compared to buses. Since the Dual Mode vehicles are electrically powered, their pollution output is calculated on an energy-consumed basis, and thus they have a high pollutant emission also. The presence of Dual Mode does cause a reduction in the emission of carbon monoxide and hydrocarbons, though, because the automobiles riding the pallets have their engines running only during the off-guideway portions of the trip and because a number of automobile travelers are diverted to the Dual Mode buses. As is discussed in Volume III, Chapter 6.1, however, these are relatively innocuous pollutants in terms of associated costs, while the significant increases in pollutants are among the more obnoxious species. This, of course, is dependent upon the assumptions made concerning pollutant emissions and costs.

Household and business displacements associated with the pallet system are only 10% and 8%, respectively, of those required by the planned highway and transit additions, despite the fact that the Dual Mode guideway network has nearly double the route mileage. The reason for this dramatic difference is twofold: first, the pallet system can satisfy the same regional travel needs as the 1990 plan with only 3,290 as opposed to 19,100 acres of right of way. (To illustrate why the right of way acreage for Dual Mode is so much smaller, its guideway is only 3 lanes, or 36 feet wide, whereas the planned highway additions are around 6 lane or 150 to 200 feet wide.) More important, the guideway network makes extensive use of existing transportation right of way (e.g., abandoned railroad lines), while the planned highway and transit additions are located almost entirely on new right of way.

The pallet system results in only one-fifth the tax revenue losses associated with the 1990 plan. This is primarily on accoun of differences in total right of way requirements, rather than network location, since the rail right of way which must be acquired to accommodate a large portion of the Dual Mode network is privately owned property and hence a source of tax revenues.

The most impressive benefit of the pallet system is in the area of noise impacts. Dual Mode vehicles operating over 250 route miles of guideway adversely impact less than 1% of the number of households affected by traffic noise from planned highway and transit additions. Part of the explanation is that for a particular construction type, speed, and number of lanes, the pallet is much quieter than conventional modes because automobiles have their internal combustion engines turned off and the pallets are electrically powered (leaving tires as the predominant noise source)*. The Dual Mode buses, being electrically powered, also are quieter than their conventional counterparts. Other reasons are the more extensive and effective use of barriers (every Dual Mode lane has a barrier on either side, whereas highways are only assumed to have barriers between the median strip and the inner lanes) and the location of 80% of the Dual Mode guideway along existing transportation right of way. In the case of facilities which are still in operation, the noise level due to conventional modes generally masks the presence of Dual Mode vehicles; in the case of abandoned rail lines, there is no masking effect, but the relatively large right of way width (60 to 90 feet) provides additional buffer space between the Dual Mode noise band and the nearest houses.

Figure 3-8 shows accessibility results for the pallet system. Comparing the pallet component of this baseline to the 1990 highway and transit system, it can be seen that in the peak period, the pallet provides increased accessibility compared to the 1990 plan for all major activity centers considered. The percentage increase in the number of people who can reach a particular destination within 40 minutes ranges from .1% for the hospital to 50% for the suburban shopping center. In the off-peak period, the introduction of the pallet improves accessibility to four out of the six activity centers, but the relative increase is less impressive owing to the greater base numbers (the highway system in particular provides excellent mobility during non-rush hours). For the 20-minute travel time range (not shown in the table), the

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*See Volume III, Appendix F for tables showing the gross noise impact distance data used in the noise analysis of Dual Mode and conventional systems.

Major Activity Center	Additional People Within 40 Minutes of Major Activity Center by Dual Mode vs.:			
	1990 Highway and Transit		1990 Transit	
	Peak Period	Off-Peak Period	Peak Period	Off-Peak Period
Airport	435,000	75,000	0	0
Suburban Shopping Center	606,000	1,800	0	0
University	196,000	147,000	0	23,100
CBD	610,000	374,000	42,900	0
Hospital	13,100	0	0	0
Sports Arena	X	0	X	79,900

Analysis Zone	Parameter	Additional Work/Nonwork Destinations Within 40 Minutes of Special Zone by Dual Mode vs. 1990 Transit	
		Peak Period	Off-Peak Period
Poor, Suburban	Blue collar positions	0	X
Ghetto		0	X
Ghetto	Nonwork trip ends, including school	X	47,900
Young, Central		X	0
Young, Suburban		X	0
Old, Central	Nonwork trip ends, excluding school	X	0
Old, Suburban		X	0

X - Accessibility value not counted for this time period, due to the nature of the trip purpose.

Figure 3-8 Accessibility Results - Pallet System pallet improves accessibility to only one destination, the suburban shopping center. The comparatively poor performance of this system for shorter trips is due mainly to the granularity of the network: since the average access/egress time to the network is 8 minutes (or 16 minutes of off-guideway travel per trip), it is unlikely that a person can travel any further by the pallet than by conventional modes within a 20-minute period. Since the pallet requires private access to a car, it has no potential for improving the mobility of transportation disadvantaged groups vis-a-vis jobs and nonwork destinations.

The bus component of this baseline as designed hardly improves accessibility over the 1990 transit system. In the peak period, the number of people who can reach the CBD within 40 minutes increases by 1.9%, and in the off-peak period (40-minute range) the percentage changes in accessibility for the university and sports arena are 2.3% and 6.6%, respectively. The slightly better performance of the Dual Mode bus in the off-peak period is due primarily to the relatively poorer accessibility afforded by the transit system. In the case of transportation disadvantaged groups, the only improvement noted is a 2.2% increase in the number of nonwork destinations accessible to central city ghetto dwellers in the off-peak period.

Although this baseline provides only negligible improvements in service to specific areas having high concentrations of poor, young, and elderly people, it by no means ignores low-income or minority groups when the overall region is considered. Figure 3-9 shows the percentage of each ethnic and income subgroup of the population within 40 minutes (peak period) of the CBD and the suburban shopping center by 1990 highway and transit vs. the pallet system. Even without the pallet system, minority groups have relatively better access to the CBD and suburban shopping center than white, middle-to upper-income families. The introduction of Dual Mode brings another 4.0% of the regionwide black population (i.e., 6,710 more persons) and another 10.3% of the

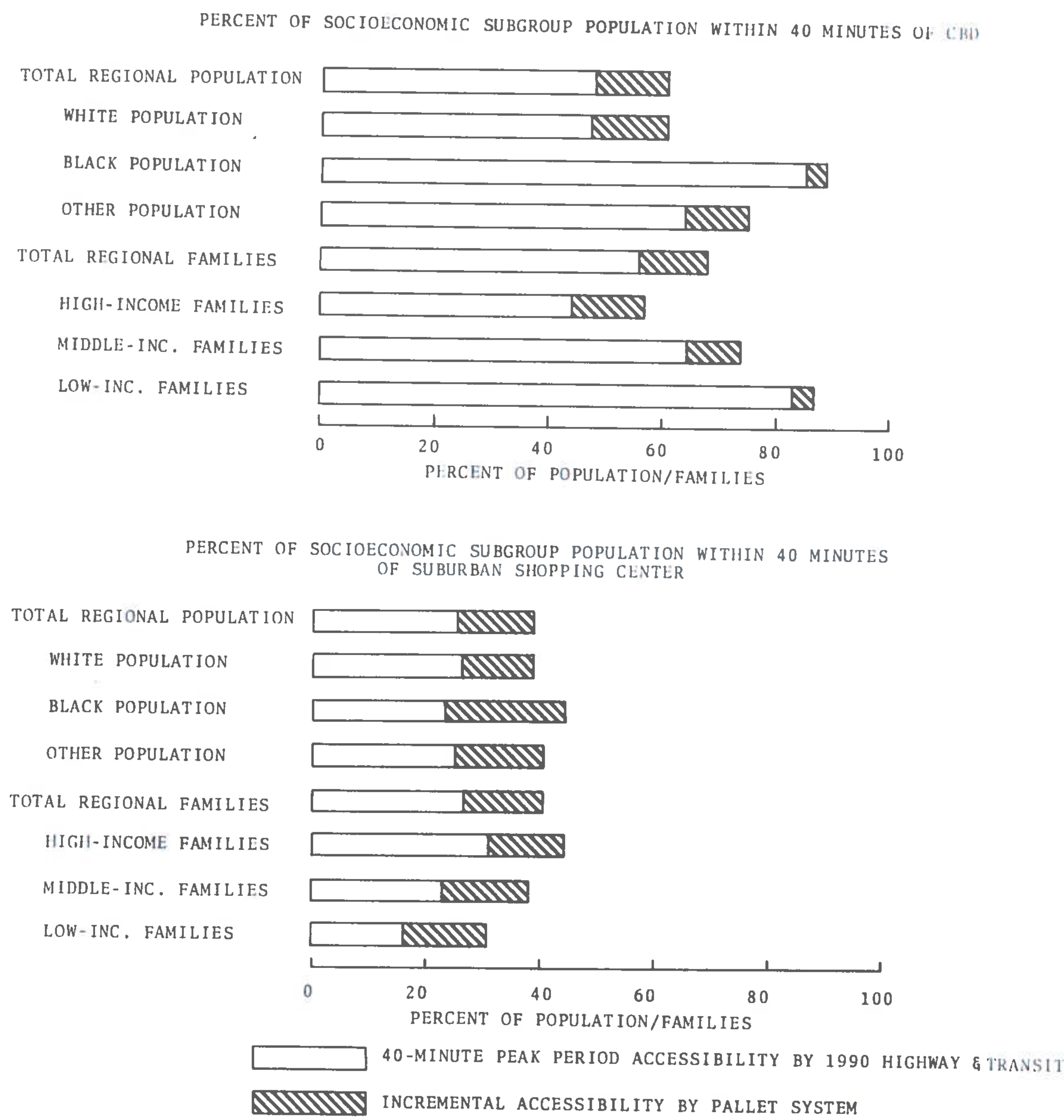

Figure 3-9 Comparative Accessibility by Pallet System vs. 1990 Plan

remaining minority population (3,660 people) within a 40-minute travel time range of the CBD. Low-income families benefit from this baseline by a comparable degree, with another 3.5% of this group (1,350 families) coming within the 40-minute contour. In the case of the suburban shopping center, the percentage increments in accessibility for blacks, other minority, and low-income families are even higher -- 21.0%, 16.5%, and 16.1%, respectively. This is because the travel time savings due to Dual Mode extends part of the shopping center-based accessibility contour toward the central portion of the region, where the majority of low-income and minority people reside. Comparing the upper and lower bar charts it is apparent that the 1990 transportation system, whether it includes Dual Mode or not, provides each segment of the population much better access to centrally located major activity centers than to suburban destinations.

Since business and industry will probably continue their exodus to the outlying portions of the metropolitan area, this finding points up a serious shortcoming in the ability of the future transportation network to move people between homes and work sites; moreover, this problem is more serious for minority groups than for white, middle-to high-income persons who (assuming current housing market trends persist) have more discretionary power to choose their place of residence. Nevertheless, with respect to the pallet-induced increases in accessibility to the suburbs, minority groups stand to benefit more than the groups traditionally favored by transportation systems.

3.1.3 Costs and Benefits

The pallet system described in this analysis has a capital cost of $2.63 billion. The three largest elements of capital cost are the guideway (38%), vehicles (26%), and terminals (13%), as shown in Figure 3-10. Figure 3-11 shows the sensitivity of the total capital cost to changes in each of the three elements. For example, an increase of 50% in the guideway cost would increase the capital cost of the system by 19% to $3.130 billion.

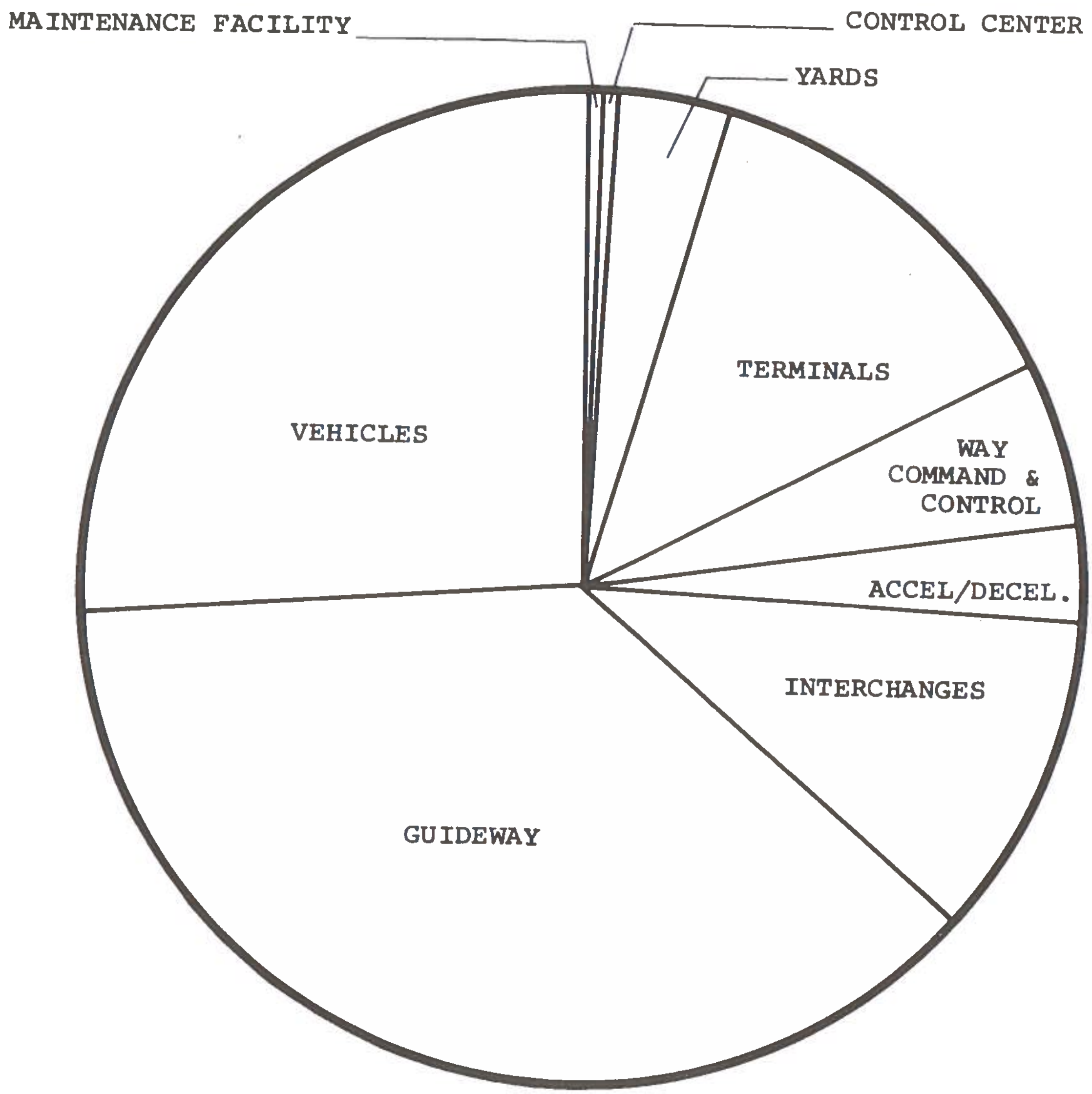

Figure 3-10 Pallet System Capital Costs

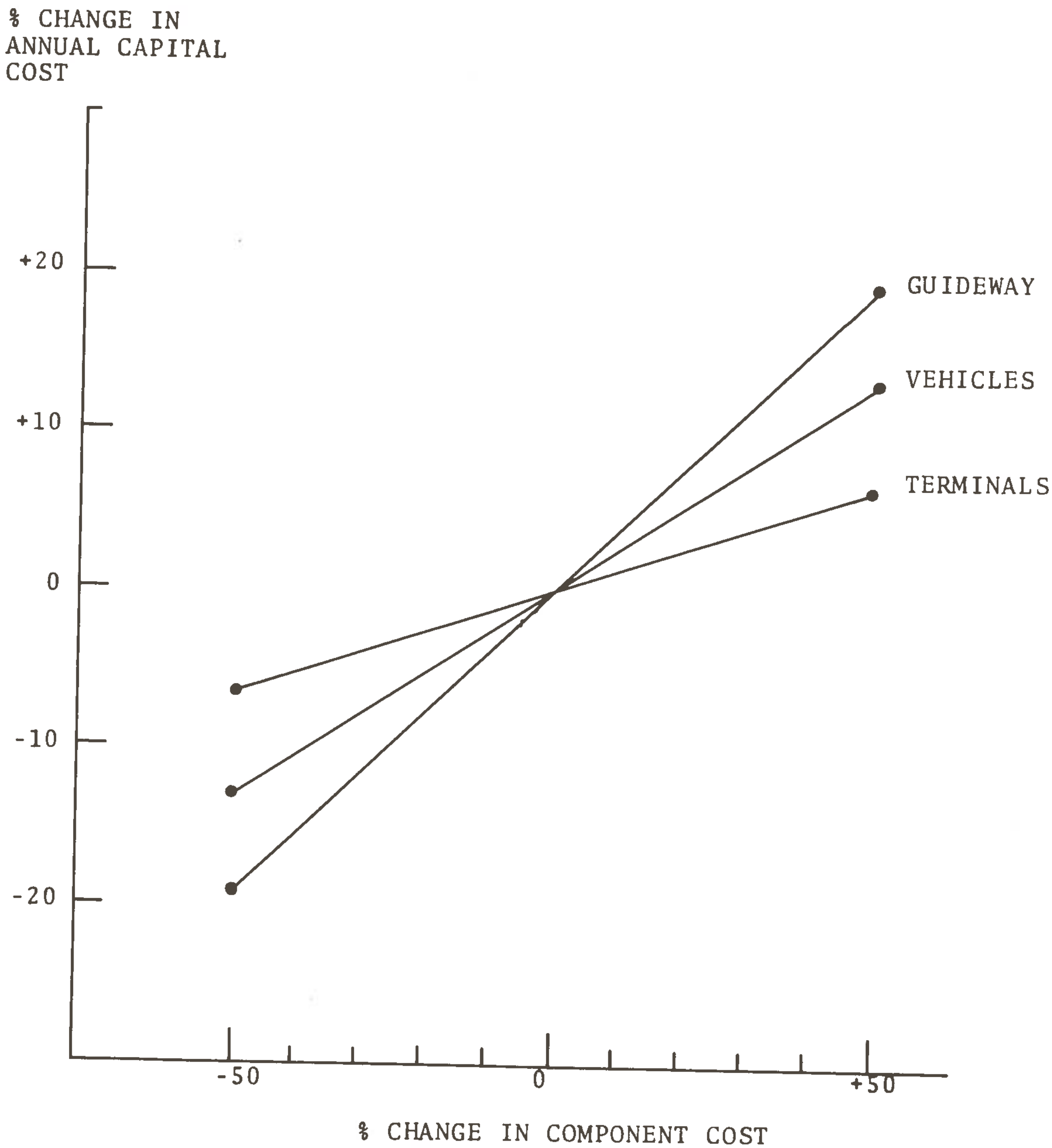

Figure 3-11 Capital Cost Sensitivity for Pallet System

The pallet system owner is unable to cover operating costs with revenues at the nominal assumed fare level, as is indicated in Figure 3-12. A modest revenue increase of $4 million per year would allow this system to break even on operating costs. Figure 3-13 shows the system net revenue as a function of fare level. A 20% increase in fare provides sufficient revenue to cover operating costs. The increased fare causes a ridership loss of one-third, however. The base fare assumed for the bus is $.50 per trip and the base pallet fare is $.10 per mile plus parking.

Figure 3-14 shows the derivation of annual dollar benefits for the pallet system. The quantitative units of each type of benefit relative to the 1990 plan (first column) are multiplied by the respective assumed dollar value per unit (second column) to yield monetary benefits. Those benefits which accrue only once (i.e., displacement savings and land value increases) are converted to annual values using a 10% interest rate and an infinite lifetime. On the basis of these assumed monetary values, travel time savings and land value increases are the two most important monetary benefits of Dual Mode.

The annual incremental costs and benefits for the region with the pallet system, relative to the 1990 plan, are shown in Figure 3-15. These incremental values represent the total annual capital and operating costs and benefits for the region if the pallet system were implemented, minus the values corresponding to implementation of the 1990 plan. Costs to the region are higher with the pallet system than with the 1990 plan, but the increased benefits more than offset the cost differential. The $416 million excess of incremental benefits over incremental costs results in a benefit-to-cost ratio of 2.3.

The pallet fleet is expensive, accounting for 29% of the annual capital cost of this Dual Mode system. As discussed in Volume III, Chapter 4.4, the round trip time of the pallet is a critical factor in fleet size, and Figure 3-16 shows its effect on the pallet fleet and its resulting impact on the annual capital costs. The advantage of having shorter round trip times is significant in terms of fleet size, and although the effects on costs are a bit more moderate they are nonetheless sizable. Round trip times can be shortened by reducing the turnaround, loading and delay times (assumed to consume altogether 5 minutes at each trip end) or by reducing line haul times. The latter can be accomplished by increasing speeds, eliminating longer trips or

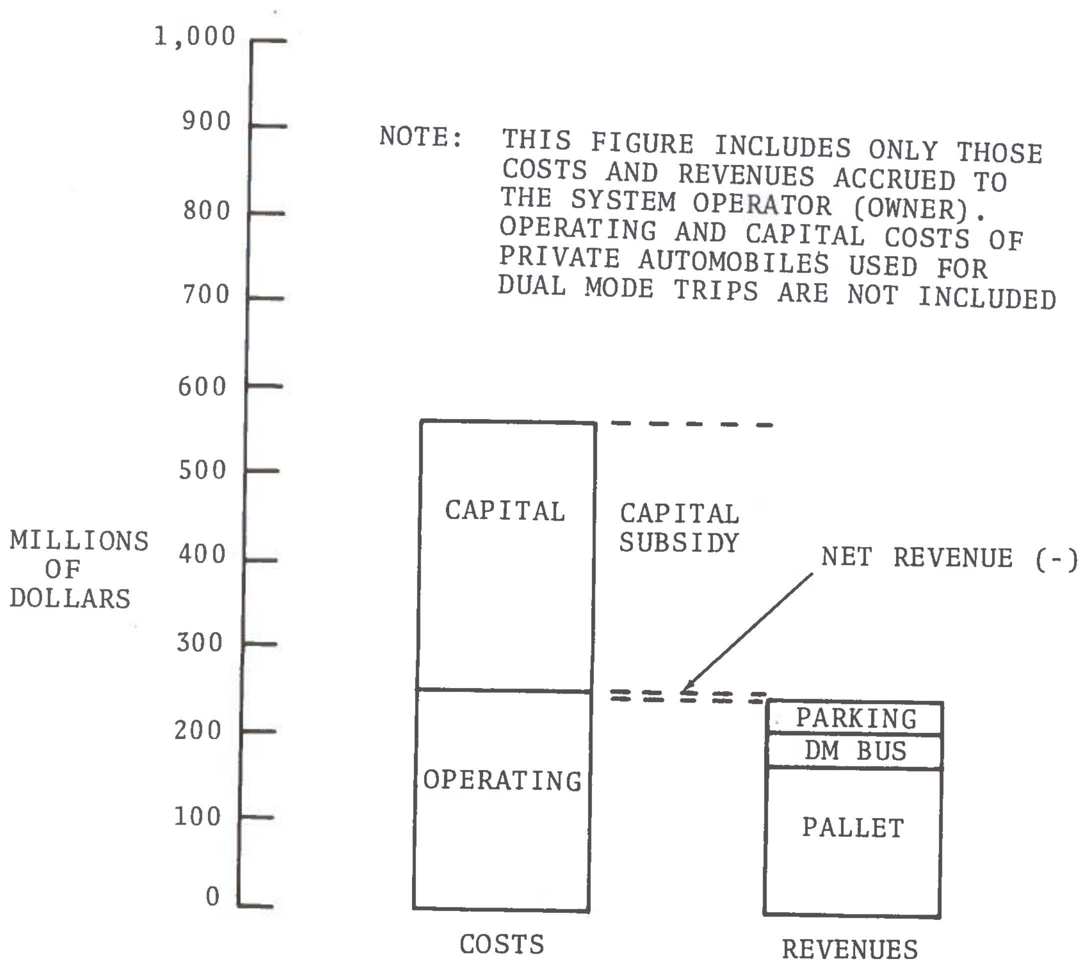

Figure 3-12 Dual Mode System Operator Annual Costs and Revenues (Pallet System)

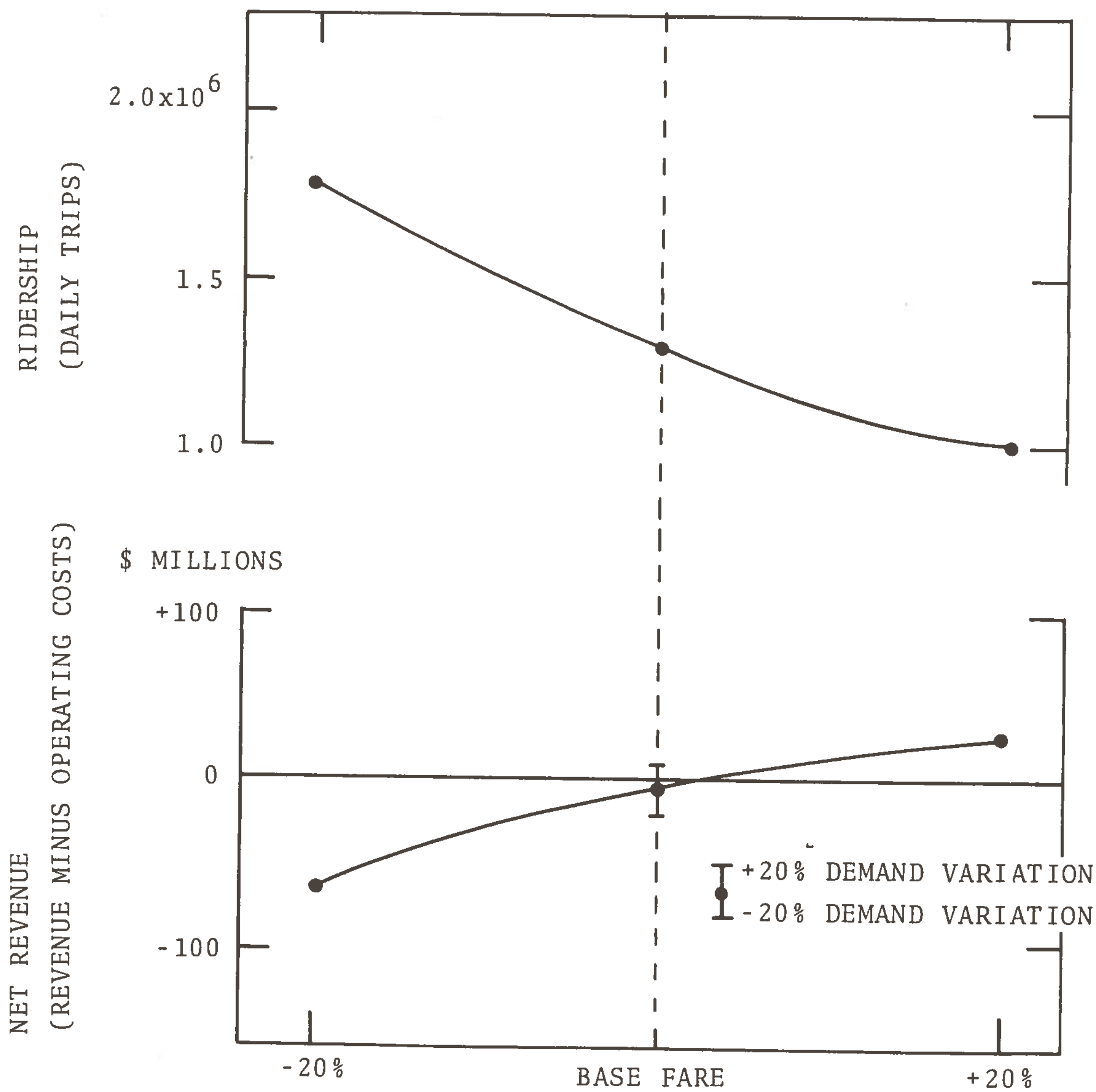

Figure 3-13 Effect of Fare Variations on Net Revenue and Ridership of the Pallet System

Impact (Relative to 1990 Plan)	Quantitative Units	Dollar Value Per Unit	Total $ Benefits ($x 10^6$)	Annual $ Benefits ($x 10^6$)
Benefits:				
Travel Time Savings				
Passenger Modes	51.1×10^6 hours/yr.	$3.00/hour	--	153
Trucks	4.6×10^6 hours/yr.	$6.00/hour	--	27
Total				180
Driver Relief	42.4×10^6 hours/yr.	$1.50/hour	--	64
Accident Savings	5,800 accidents/yr.	$1,108/accident	--	6
Displacement Savings				
Relocation (Household)	52,000 households	$ 1,604/household	83	8
Aggravation (Household)	52,000 households	$20,000/household	1,040	104
Relocation (Business)	330 businesses	$ 3,076/business	1	--
Total			1,124	112
Land Value Increase				
Improved Accessibility	14.3% incr. in speed	Note 1	2,044	204
Reduction in Noise Impacted Households	40,600 households	$4,650/household[2]	189	19
Total			2,233	223
Tax Revenue Increase				
Savings in Land Acquisition	$ 322 $\times 10^6$	$54/$1,000 annually[2]	--	17
Land Value Increase-Access.	$2,044 $\times 10^6$	$59/$1,000 annually[2]	--	121
Land Value Increase-Noise	$ 189 $\times 10^6$	$57/$1,000 annually[2]	--	11
Total				149

Figure 3-14 Dollar Valuation of Benefits - Pallet System

Impact (Relative to 1990 Plan)	Quantitative Units	Dollar Value Per Unit	Total $ Benefits (x 10^6)	Annual $ Benefits (x 10^6)
Disbenefits:				
Pollution Increase				
NO_x	6,900 tons/yr.	$ 51/ton	--	--
Particulates	1,200 tons/yr.	$205/ton	--	--
SO_2	14,000 tons/yr.	$250/ton	--	4
CO	-4,700 tons/yr.	$ 2/ton	--	--
HC	-500 tons/yr.	$130/ton	--	--
Total	16,900 tons/yr.			4
Net Benefits:				$730

(1) The percentage increase in speed was used to determine the percentage increase in land value, which in turn was applied to the base value of land in the affected region (about $17 billion) to obtain the net increase in land value. (See Volume III, Chapter 6.8 for a detailed description of land value change calculations).

(2) This is a weighted average of the actual values used. The calculation was performed by multiplying the number of impacts in the CBD, urban, and suburban rings by the respective unit dollar value. Household values and tax rates by ring are given in Volume III, Chapter 6.

Figure 3-14 Dollar Valuation of Benefits - Pallet System (Cont.)

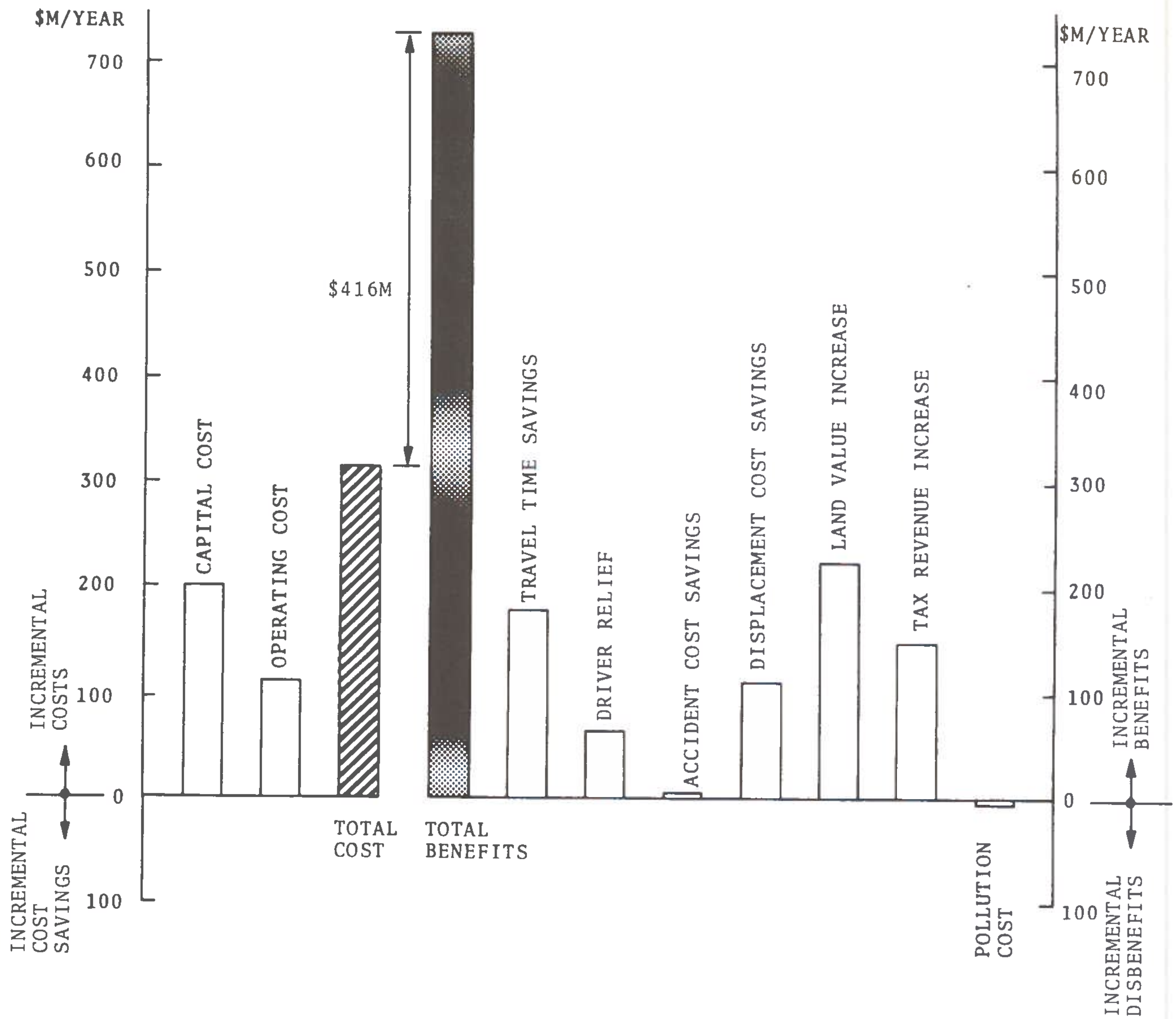

Figure 3-15 Regional Annual Incremental Costs and Benefits Relative to 1990 Plan (Pallet System)

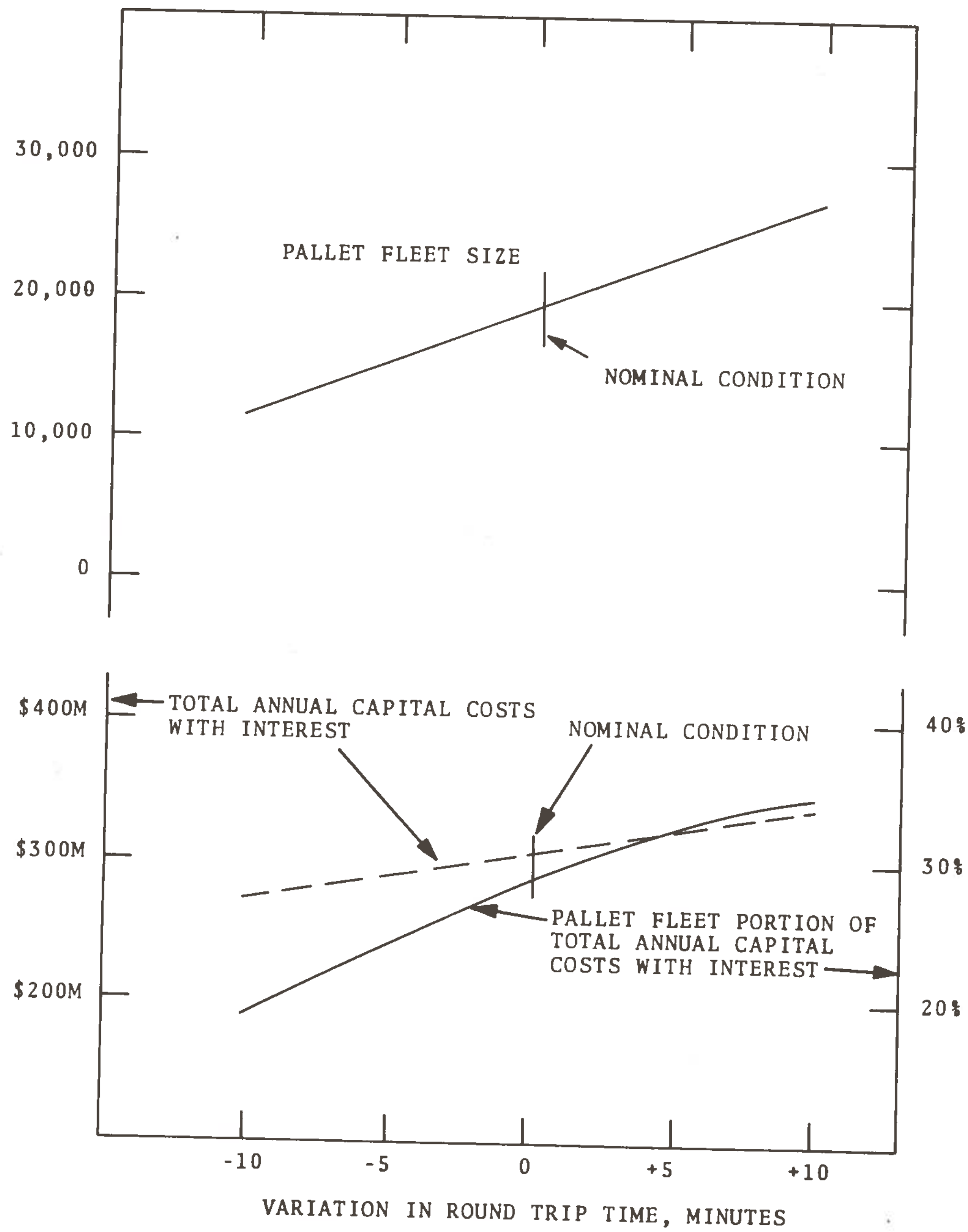

Figure 3-16 Effect of Round Trip Time on Pallet Fleet Size

improving the connectivity of the guideway. The effect of fleet size on operating costs is quite small if the changes in round trip time are caused only by reducing turnaround, loading and delay times. This is due to the fact that the same number of passengers will be transported over the same distances, and therefore the vehicle miles traveled will remain the same.

3.2 AUTOMATED HIGHWAY VEHICLE SYSTEM

Figure 3-17 presents data on network and ridership characteristics, costs, and impacts for the automated highway vehicle system. Unless otherwise indicated, the following discussion is based on results in this table.

3.2.1 Service

The automated highway vehicle system performs very similarly to the pallet system. It provides faster transportation between many origin-destination points than can be achieved by transit or highway, and it attracts enough people from highways to noticeably relieve congestion there. There is an increase in passenger and vehicle miles over the 1990 plan, reflecting the longer distances involved in Dual Mode trips, both on and off the guideway.* In spite of longer regional trip lengths than the 1990 plan, the relatively high guideway trip speeds coupled with the increased speeds on freeways and surface arterials leads to a daily regional travel time savings of about 19.3 years (comparable with the pallet system).

The automated highway vehicle system effectively offers guideway access and services similar to the pallet system. Bus service is structured identically to that baseline. Since the Dual Mode automobile is privately owned and maintained, smaller system costs are conveyed to the user through fare charges. CBD

*However, the vehicle miles are not so high as with the pallet, partially because there are no empty vehicles being backhauled.

	1990 Plan[1]	Dual Mode
System Extent:		
Route Miles Constructed	144	249
New Construction Acreage	19,100	3,150
DM Lane Miles		966
Costs:		
Capital Cost	$\$1,020 \times 10^6$	$\$1,620 \times 10^6$
DM Annual Capital Cost		$\$180 \times 10^6$
DM Total Annual Operating Cost		$\$445 \times 10^6$ (2)
Total Region Annual Operating Cost (3)	$\$2,050 \times 10^6$	$\$2,250 \times 10^6$
Total Region Annual Oper. & Cap. Cost (3)	$\$2,160 \times 10^6$	$\$2,430 \times 10^6$
DM Revenue		$\$118 \times 10^6$
DM System Operator Profit		
a. revenues less system operating cost		$\$72 \times 10^6$
b. Revenues less system operating & capital cost		$-\$109 \times 10^6$
Network Statistics:		
Daily DM Person Trips		
DM Auto		0.97×10^6
DM Bus		0.18×10^6
DM Modal Split		
Daily		11%
Peak Period CBD - Round Trips		21%

Figure 3-17 Automated Highway Vehicle System Characteristics

Network Statistics (Cont.)	1990 Plan[1]	Dual Mode
DM Average Trip Length		
DM Auto		14.6 mi.
DM Bus		8.9 mi.
Region Average Trip Length (3)	5.3 mi.	5.7 mi.
DM Average Trip Speed		23.8 mph
Region Average Trip Speed (3)	16.1 mph	18.1 mph
Peak Period Surface Arterial Speed	15.8 mph	17.5 mph
Region Daily Time Savings (3)		19.3 yrs.
DM Annual Passenger Miles Traveled (on & off guideway)		4.72×10^9
% on guideway		56.7
Region Annual Passenger Miles Traveled (3)	17.1×10^9	18.3×10^9
DM Annual Vehicle Miles Traveled (on & off guideway)		2.86×10^9
% on guideway		56.3
Region Annual Vehicle Miles (without trucks) (3)	11.1×10^9	11.8×10^9
DM Fleet Size		
DM Bus		2,300
Impacts:		
Total Region Annual Traffic Accidents (3)	62,100	57,200
Total Region Annual Traffic Accidents per Pass. Mile (3)	3.63×10^{-6}	3.13×10^{-6}
Total Region Annual Fatalities (3)	320	296
Total Region Annual Fatalities per Pass. Mile (3)	0.02×10^{-6}	0.02×10^{-6}
Total Region Daily Transportation Energy Consumption (BTU's)(3)	22.2×10^{10}	25.7×10^{10}

Figure 3-17 Automated Highway Vehicle System Characteristics (Continued)

Impacts (Cont.)	1990 Plan[1]	Dual Mode
Total Region Daily Pollutant Output (LBS) (3)	994,000	1,030,000
NO_x	396,000	408,000
Particulates	13	10
SO_2	161	111
CO	549,000	571,000
HC	48,700	51,000
Household Displacements	58,000	6,060
Household Displacements per Route Mile	402	24
Household Displacement Acres	8,680	836
Business Displacements	355	27
Tax Revenue Losses	$\$21.9 \times 10^6$	$\$4.4 \times 10^6$
Tax Revenue Losses per Route Mile	$\$151 \times 10^3$	$\$18 \times 10^3$
Tax Revenue Loss Acres	8,715	1,860
Noise Impacted Households Daytime	41,000	1,030
Noise Impacted Households Nighttime	152,000	1,690
Noise Impacted Households per Route Mile - Daytime	284	4
Noise Impacted Households per Route Mile - Nighttime	1,050	7

(1) Data for the 1990 plan on system extent, capital cost, displacements, tax revenue losses and noise impacts refer to new highway and transit facilities that would be built if Dual Mode were not implemented.
(2) Includes guideway and off-guideway operating and depreciation costs of private automobiles used for Dual Mode trips.
(3) Regional data reflect all transportation modes throughout the entire study area.

Figure 3-17 Automated Highway Vehicle System Characteristics (Continued) parking requirements and charges are similar to those experienced with the pallet. Bus fixed fare is set at $.50 per passenger trip. A fare rate of $.04 per vehicle mile is charged the users of privately owned vehicles. A ridership vs. fare analysis was conducted for this baseline, and results are presented in Figure 3-18.

Ridership on the Dual Mode automobile is approximately 14% lower than pallet ridership even though the fare rate is only $.04/mile as compared to the pallet $.10/mile charge. The lower level of ridership is due to the fact that the total perceived costs per vehicle mile are higher for the automated highway user than for the pallet user since the former must assume responsibility for maintaining his vehicle (with its Dual Mode equipment) in excellent operating condition.

Demand analysis is based upon perceived cost, and in calculating the modal split it was assumed that the increased cost of Dual Mode equipment (repair and maintenance) would be perceived. However, since one cannot use the automated highway vehicle system with a private vehicle unless it has the appropriate equipment, and since a decision to purchase a vehicle with this equipment is generally made based upon the purchase price rather than a per mile or per trip cost, it is not clear how the modal split would be affected. One would assume that initial resistance to the purchase would be higher than the analysis technique reflects, but that once purchased the perceived operating cost would be lower than the assumed amount of 2.4 cents per on-guideway passenger mile. Hopefully, these two effects balance; however, it must be stated that the uncertainty in modal split prediction for the automated highway is greater than for other alternatives because of this consideration.

The Dual Mode bus component of the automated highway vehicle system attracts 16% of the 1.2 million daily Dual Mode trips. This is a 20% greater split of the Dual Mode users than is attained in the pallet alternative and reflects the higher cost (and hence

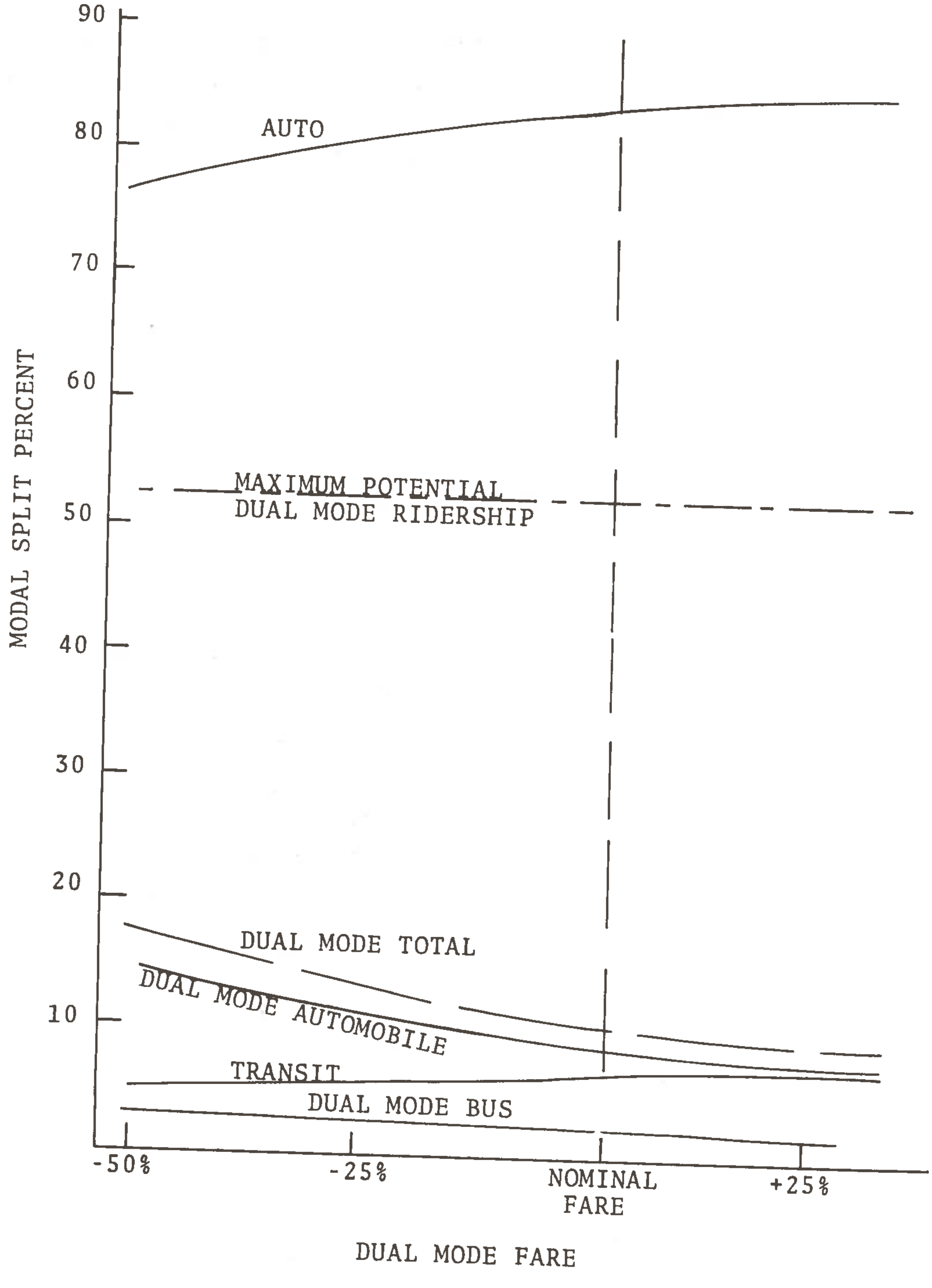

Figure 3-18 Automated Highway Vehicle System Regional Modal Split vs. Simultaneous Dual Mode Fare Changes

lower attractiveness) of operation with one's own Dual Mode vehicle compared to use of the pallet. The automated highway modal split is 13% less than the regionwide 1.3 million daily riders for the pallet case, again reflecting this cost differential.

3.2.2 Impacts

Figure 3-19 presents total regional accidents and fatalities for the automated highway vehicle baseline and for the 1990 plan as a function of the on-guideway accident/fatality rate.* If the former rate is less than 3.1 accidents per million VMT (a rate almost five times higher than that experienced by rapid transit systems) and if the fatality rate is as low as that of airlines or bus systems, the automated highway vehicle baseline results in fewer traffic accidents and fatalities than the 1990 plan.

Assuming that on-guideway accident and fatality rates are equivalent to those experienced by airlines,** the introduction of the automated highway vehicle baseline gives rise to a 7.9% decrease in total region annual traffic accidents and a 7.5% reduction in fatalities. Although the regionwide VMT is lower for this baseline than for the pallet system, the automated highway vehicle system results in a larger number of traffic accidents; the reason is that its associated highway and transit VMT is higher and the Dual Mode VMT is lower, making the relatively safe on-guideway travel a much smaller proportion of total travel.

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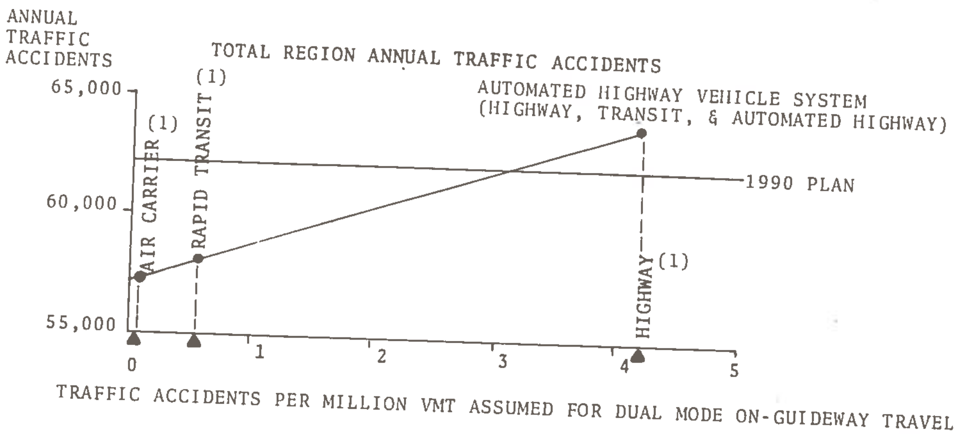
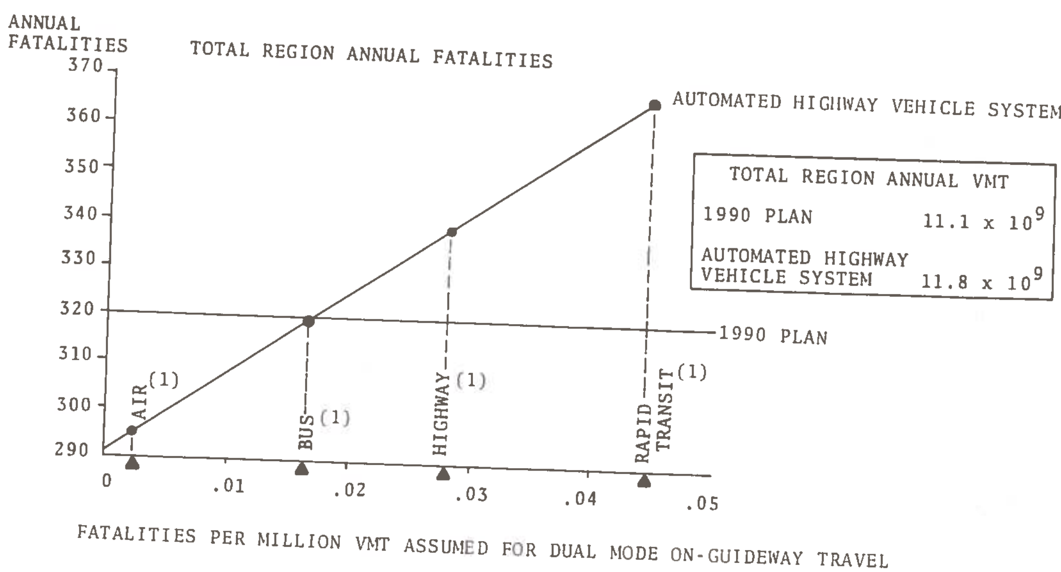
* The method of calculating Dual Mode accidents and fatalities for on- and off-guideway travel is explained in Section 3.1.2 of this volume and in Volume III, Chapter 6.4.

**The rationale for this assumption appears in Section 3.1.2 of this volume.





(1) Nationwide average rate for this mode

Figure 3-19 Effect of Varying On-Guideway Accident/Fatality Rate - Automated Highway Vehicle System

This baseline consumes considerably less energy than does its electrically powered counterpart, the pallet system. This results from the fact that there are no large, bulky pallets involved, but instead only standard sized automobiles and buses. The net effect on the regional transportation energy consumption is an 11% reduction over that with the pallet system. This occurs in spite of the fact that the internal combustion engines powering the vehicles in the automated highway vehicle baseline are inherently less efficient at converting fuel to energy than are the electric generating plants assumed in the pallet case. The addition of Dual Mode to the region's transportation system does increase the regional transportation energy consumption compared with the 1990 plan, however. This is due to the fact that Dual Mode vehicles travel longer at higher speeds than do conventional automobiles and transit vehicles.

The total pollutant output for the region is also less with the automated highway vehicle Dual Mode system than with its pallet counterpart, in spite of the potentially cleaner energy production process associated with the electrically powered pallet and bus. This is due to the lower amount of energy consumed by the automated highway vehicle baseline. All the various constituents are reduced, including the highly costly particulates and sulfur dioxide.

The automated highway vehicle baseline does cause an increase in total regional transportation pollution compared with the 1990 plan, however, due to the extra travel involved in Dual Mode trips. There is a reduction in the amount of particulates and sulfur dioxide emitted, since these constituents are produced by electrically powered conventional transit and Dual Mode reduces transit usage. However, although these two constituents are the most serious in terms of unit cost, their quantities for the 1990 plan are so small that the reductions caused by the introduction of the automated highway system are of little significance.

Since the automated highway vehicle system has the same network and right of way requirements as the pallet system,* the number of household and business displacements is identical. Again, it is the comparatively small total acreage requirements, plus the location of 80% of the guideway along existing transportation right of way, that causes displacements to be only 10% of those resulting from the planned highway and transit additions.

Tax revenue losses for this baseline are slightly less than for the pallet system, with the $99,000 savings coming from the reduction in storage and maintenance area.

The automated highway vehicle baseline performs far better than the 1990 plan from a noise standpoint, owing to fewer lanes and more effective use of barriers and existing right of way. However, the introduction of this system as opposed to the pallet system results in more than double the number of noise impacted households at night. The reason is that internal combustion engines are inherently noisier than electric motors. For the automated highway vehicle system, automobile engines are operating during the on-guideway portion of a trip (whereas an auto on an electrically powered pallet has its engine off), and buses are powered by internal combustion engines rather than electric motors.

Accessibility results for the automated highway vehicle system are given in Figure 3-20. These results are the same as for the pallet baseline, because of the identical network lay-out, travel speeds, and bus service levels (headway and superzone coverage), which in turn lead to equivalent zone-to-zone travel times.

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*The exception is yards and maintenance facilities, which are larger in the latter case to accommodate pallets. However, since these facilities are located on nonresidential land, their size does not affect the number of household displacements.

Major Activity Center	Additional People Within 40 Minutes of Major Activity Center by Dual Mode vs.:			
	1990 Highway and Transit		1990 Transit	
	Peak Period	Off-Peak Period	Peak Period	Off-Peak Period
Airport	435,000	74,900	0	0
Suburban Shopping Center	606,000	1,800	0	0
University	196,000	147,000	0	23,100
CBD	610,000	374,000	42,900	0
Hospital	13,100	0	0	0
Sports Arena	X	0	X	79,900

Analysis Zone	Parameter	Additional Work/Nonwork Destinations Within 40 Minutes of Special Zone by Dual Mode vs. 1990 Transit	
		Peak Period	Off-Peak Period
Poor, Suburban	Blue collar positions	0	X
Ghetto		0	X
Ghetto	Nonwork trip ends, including school	X	47,900
Young, Central		X	0
Young, Suburban		X	0
Old, Central	Nonwork trip ends, excluding school	X	0
Old, Suburban		X	0

X - Accessibility value not calculated for this time period, due to the nature of the trip purpose.

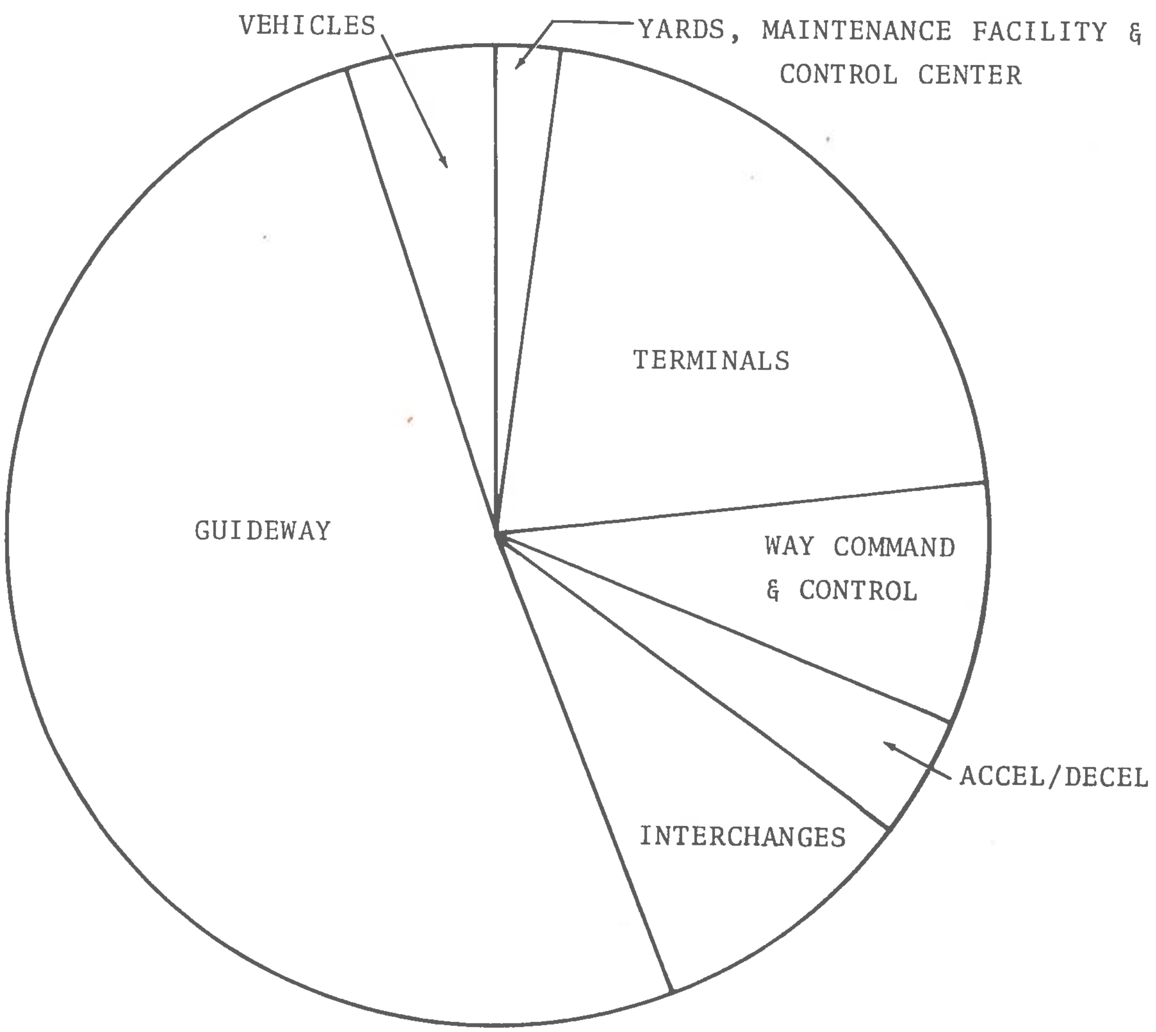
Figure 3-20 Accessibility Results - Automated Highway Vehicle System

3.2.3 Costs and Benefits

The automated highway vehicle system is assumed to be operated by a public or private agency with automobiles owned by private individuals. The total capital cost for this system is $1,620 million excluding interest charges and automobile capital costs. The distribution of the operating agency's capital cost is shown in the pie chart, Figure 3-21. As shown, the largest portion of the cost is guideway and related fixed facilities. The vehicle cost shown is the capital cost of the system owned Dual Mode buses which are a part of this baseline. The total capital cost of the system is most sensitive to changes in guideway cost, followed by changes in terminal costs. This baseline is relatively insensitive to vehicle costs. The cost sensitivities of the three items cited are shown in Figure 3-22. A 50% increase in guideway cost increases the total system capital cost by 33%, for instance.

This baseline makes a substantial operating profit for the system operator which is available to support about 40% of the annual capital cost as shown in Figure 3-23. Note that the costs in this figure do not include the automobile ownership and operating costs, which are private costs and thus outside the domain of the system operator.

Figure 3-24 shows the effect of fare variations on net revenue position. An increase in fare of 39% reduces patronage by 18% while increasing operating profit from a base of $72 million per year to $78 million. The base fare for this baseline is $0.50 per Dual Mode bus trip and $0.04 per on-guideway vehicle mile plus parking for Dual Mode automobiles. The derivation of annual monetary benefits for the automated highway vehicle system is shown in Figure 3-25. For each type of impact, the quantitative units relative to the 1990 plan are multiplied by the respective dollar value per unit to obtain annual dollar benefits (a 10% interest rate and infinite lifetime are used to annualize displacement savings and land value increases). As shown in Figure 3-26, the annual incremental benefits of the automated highway vehicle system are $377 million greater than incremental costs, yielding a benefit-to-cost ratio of 2.4.



NOTE: VEHICLE CAPITAL COSTS INCLUDE ONLY BUS COST. AUTOMOBILES ARE DEPRECIATED AS AN OPERATING COST AND NOT INCLUDED ABOVE.

Figure 3-21 Automated Highway Vehicle System Capital Costs

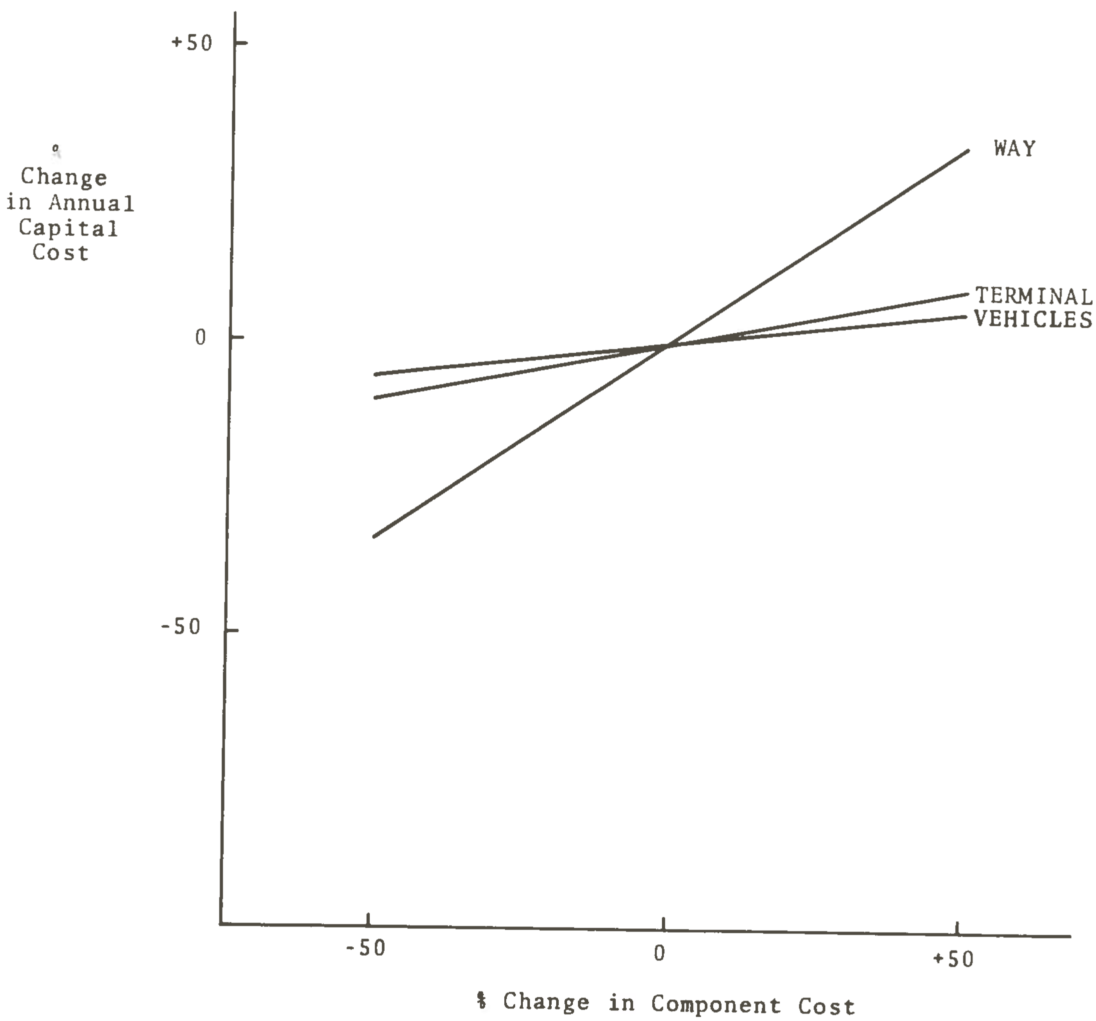


Figure 3-22 Capital Cost Sensitivity for Automated Highway Vehicle System

NOTE: THIS FIGURE INCLUDES ONLY THOSE COSTS AND REVENUES ACCRUED TO THE SYSTEM OPERATOR (OWNER). OPERATING AND CAPITAL COSTS OF PRIVATE AUTOMOBILES USED FOR DUAL MODE TRIPS ARE NOT INCLUDED.

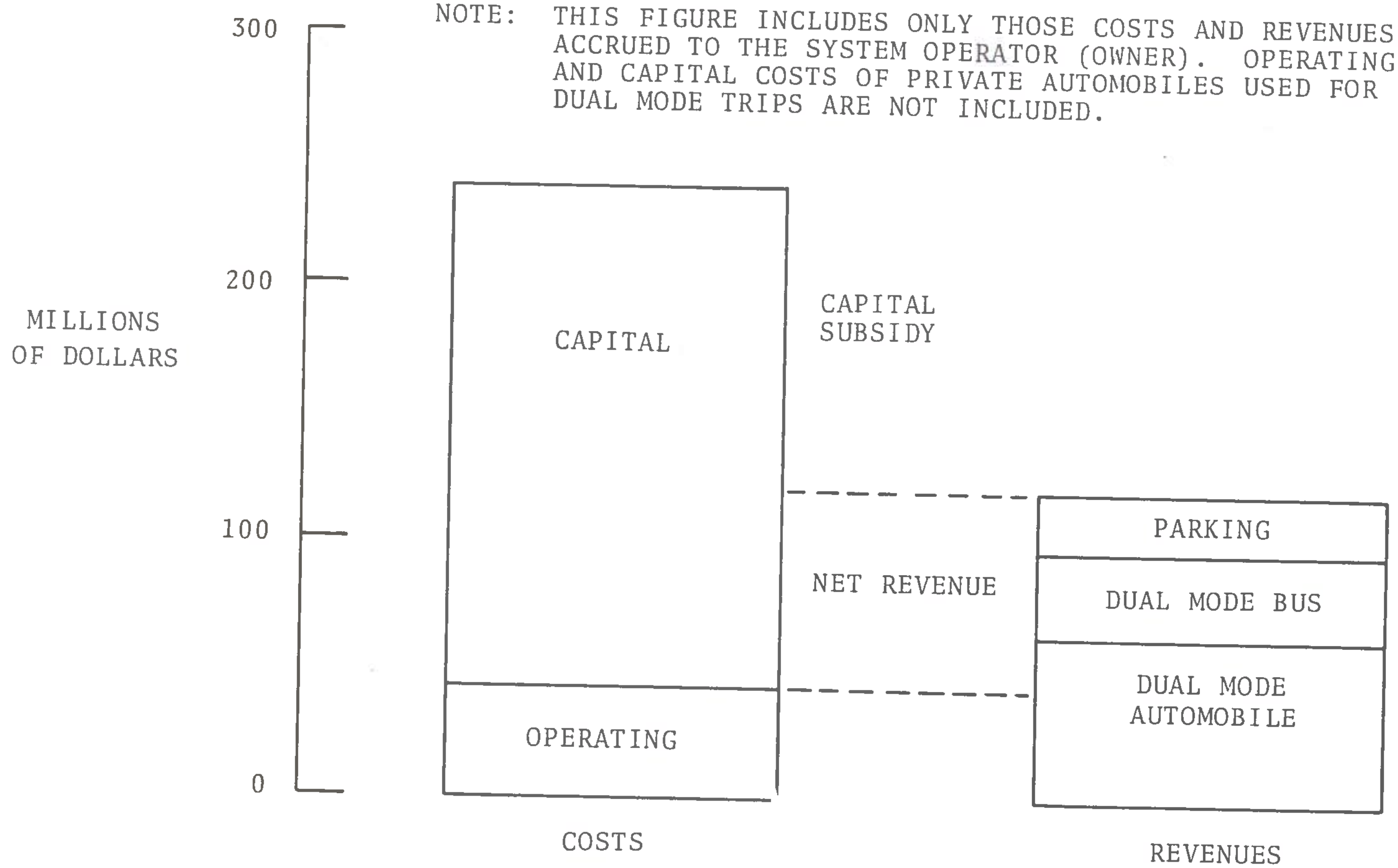


Figure 3-23 Dual Mode System Operator Annual Costs and Revenues (Automated Highway Vehicle System)

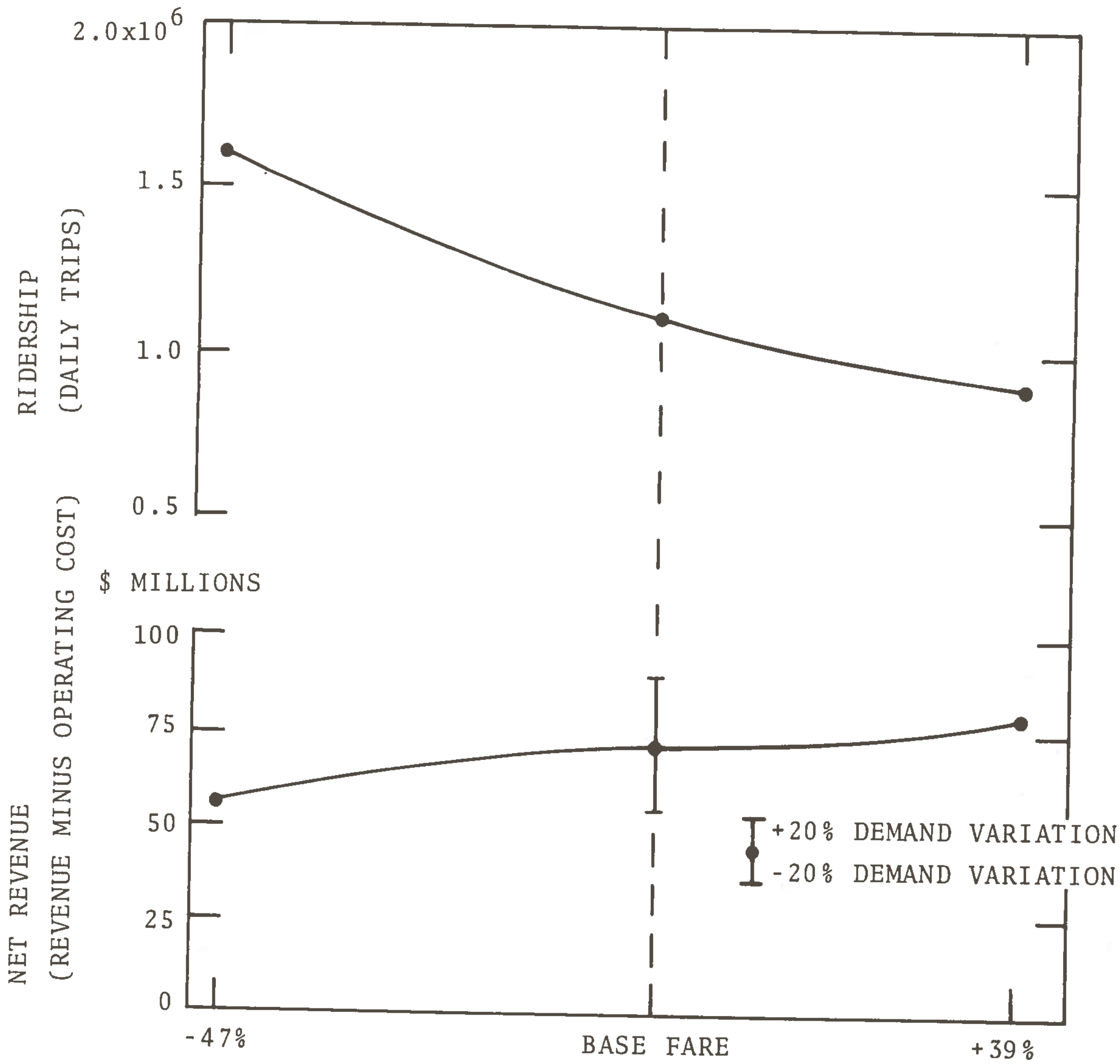


Figure 3-24 Effect of Fare Variations on Net Revenue and Ridership of the Automated Highway Vehicle System

Impact (Relative to 1990 Plan)	Quantitative Units	Dollar Value Per Unit	Total $ Benefits (x 10^6)	Annual $ Benefits (x 10^6)
Benefits:				
Travel Time Savings				
Passenger Modes	50.7 x 10^6 hours/yr.	$3.00/hour	--	152
Trucks	3.6 x 10^6 hours/yr.	$6.00/hour	--	22
Total				174
Driver Relief	35.3 x 10^6 hours/yr.	$1.50/hour	--	53
Accident Savings	4,900 accidents/yr.	$1,108/accident	--	5
Displacement Savings				
Relocation (Household)	52,000 households	$ 1,604/household	83	8
Aggravation (Household)	52,000 households	$20,000/household	1,040	104
Relocation (Business)	330 businesses	$ 3,076/business	1	-
Total			1,124	112
Land Value Increase				
Improved Accessibility	12.4% incr. in speed	Note 1	1,602	160
Reduction in Noise Impacted Households	40,000 households	$4,650/household[2]	186	19
Total			1,788	179
Tax Revenue Increase				
Savings in Land Acquisition	$ 324 x 10^6	$54/$1,000 annually[2]	--	17
Land Value Increase-Access.	$1,602 x 10^6	$59/$1,000 annually[2]	--	95
Land Value Increase-Noise	$ 186 x 10^6	$57/$1,000 annually[2]	--	11
Total				123

Figure 3-25 Dollar Valuation of Benefits - Automated Highway Vehicle System

Impact (Relative to 1990 Plan)	Quantitative Units	Dollar Value Per Unit	Total \$ Benefits (x 10^6)	Annual \$ Benefits (x 10^6)
Disbenefits:				
Pollution Increase				
NO_x	1,700 tons/yr.	\$ 51/ton	--	--
Particulates	- tons/yr.	\$205/ton	--	--
SO_2	- tons/yr.	\$250/ton	--	--
CO	3,400 tons/yr.	\$ 2/ton	--	--
HC	300 tons/yr.	\$130/ton	--	--
Total	5,400 tons/yr.			
Net Benefits:				\$646

(1) The percentage increase in speed was used to determine the percentage increase in land value, which in turn was applied to the base value of land in the affected region (about \$17 billion) to obtain the net increase in land value. (See Volume III, Chapter 6.8 for a detailed description of land value change calculations).

(2) This is a weighted average of the actual values used. The calculation was performed by multiplying the number of impacts in the CBD, urban, and suburban rings by the respective unit dollar value. Household values and tax rates by ring are given in Volume III, Chapter 6.

Figure 3-25 Dollar Valuation of Benefits - Automated Highway Vehicle System (Cont.)

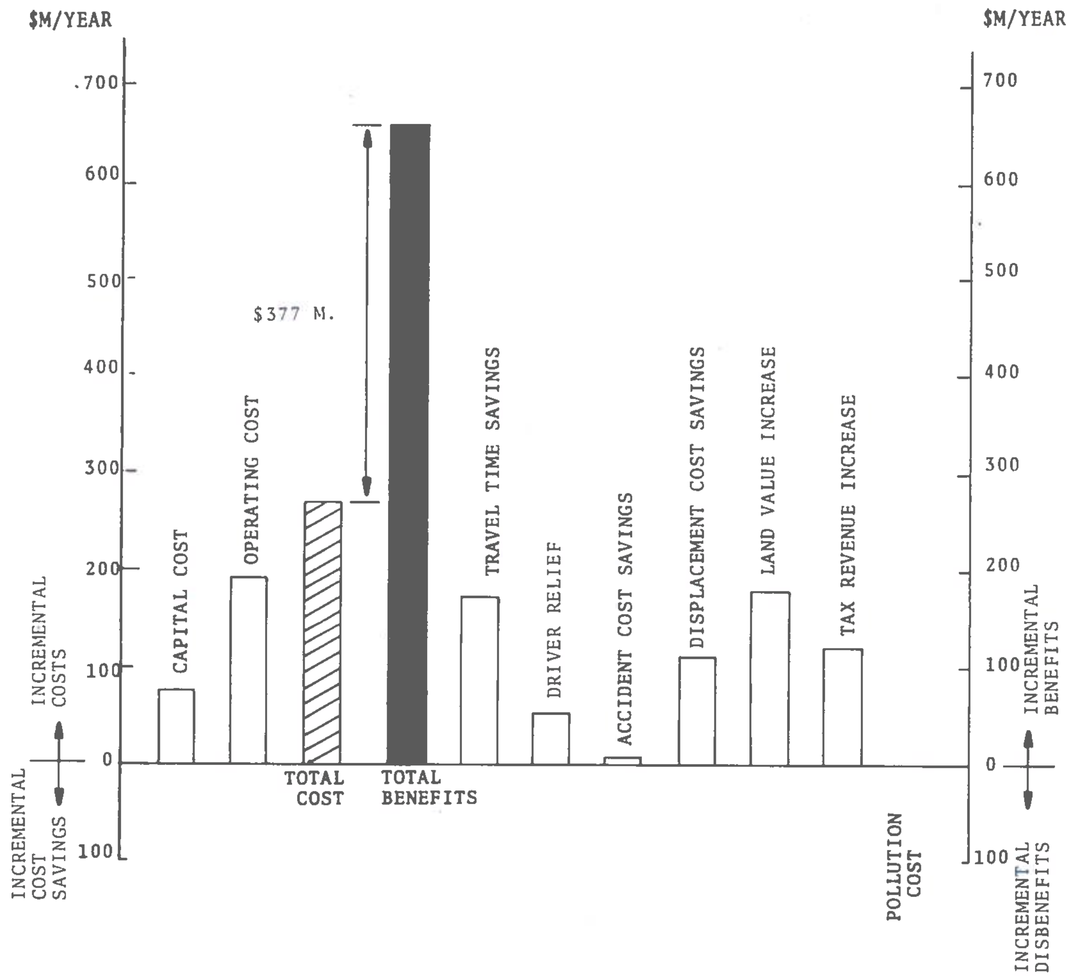


Figure 3-26 Regional Annual Incremental Costs and Benefits Relative to 1990 Plan (Automated Highway Vehicle System)

3.3 NEW SMALL VEHICLE SYSTEM

Figure 3-27 presents data on network and ridership characteristics, costs, and impacts for the new small vehicle system. Unless otherwise indicated, the following discussion is based on results in this table.

3.3.1 Service

The new small vehicle system has the greatest impact on the regional transportation system of any of the Dual Mode baselines studied. This system attracts approximately 1.7 million daily riders, representing 15.8% of the daily regional trips and 29.3% of the trips for which it is an option. It attracts 52.7% of all CBD-related trips. It achieves the greatest regional time savings and results in the highest average regional, surface arterial peak period, and Dual Mode trip speeds. These effects come from its ability to attract highway travelers which in turn results from its rapid trip times. As with the other highly-patronized Dual Mode systems, vehicle miles and passenger miles are higher than those of the 1990 plan. This, as before, is due to the circuity of the Dual Mode trips, a characteristic imposed by the layout of the network. But the speeds on the system are sufficiently high that shorter trip times result in spite of the often greater distances traveled.

The small personal vehicle (SPV) portion attracts 93% of the Dual Mode riders. Twenty-five percent of the regional SPV trips are diverted from conventional transit and the remaining 75% come from automobiles. Of the CBD-related trips the small personal vehicle attracts nearly 41%, and these trips are predominantly diverted from automobile users (85%). The relatively high modal split for Dual Mode in the CBD can be attributed to several factors: the downtown portion of the new small vehicle network is quite extensive and thus provides good service for intra-CBD trips as well as an excellent collection-distribution system. Furthermore, there are no parking delays or costs in the

	1990 Plan	Dual Mode
System Extent:		
Route Miles Constructed	144	261
New Construction Acreage	19,100	3,840
DM Lane Miles		1,510
Costs:		
Capital Cost	$\$1,020 \times 10^6$	$\$4,200 \times 10^6$
DM Annual Capital Cost		$\$681 \times 10^6$
DM Total Annual Operating Cost		$\$291 \times 10^6$ (2)
Total Region Annual Operating Cost (3)	$\$2,050 \times 10^6$	$1,900 \times 10^6$
Total Region Annual Oper. & Cap. Cost (3)	$\$2,160 \times 10^6$	$\$2,580 \times 10^6$
DM Revenue		$\$405 \times 10^6$
DM System Operator Profit		
a. revenues less system operating cost		$\$113 \times 10^6$
b. revenues less system operating & capital cost		$-\$567 \times 10^6$
Network Statistics:		
Daily DM Person Trips		
Small Personal Vehicle		1.58×10^6
Minibus		1.12×10^6
DM Modal Split		
Daily		16%
Peak Trips Period CBD-Bound		53%
DM Average Trip Length		
Small Personal Vehicle		14.5 mi.
Minibus		10.6 mi

Figure 3-27 New Small Vehicle System Characteristics

Network Statistics (Cont.)	1990 Plan (1)	Dual Mode
Region Average Trip Length (3)	5.3 mi.	5.7 mi.
DM Average Trip Speed		25.3 mph
Region Average Trip Speed (3)	16.1 mph	19.1 mph
Peak Period Surface Arterial Speed	15.8 mph	18.6 mph
Region Daily Time Savings (3)		36.0 yrs.
DM Annual Passenger Miles Traveled (on & off guideway)		7.24×10^9
% on guideway		59.0
Region Annual Passenger Miles Traveled (3)	17.1×10^9	18.5×10^9
DM Annual Vehicle Miles Traveled (on & off guideway)		4.74×10^9
% on guideway		59.0
Region Annual Vehicle Miles (without trucks) (3)	11.1×10^9	12.2×10^9
DM Fleet Size		
Small Personal Vehicle		418,000
Minibus		2,900
Impacts		
Total Region Annual Traffic Accidents (3)	62,100	53,300
Total Region Annual Traffic Accidents per Pass. Mile (3)	3.63×10^{-6}	2.89×10^{-6}
Total Region Annual Fatalities (3)	320	270
Total Region Annual Fatalities per Pass. Mile (3)	0.02×10^{-6}	0.01×10^{-6}
Total Region Daily Transportation Energy Consumption (BTU's) (3)	22.2×10^{10}	23.0×10^{10}

Figure 3-27 New Small Vehicle System Characteristics (Continued)

Impacts (Cont.)	1990 Plan (1)	Dual Mode
Total Region Daily Pollutant Output (LBS) (3)	994,000	960,000
NO_x	396,000	10,000
Particulates	13	4,360
SO_2	161	52,300
CO	549,000	456,000
HC	48,700	37,800
Household Displacements	58,000	5,360
Household Displacements per Route Mile	402	21
Household Displacement Acres	8,680	794
Business Displacements	355	22
Tax Revenue Losses	$\$21.9 \times 10^6$	$\$3.8 \times 10^6$
Tax Revenue Losses per Route Mile	$\$151 \times 10^3$	$\$15 \times 10^3$
Tax Revenue Loss Acres	8,715	2,330
Noise Impacted Household Daytime	41,000	336
Noise Impacted Household Nighttime	152,000	956
Noise Impacted Households per Route Mile - Daytime	284	1
Noise Impacted Households per Route Mile - Nighttime	1,050	4

(1) Data for the 1990 plan on system extent, capital cost, displacements, tax revenue losses and noise impacts refer to new highway and transit facilities that would be built if Dual Mode were not implemented.
(2) Includes off-guideway operating costs of new small vehicles.
(3) Regional data reflect all transportation modes throughout the entire study area.

Figure 3-27 New Small Vehicle System Characteristics (Continued)

CBD, since the passenger is free to vacate the vehicle immediately upon arrival at his station. The results suggest that the SPV has a significant ability to divert ridership from the private auto, particularly in the CBD.

The small personal vehicle fleet is quite large, numbering around 420,000 vehicles. This is necessitated by the fact that utilization of these vehicles is very similar to that of private automobiles, with relatively little shared usage. Thus, the number of small personal vehicles necessary to handle a given number of passengers is very nearly equal the number of automobiles that would be required.

Of the 1.7 million daily person trips attracted to the new small vehicle system, about 115,000 choose the minibus portion. This suggests that the small personal vehicle is more effective than the minibus in attracting the medium-to-long journey trip-maker, the primary user of the Dual Mode system. The minibus does capture nearly 12% of the total CBD-related trips.

The minibus operation is designed to provide for the aged, the handicapped, and others who cannot gain access to or make use of personal vehicles. It is assumed to be a no-transfer operation. For both the minibus and the SPV, no facilities for transfer to local transit for collection and distribution off the guideway exist.

The minibus is configured as a demand responsive (dial-a-ride) system with an off-guideway tour area. The tour area service characteristics are based on a "many-to-one" concept where the "many" riders are randomly distributed in the tour area (origin or destination) bound to or from the "one" nearby Dual Mode station. Off-guideway distribution of passengers is always performed prior to collection of riders bound for some new destination. This provides the best overall service to the average user. Figure 3-28 shows a number of pertinent characteristics of the minibus off-guideway service.

	NON-CBD TRIP ENDS (VEHICLE LEAVES GUIDEWAY)	CBD TRIP ENDS (VEHICLE REMAINS ON GUIDEWAY)
TRAVEL TIME/PASSENGER - MINUTES	13.2	6.0
TOUR LENGTH/PASSENGER - MILES	3.7	.3 (1)
TOUR SPEED - MPH	20	15
TOUR AREA - SQUARE MILES	1.14	2.5
NUMBER OF STOPS/TOUR	9 (2)	3
WAIT TIME - MINUTES	7.2	8.4
WALK TIME - MINUTES	NA	2.8

(1) Represents true excess distance, imposed by guideway circuity, over the most direct possible route.

(2) Assumes 75% bus load factor.

Figure 3-28 Average Dial-A-Ride Minibus Collection/Distribution Service Data

The fare structure chosen for the system is an $0.08/mile rate for the SPV and $0.90/trip for the minibus. The flat fixed fare for the minibus has the greatest appeal to riders making longer trips and provides a reasonable balance between revenue and patronage. Figures 3-29 and 3-30 illustrate the effect on ridership of simultaneously varying Dual Mode fares. For all cases where fares are increased the Dual Mode ridership decreases. However, for trips to the CBD, uniform fare increases cause the SPV ridership to increase until the SPV rate reaches approximately $0.08/mile, at which point it begins to decrease. Minibus ridership continues to decrease past this point until the SPV fare reaches the $0.095/mile level, where it begins to increase somewhat as more and more potential SPV riders are driven to more economical transportation options. As this happens, the automobile tends to be the major victor as Dual Mode fares are increased and the minibus gathers a number of travelers as fares are decreased. The SPV loses in either case for uniform variations away from the base rate of $0.08/mile.

For non-CBD areas where private vehicle parking charges are normally required, the minibus patronage does not appreciably benefit from an increase in SPV parking charges. Minibus ridership to these areas is low regardless of the SPV parking charge since these areas tend to become congested and off-guideway distribution consequently becomes a more time consuming (and hence a less attractive) proposition. Effects on patronage are shown in Figure 3-31.

For purposes of comparison, a brief analysis was done on a scenario wherein the minibus sometimes does not travel on the guideway, but instead acts as a collector and distributor for non-driving Dual Mode patrons. These patrons then travel on the guideway in small personal vehicles under automatic control. Time delays in transferring from minibus to SPV and back are assumed less than one minute. This mode of operation would result in a smaller minibus fleet and would not require a significant increase

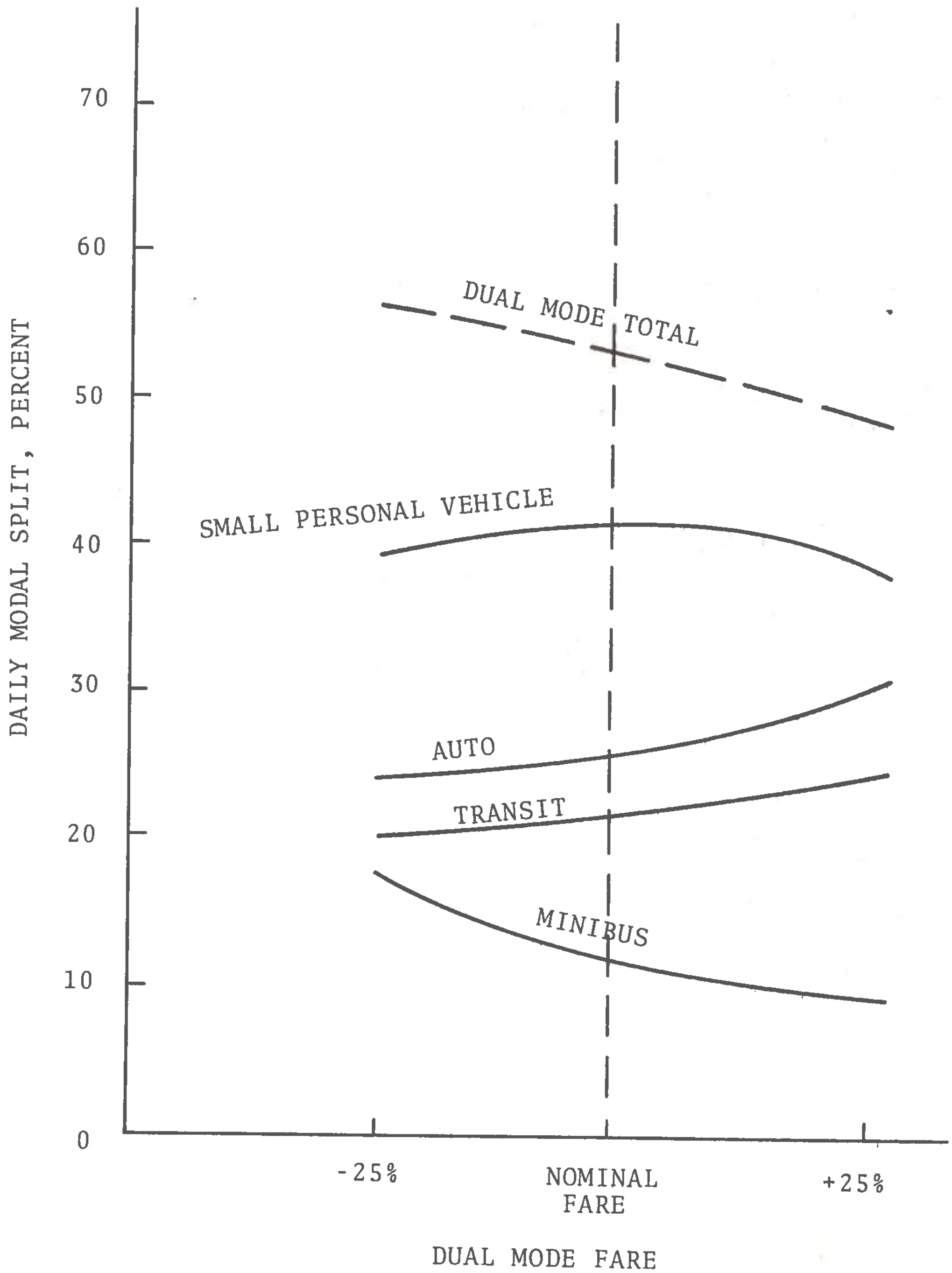


Figure 3-29 New Small Vehicle System CBD Modal Split vs. Simultaneous Dual Mode Fare Changes

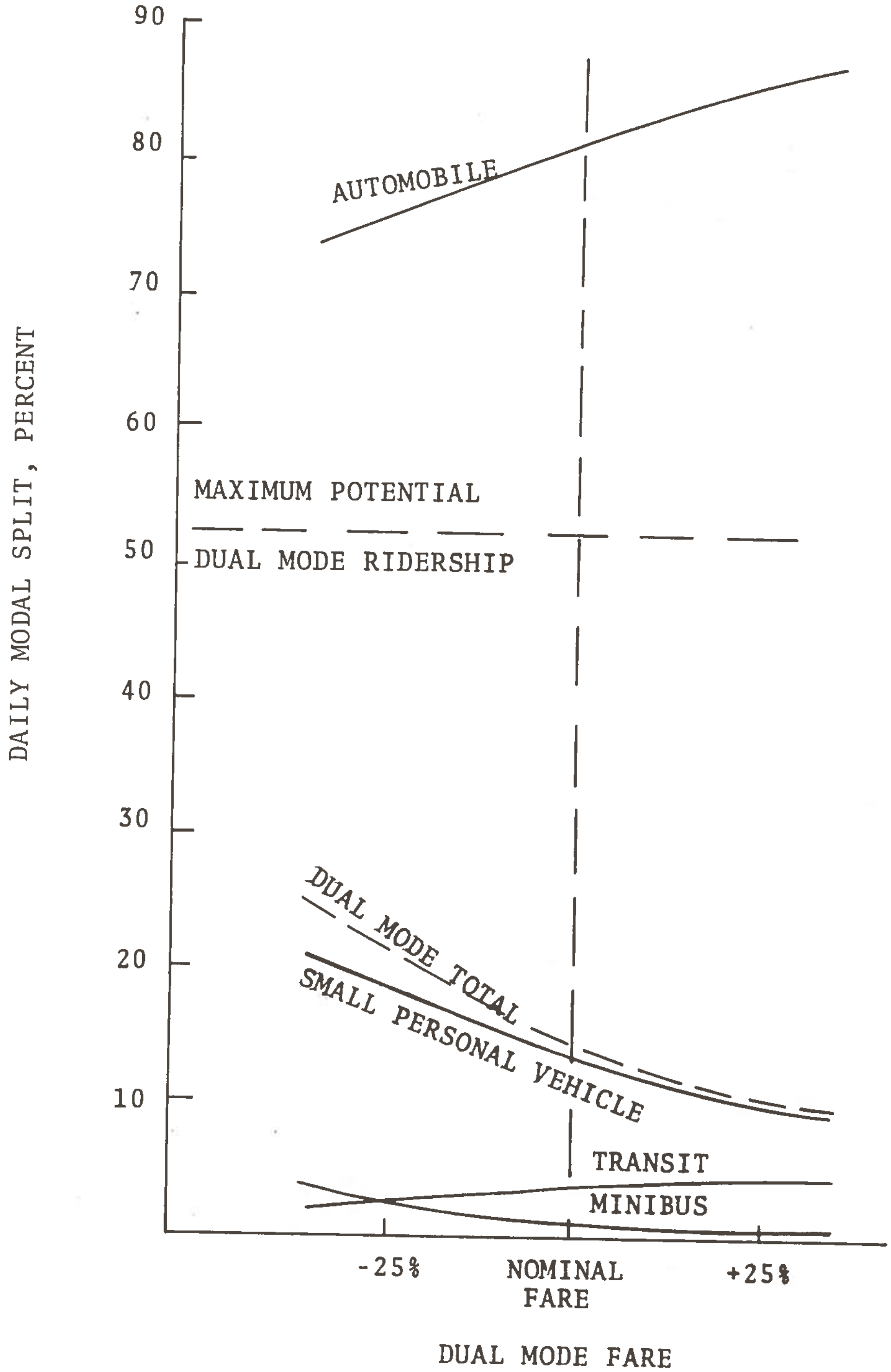


Figure 3-30 New Small Vehicle System Regional Modal Split vs. Simultaneous Dual Mode Fare Changes

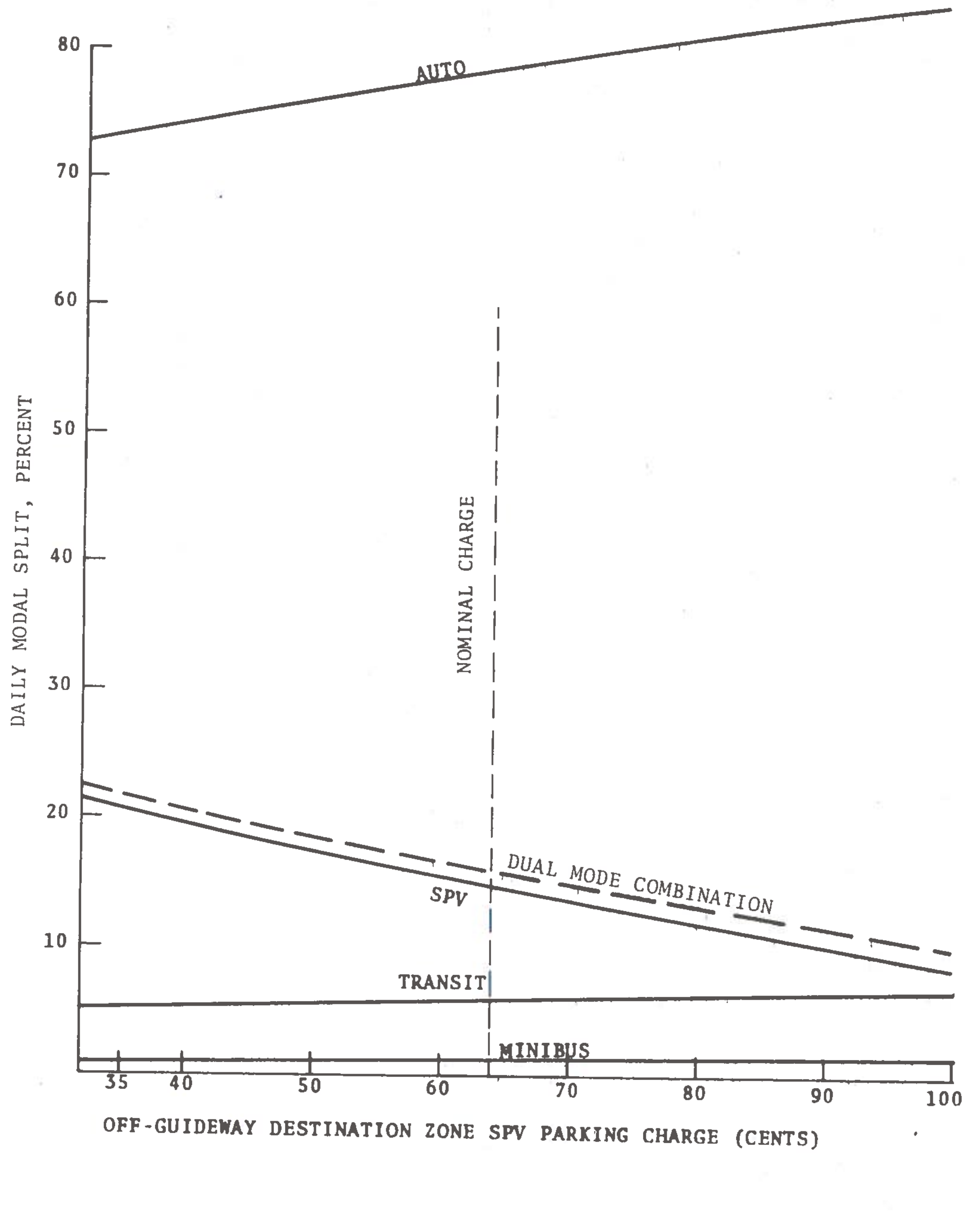


Figure 3-31 New Small Vehicle System Regional Modal Split vs. Destination Zone SPV Parking Charge

in the SPV fleet, since these latter vehicles are highly under-utilized in the nominal mode of operation and many are idle during the day when not serving peak period trips to the CBD. The option exists to maintain the minibus in a Dual Mode configuration for those origin/destination pairs generating sufficient patronage. Not having to provide Dual Mode capability to all the minibus fleet would relieve the fleet capital cost somewhat. Figure 3-32 suggests that increases of as much as 40% in the minibus ridership might occur with this scenario.

3.3.2 Impacts

Figure 3-33 shows total regional accidents and fatalities for the new small vehicle system as a function of various assumed rates for on-guideway travel.* It can be seen that this baseline results in fewer traffic accidents than the 1990 plan if the on-guideway accident rate is less than 3.2 accidents per million vehicle miles traveled (a rate far in excess of that experienced by rapid transit systems); it likewise causes fewer fatalities if the combined SPV-minibus on-guideway fatality rate is under .02 (both bus and airline rates are within this limit).

However, assuming that the new small vehicle system can achieve (or is required to achieve) on-guideway accident and fatality rates equivalent to those experienced by airlines,** its introduction results in a 14.2% decrease in total region annual traffic accidents and a 15.6% reduction in fatalities over the

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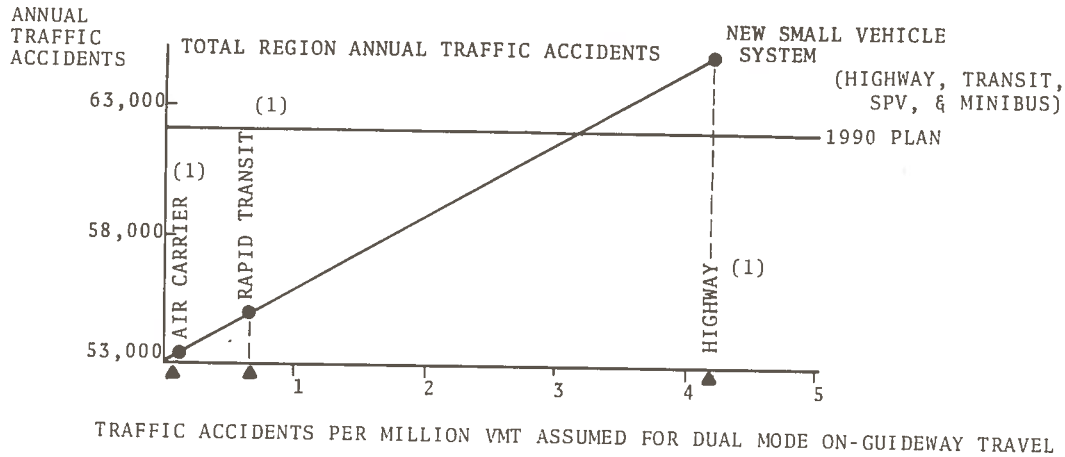
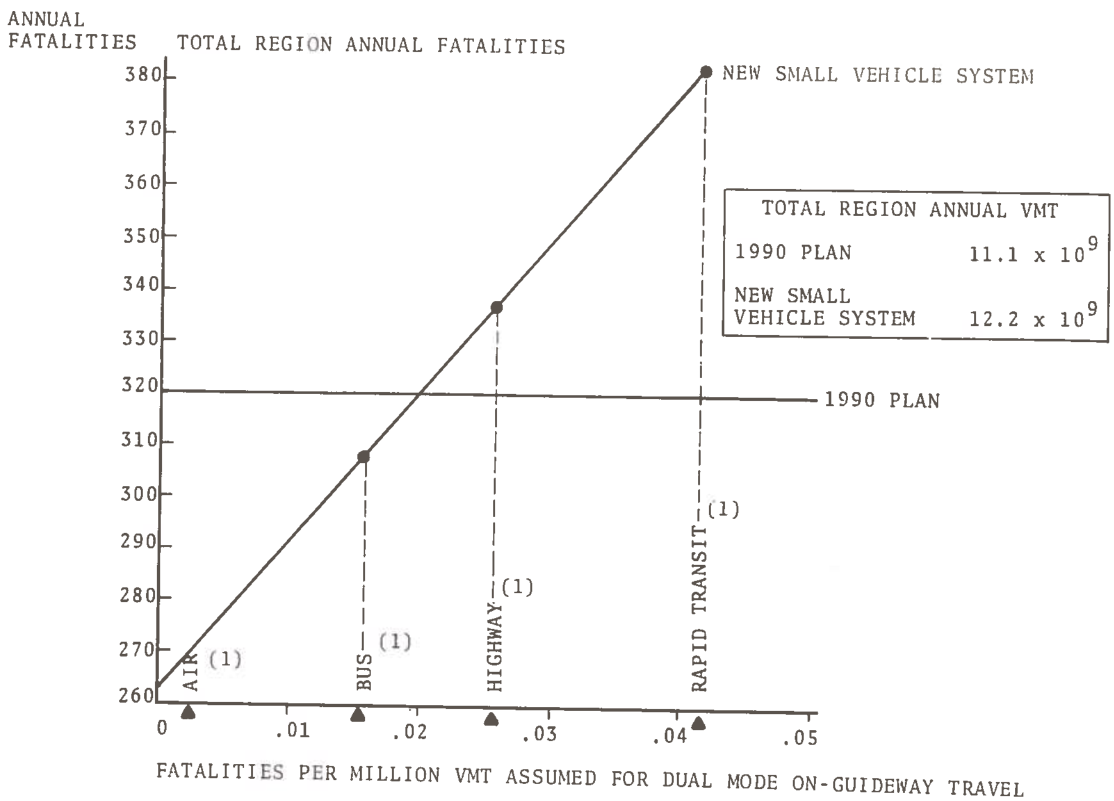
* The method of calculating Dual Mode accidents and fatalities for on- and off-guideway travel is explained in Section 3.1.2 of this volume and in Volume III, Chapter 6.4.

**The rationale for this assumption appears in Section 3.1.2 of this volume.

	NO TRANSFERS (AS RUN)	TRANSFERS (MINIBUS SYSTEM)	COORDINATED TRANSFERS (ADDITIONAL VEHICLES)
STATION TRANSFER DELAY (MIN)	0	3.5	1.0
THEORETICAL MODAL SPLIT (POTENTIAL ATTRACTION)	4.1%	2.2%	3.5%
DAILY PERSON TRIPS	2.68×10^5	2.31×10^5	3.77×10^5
% CHANGE IN RIDERSHIP	0	-31.3%	+40.7%

Figure 3-32 Effects of Transfers in the Minibus Alternatives





(1) Nationwide average rate for this mode

Figure 3-33 Effect of Varying On-Guideway Accident/Fatality Rate - New Small Vehicle System

1990 plan. This improved safety record is due to the fact that 16% of the travel that would otherwise take place on highway and transit facilities is diverted to a Dual Mode system with an on-guideway component which is assumed to be safer than highway and transit travel.

As with the other Dual Mode systems, the regional transportation energy consumption for this baseline increases over that of the 1990 plan. The reason is that the Dual Mode vehicles spend a large portion of their time at high speeds. From a pollution standpoint, results typical of the electrically powered Dual Mode vehicles occur. The total pollutant output for the region decreases compared with the 1990 plan, due to the diversion of automobile travel onto Dual Mode. However, there is a significant increase in emission of the relatively costly particulates and sulfur dioxide.

Household and business displacements for this baseline are only 9.2% and 6.3%, respectively, of those required by the highway and transit additions in the 1990 plan. Further, it results in 700 fewer household displacements than the pallet system. This difference is explained primarily by differences in terminal size (small personal vehicle stations do not require any parking spaces for cars) and by the fact that several links leading to the downtown network are at-grade for the pallet system, but tunnelled for this baseline. The slight increase in network length (due to the CBD network) and yard acreage for the new small vehicle vs. the pallet has no impact on the number of household displacements because the additional CBD route mileage is tunneled, and the additional storage area to accommodate the larger vehicle fleet is on non-residential land.

The new small vehicle system results in 17.4% of the tax revenue losses associated with the 1990 plan. This system also compares favorably to the other baselines; since much of its network is located underground or on low-cost land, tax loss savings are larger than for the pallet and automated highway vehicle systems.

Like other electrically powered Dual Mode systems, this system presents a significant improvement over the 1990 plan from a noise standpoint because of generally quieter vehicles and more effective use of lane barriers and existing right-of-way. The new small vehicle system is assumed to have the same noise characteristics as the pallet; however, owing to the tunneling of a few links leading to the downtown network, the new small vehicle system results in 95 fewer noise impacted households during the day and 130 fewer nighttime impacts.

Figure 3-34 presents accessibility results for the new small vehicle baseline. This system provides far better mobility than any of the other Dual Mode systems because it supplies fast, efficient service (due to the fine-grained downtown network and the elimination of the need for parking and transfers to transit) and because it provides excellent individual vehicle service to those able to drive but unable or unwilling to purchase a vehicle outright (namely, the poor and people with an infrequent need for a private vehicle). In comparison to the 1990 highway plus transit system, this new small vehicle baseline (primarily the small personal vehicle component) improves accessibility to all major activity centers during peak and off-peak periods, with the percentage increase in the number of people who can reach a particular destination within 40 minutes ranging as high as 46.2% (for the suburban shopping center). The percentage increase in the number of people within 40 minutes of a major activity center by this system vs. transit ranges from 1.4 to 363.6% for the suburban shopping center, peak and off-peak periods, respectively. For the poor suburban area and center city ghetto, the small vehicle portion of this baseline provides access to about 30% more blue collar jobs than does transit, and it practically doubles the number of nonwork destinations that ghetto dwellers can reach within 40 minutes. The minibus portion of this baseline results in a slight increase in the number of nonwork destinations within 40 minutes of the "young, central" analysis zone during off-peak hours. As is true of the other Dual Mode baselines, accessibility

Major Activity Center	Additional People Within 40 Minutes of Major Activity Center by Dual Mode vs.			
	1990 Highway and Transit		1990 Transit	
	Peak Period	Off-Peak Period	Peak Period	Off-Peak Period
Airport	416,000	74,900	464,000	989,000
Suburban Shopping Center	557,000	1,990	887,000	994,000
University	631,000	300,000	1,030,000	1,990,000
CBD	860,000	403,000	942,000	1,420,000
Hospital	1,140,000	465,000	1,290,000	1,800,000
Sports Arena	X	396,000	X	2,020,000

Analysis Zone	Parameter	Additional Work/Nonwork Destinations Within 40 Minutes of Special Zone by Dual Mode vs. 1990 Transit	
		Peak Period	Off-Peak Period
Poor, Suburban	Blue collar Positions	111,000	X
Ghetto		115,000	X
Ghetto	Nonwork trip ends, including school	X	2,040,000
Young, Central		X	4,670
Young, Suburban		X	0
Old, Central	Nonwork trip ends, excluding school	X	0
Old, Suburban		X	0

X - Accessibility value not calculated for this time period due to the nature of the trip purpose.

Figure 3-34 Accessibility Results - New Small Vehicle System benefits are comparatively small for shorter trips on account of the overall granularity of the network; however, this system does perform somewhat better than the pallet baseline for 20 minute travel times, reflecting its more extensive downtown coverage.

As in the case of the pallet baseline, the new small vehicle system improves the mobility of low-income and minority groups as well as that of white, middle-income families. The upper half of Figure 3-35 indicates that the introduction of the new small vehicle system brings an additional 5.7% of the black population, 12.1% of the other minority population, and 4.6% of the low-income families within 40 minutes of the CBD; the corresponding percentage point gains for the suburban shopping center are 19.5%, 15.2%, and 20.3%, respectively. Again, the minority/low-income groups benefit relatively less than the white, middle-class families when the centroid of the accessibility contour is centrally located, and relatively more than these families when the centroid is in the suburbs.

3.3.3 Costs and Benefits

The capital cost of the new small vehicle baseline is $4.2 billion. It provides 1,500 grade separated lane miles of guideway and a fleet of 420,000 small personal vehicles and 3,000 minibuses. The underground distribution network in the CBD contributes significantly to the guideway cost. The breakdown of the capital costs is shown in Figure 3-36. Vehicle costs are the largest portion of the capital cost (47%), and thus the total capital cost is most sensitive to changes in vehicle cost as shown in Figure 3-37. For example, an increase in vehicle cost of 50% ($984 million) increases the total capital cost by one-third.

The revenues of the new small vehicle baseline exceed operating costs by $113 million per year, but a capital subsidy of $567 million per year is required, as shown in Figure 3-38. If the small personal vehicles were privately owned, the system would require a capital subsidy of $135 million per year.

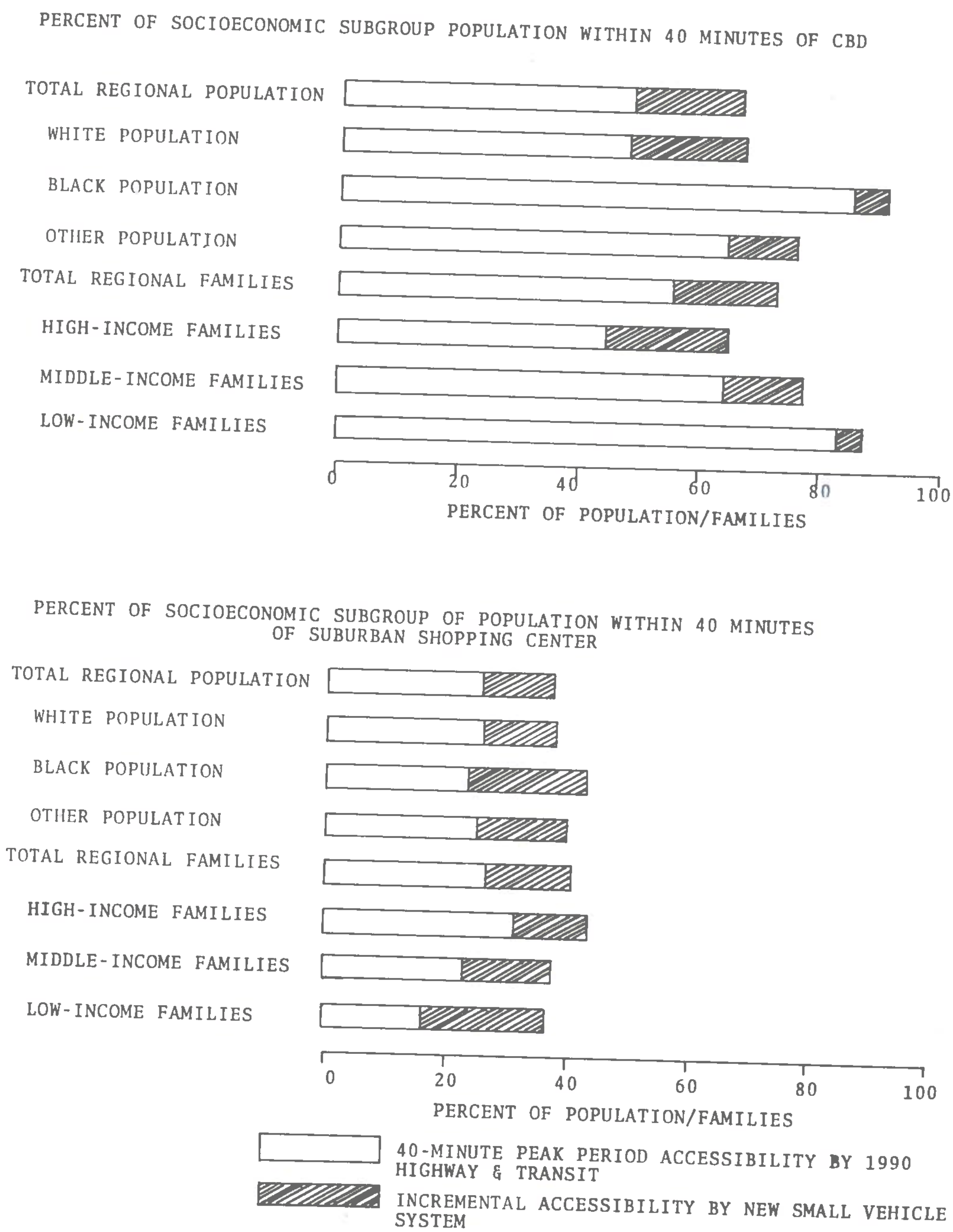


Figure 3-35 Comparative Accessibility by New Small Vehicle System vs. 1990 Plan

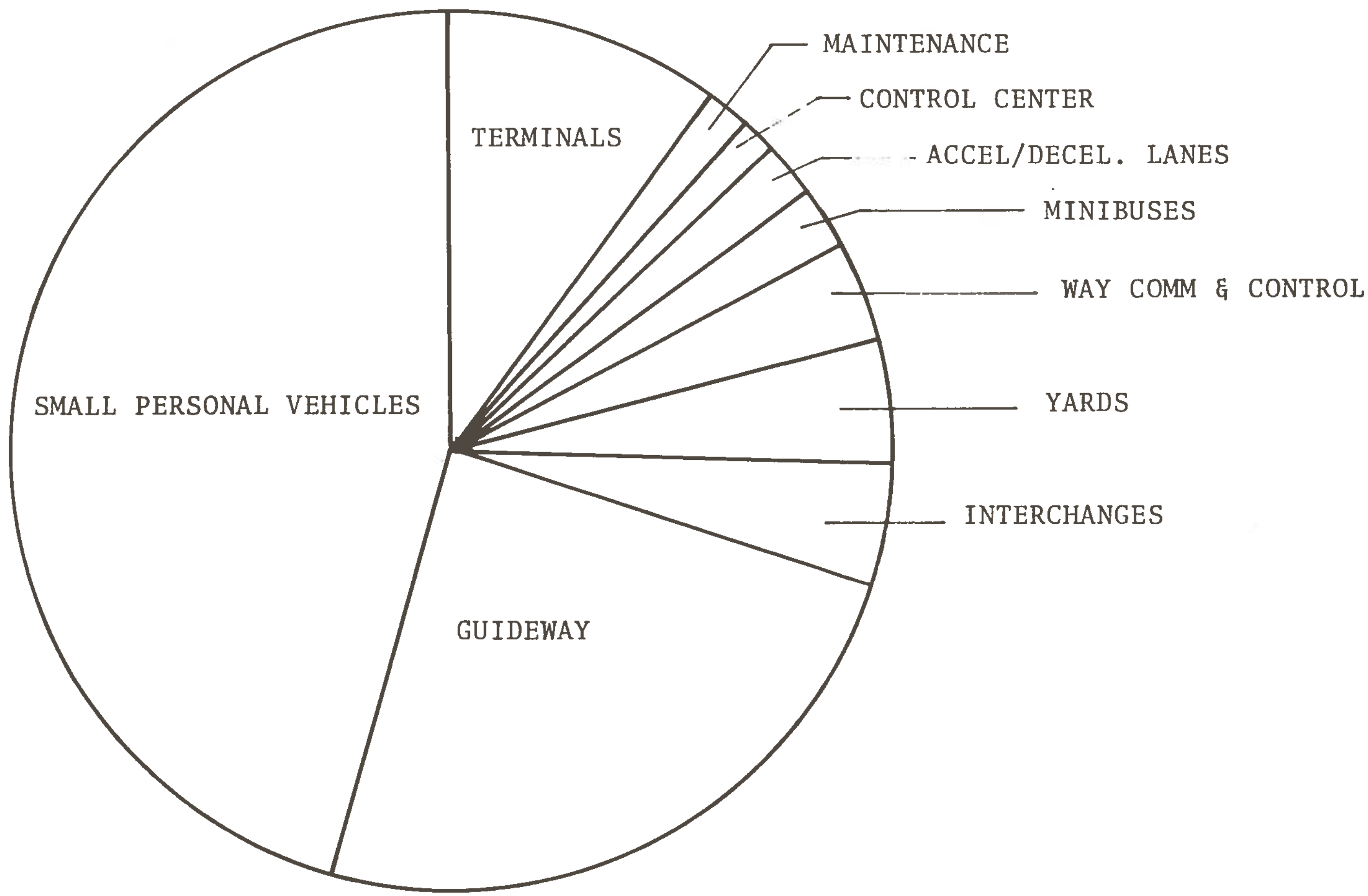


Figure 3-36 New Small Vehicle System Capital Costs

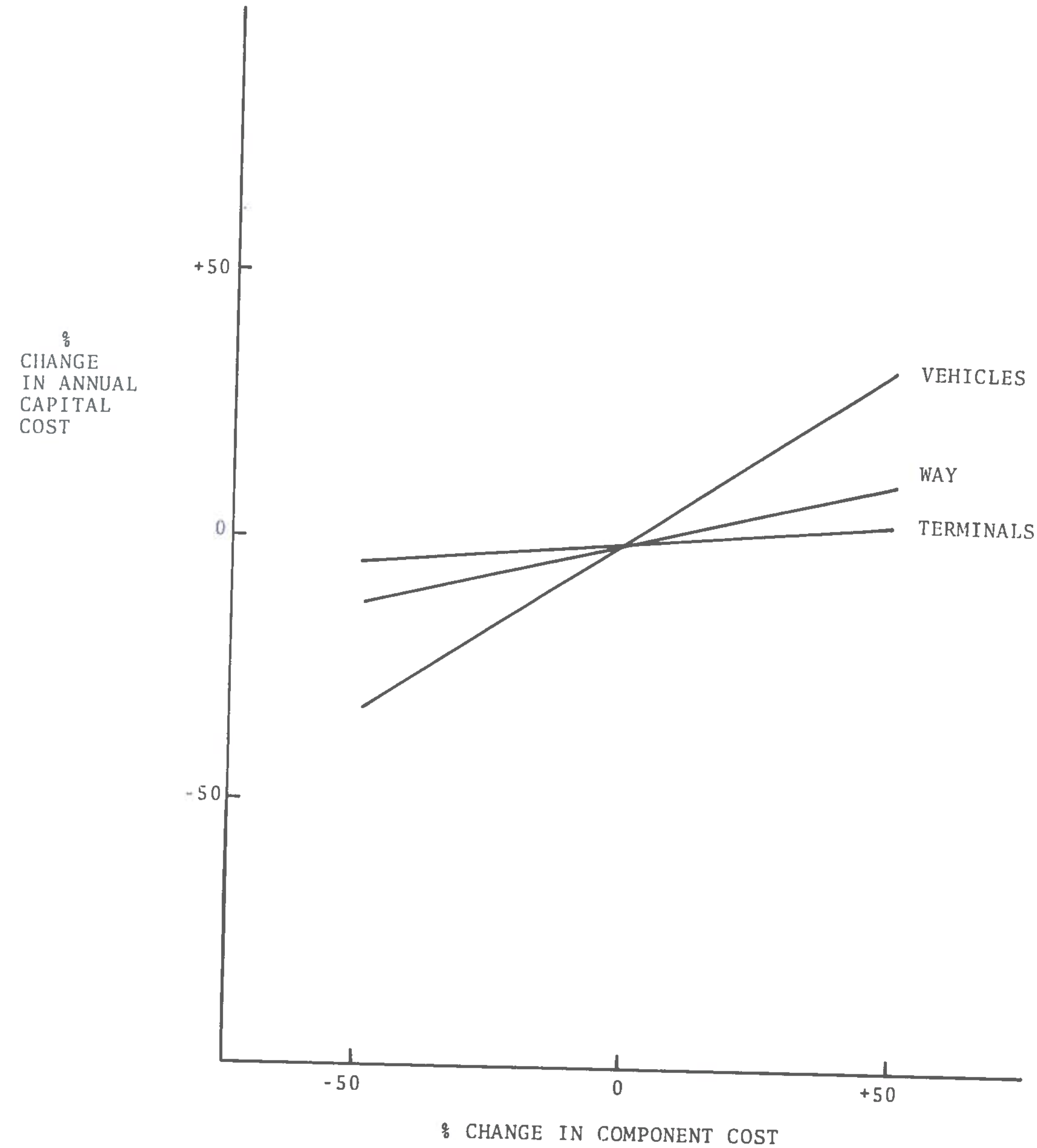


Figure 3-37 Capital Cost Sensitivity for New Small Vehicle System

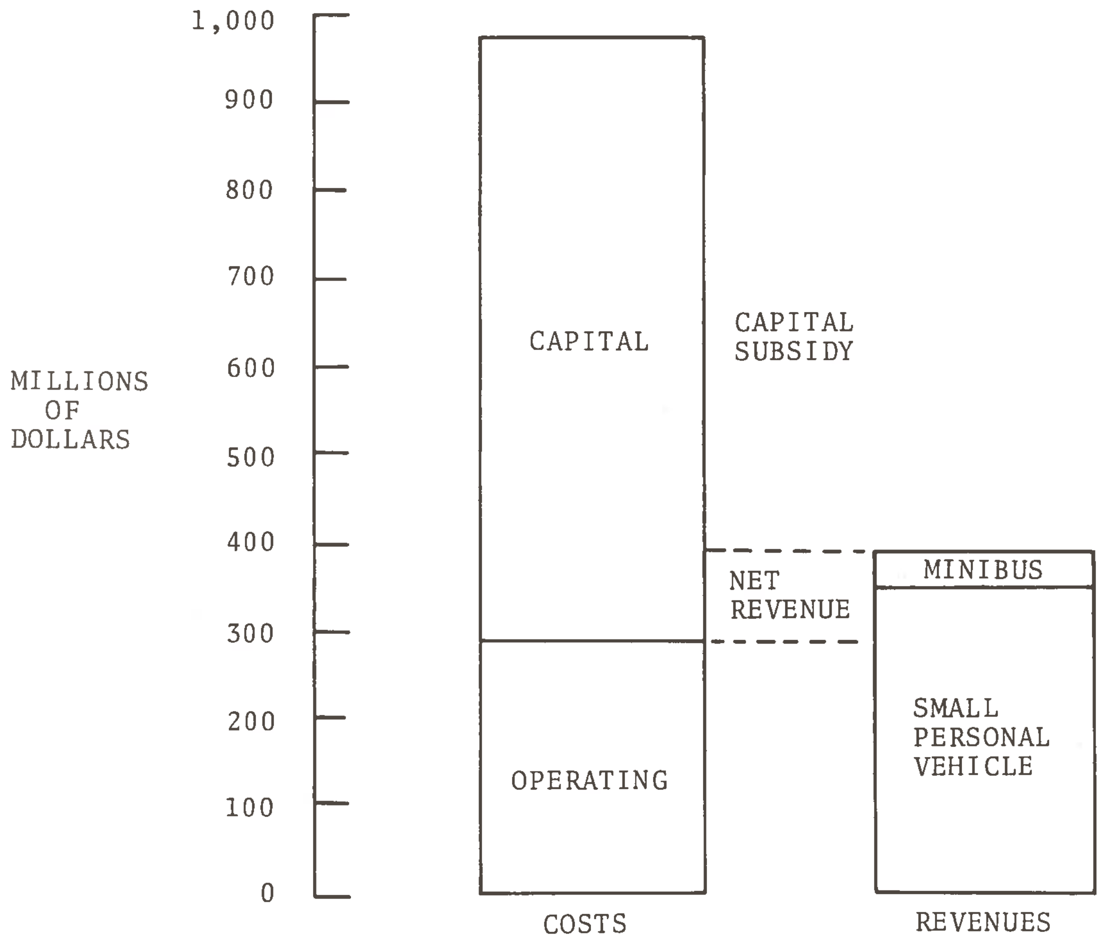


Figure 3-38 Dual Mode System Operator Annual Costs and Revenues (New Small Vehicle System)

As shown in Figure 3-39, a fare increase of 18% (nominal fares of \$.08/mile for SPV's and \$.90/trip for buses) increases net revenue by \$10 million per year. A 20% increase in demand at the base fare level increases net revenue by \$20 million per year.

Figure 3-40 shows the derivation of annual dollar benefits for the new small vehicle system. The quantitative units of each type of benefit (relative to the 1990 plan) are multiplied by the respective dollar value per unit, yielding annual dollar benefits (displacement savings and land value increases are annualized on the basis of a 10% interest rate and an infinite lifetime). The monetary benefits of the new small vehicle baseline are approximately \$605 million per year greater than the costs relative to the 1990 plan, as shown in Figure 3-41. The resultant ratio of incremental benefits to costs is 2.5.

The maximum speed on the high-speed portion of the guideway was originally set at 60 mph, and an analysis was performed on the effects on travel time and energy costs for the small personal vehicle component of this baseline with variations in this speed. All other factors, including patronage, were assumed to remain constant as the speed varied. The results are presented in Figure 3-42.

The average trip takes 34.2 minutes with a 60 mph top speed, 32.6 minutes with a 75 mph limit for a reduction of 4.6%, and 36.6 minutes with a 45 mph limit for an increase of 7%. Of these times, the on-guideway portion represents 11.3 minutes for the base 60 mph case, 9.8 minutes for the 75 mph case (for a reduction of 13.7%), and 13.7 minutes for the 45 mph case (for an increase of 21.1%). The effect of variations in maximum speed on on-guideway trip times are moderated by the presence of the slower 30 mph segments and the fact that the on-guideway trip lengths are not too long. Variations in top guideway speed have only a slight effect on total trip times because of the large amount of time spent off the guideway (22.9 minutes out of 34.2 minutes total trip time for the 60 mph case). This nonguideway time consists of time consumed by off-guideway collection and distribution from the system and by the various delays imposed on a trip. Ways

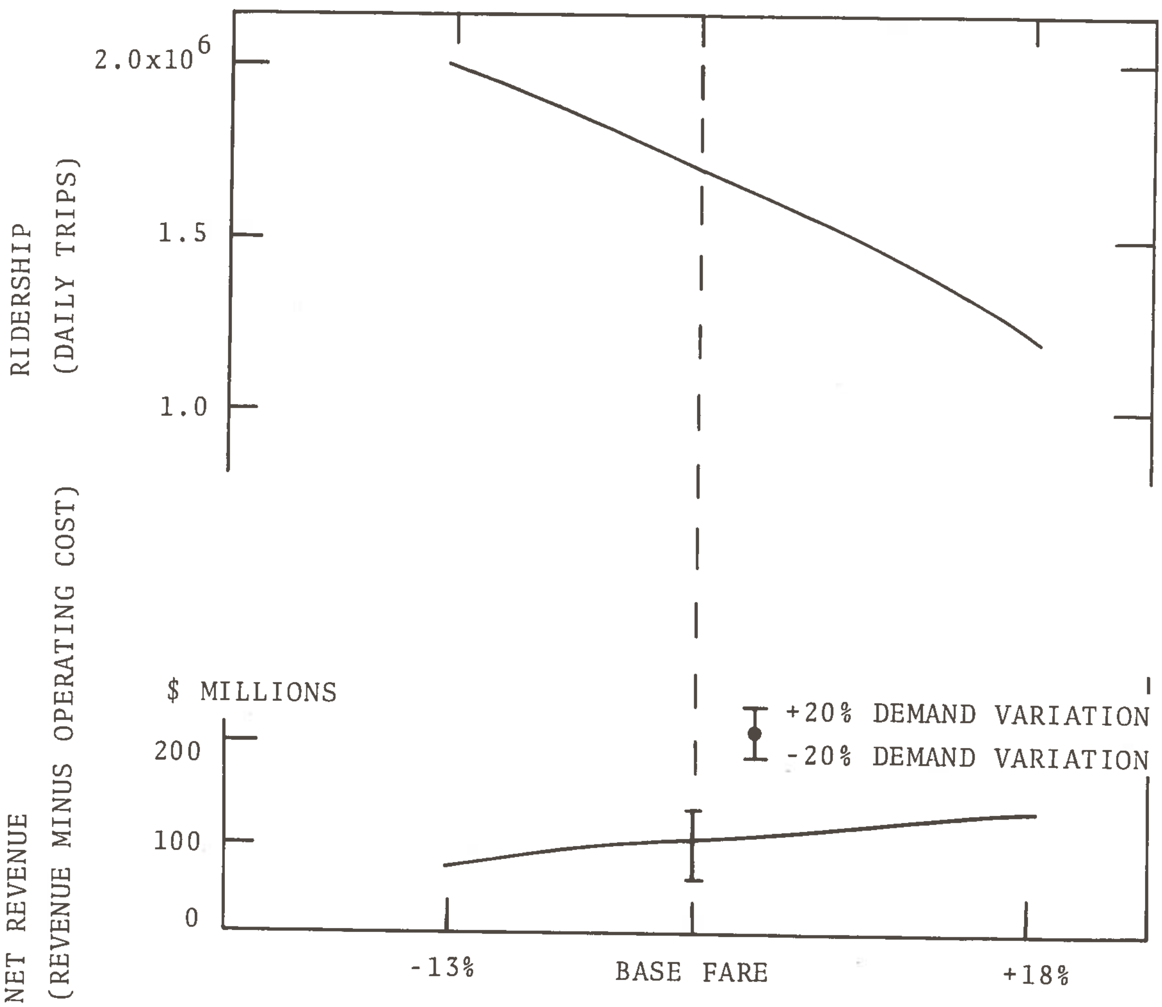


Figure 3-39 Effect of Fare Variation on Net Revenue and Ridership of New Small Vehicle System

Impact (Relative to 1990 Plan)	Quantitative Units	Dollar Value Per Unit	Total \$ Benefits (x 10^6)	Annual \$ Benefits (x 10^6)
Benefits:				
Travel Time Savings				
Passenger Modes	94.6 x 10^6 hours/yr.	\$3.00/hour	--	284
Trucks	8.2 x 10^6 hours/yr.	\$6.00/hour	--	49
Total				333
Driver Relief	63.7 x 10^6 hours/yr.	\$1.50/hour	--	96
Accident Savings	8,800 accidents/yr.	\$1,108/accident	--	10
Displacement Savings				
Relocation (Household)	52,700 households	\$ 1,604/household	85	9
Aggravation (Household)	52,700 households	\$20,000/household	1,054	105
Relocation (Business)	330 businesses	\$ 3,076/business	1	-
Total			1,140	114
Land Value Increase				
Improved Accessibility	18.6% incr. in speed	Note 1	2,670	267
Reduction in Noise Impacted Households	40,700 households	\$4,640/household	189	19
Total			2,859	286
Tax Revenue Increase				
Savings in Land Acquisition	\$ 327 x 10^6	\$55/\$1,000 annually[2]	--	18
Land Value Increase-Access.	\$2,670 x 10^6	\$59/\$1,000 annually[2]	--	158
Land Value Increase-Noise	\$ 189 x 10^6	\$57/\$1,000 annually[2]	--	11
Total				187

Figure 3-40 Dollar Valuation of Benefits - New Small Vehicle System

Impact (Relative to 1990 Plan	Quantitative Units	Dollar Value Per Unit	Total $ Benefits (x 10^6)	Annual $ Benefits (x 10^6)
Disbenefits:				
Pollution Increase				
NO_x	2,000 tons/yr.	$ 51/ton	--	-
Particulates	700 tons/yr.	$205/ton	--	-
SO_2	7,800 tons/yr.	$250/ton	--	2
CO	-14,000 tons/yr.	$ 2/ton	--	-
HC	- 1,600 tons/yr.	$130/ton	--	-
Total	- 5,100 tons/yr.			2
Net Benefits:				$1,024

(1) The percentage increase in speed was used to determine the percentage increase in land value, which in turn was applied to the base value of land in the affected region (about $17 billion) to obtain the net increase in land value. (See Volume III, Chapter 6.8 for a detailed description of land value change calculations).

(2) This is a weighted average of the actual values used. The calculation was performed by multiplying the number of impacts in the CBD, urban, and suburban rings by the respective unit dollar value. Household values and tax rates by ring are given in Volume III, Chapter 6.

Figure 3-40 Dollar Valuation of Benefits - New Small Vehicle System (Cont.)

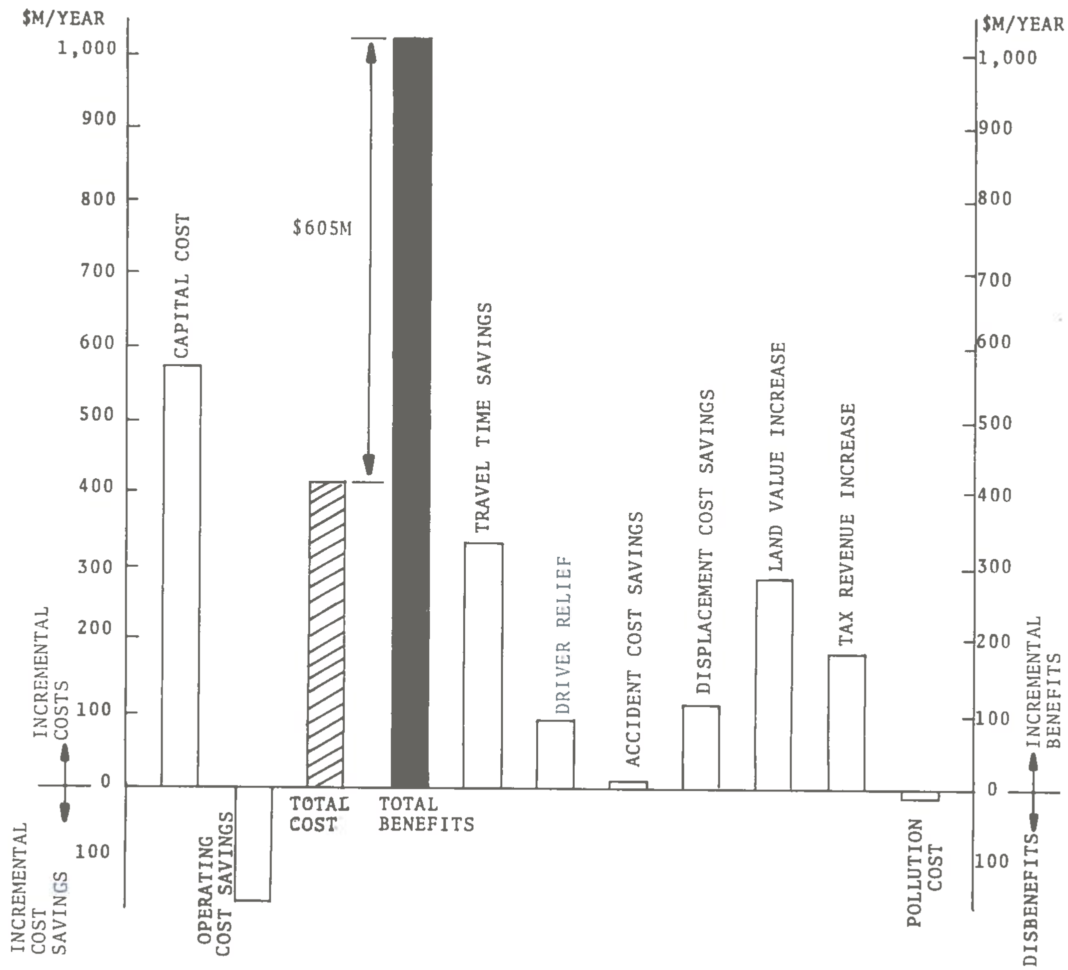


Figure 3-41 Regional Annual Incremental Costs and Benefits Relative to 1990 Plan (New Small Vehicle System)

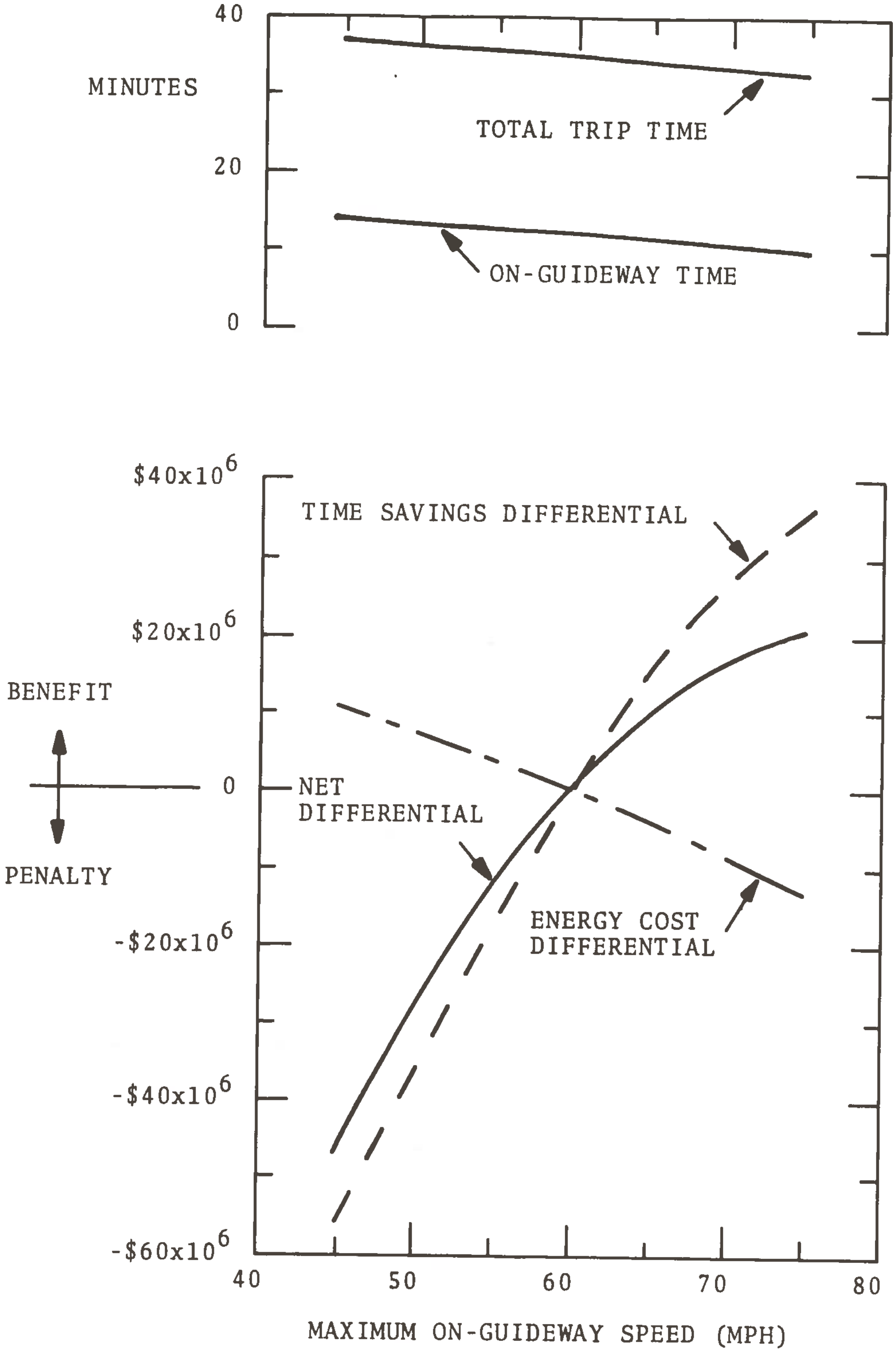


Figure 3-42 Small Personal Vehicle Speed Variation

of reducing these times must be found before significant changes in travel time can be achieved by changes in on-guideway speeds.

Although the travel time variations are small, their monetary value significantly outweighs the energy cost. The sum of the time and energy cost* differentials essentially mirrors the time cost curve. Considering the costs of time and energy, a 75 mph top speed on the guideway seems to be desirable, although speeds much above this appear to be unwarranted for the specific case studied. Longer on-guideway trips would benefit more from the higher speeds than the trips considered here. The advantage in saved time grows more slowly and the penalty in energy cost increases more rapidly at the higher speeds, and the net differential (time + energy) begins to flatten out. Conversely, at low speeds (below 60 mph) the time cost penalty increases faster than the benefit gained by reducing energy costs. This analysis ignored such factors as the effect of speed on patronage, pollution, and acceleration and deceleration lane lengths (affecting capital costs). However, it does suggest that 60 to 75 mph speeds are desirable and would be even more so in a system having a higher ratio of on-guideway to total travel time.

Since Dual Mode interchanges account for between 76 and 85% of total household displacements (depending on the particular baseline), they are an appropriate candidate for parametric analysis. The Dual Mode network was originally laid out with 15, 30, and 60 mph interchanges, which require .5, 7, and 115 acres, respectively, for a 4-way configuration.** In view of the tremendous growth in acreage requirements as speed increases (e.g., raising the speed at an interchange from 30 to 60 mph leads to a more than 16-fold increase in acreage) and in view of the predominance of 60 mph at-grade interchanges, the effect of reducing the maximum interchange speed to 30 mph was examined.

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*Based on the assumed value of energy cost and travel time used in this analysis. Significant changes in these values could alter this conclusion.

**See Volume III, Chapter 4.6 for a discussion of interchange design.

Figure 3-43 shows the effect of these speed reductions on travel time, capital cost, displacements, tax revenue losses, and land requirements. Although average trip time increases by only 2%, the annual cost of this time delay amounts to over $23 million when the total number of Dual Mode trips is taken into account. This time penalty cost is only partially balanced by the $20.3 million savings due to interchange structural, track, and land costs, savings in displacement costs associated with interchanges, and savings in tax losses. Thus, from a purely cost/benefit standpoint reduced interchange speeds are unwarranted. However, outside of the realm of cost/benefit analysis which considers only monetary factors, it is conceivable that individual travelers would be willing to spend an additional .7 minutes per trip to minimize the aesthetic disharmony and neighborhood disruption caused by very large interchanges.

A parametric analysis was performed on the effect of varying guideway speed, queuing or merge delays, and terminal processing delays on small personal vehicle ridership. The results of these studies are shown in Figure 3-44. The leftmost plot on Figure 3-44 shows the effect on ridership when speed is uniformly varied over the Dual Mode guideway. A reduction of 67% from the nominal speed of 60 mph results in a loss of 50% of the ridership. The center plot illustrates the effect on ridership when variations occur in the time spent queuing for a reserved path through the guideway (equivalently, delays due to merging), expressed as a function of the number of merges in a trip. That is, the time variable is the delay per on-guideway merge encountered in a Dual Mode trip. A 67% increase in this delay time results in a 20% loss in ridership. The plot on the right shows the effect of varying station processing time. Like queuing or merge delays, ridership is relatively insensitive to station processing time. Doubling the nominal value of this variable decreases ridership by only 20%. For SPV trips terminating off the guideway, conventional parking associated with the destination zone was charged the same as for the conventional

	Change Due to Conversion of 60 mph to 30 mph Interchanges	Resultant Change in Annual Dollar Value
Additional Cost:		
Increase in Average Trip Time	+ 0.7 minutes (1)	$23,200,000 (2)
Additional Benefits:		
Decrease in Interchange Capital Cost		$ 8,900,000
Decrease in Displacements Due to Interchanges	-4,170 households	$ 9,000,000 (3)
Decrease in Tax Losses Due to Interchanges		$ 2,400,000
		$20,300,000
Net Cost		$ 2,900,000

(1) The time delay per trip is based on the assumption that the average trip is routed through 5 interchanges, with a 90° turn at 3 of these. The average time needed for a turn was calculated to be 0.46 minutes at 60 mph and 0.69 minutes at 30 mph.

(2) Passenger time is valued at $3.00 per hour, and driver relief time is valued at $1.50 per hour.

(3) Household displacements are costed at $21,600 per displaced unit, reflecting relocation and aggravation costs.

Figure 3-43 Effect of Reducing Interchange Speed from 60 mph to 30 mph

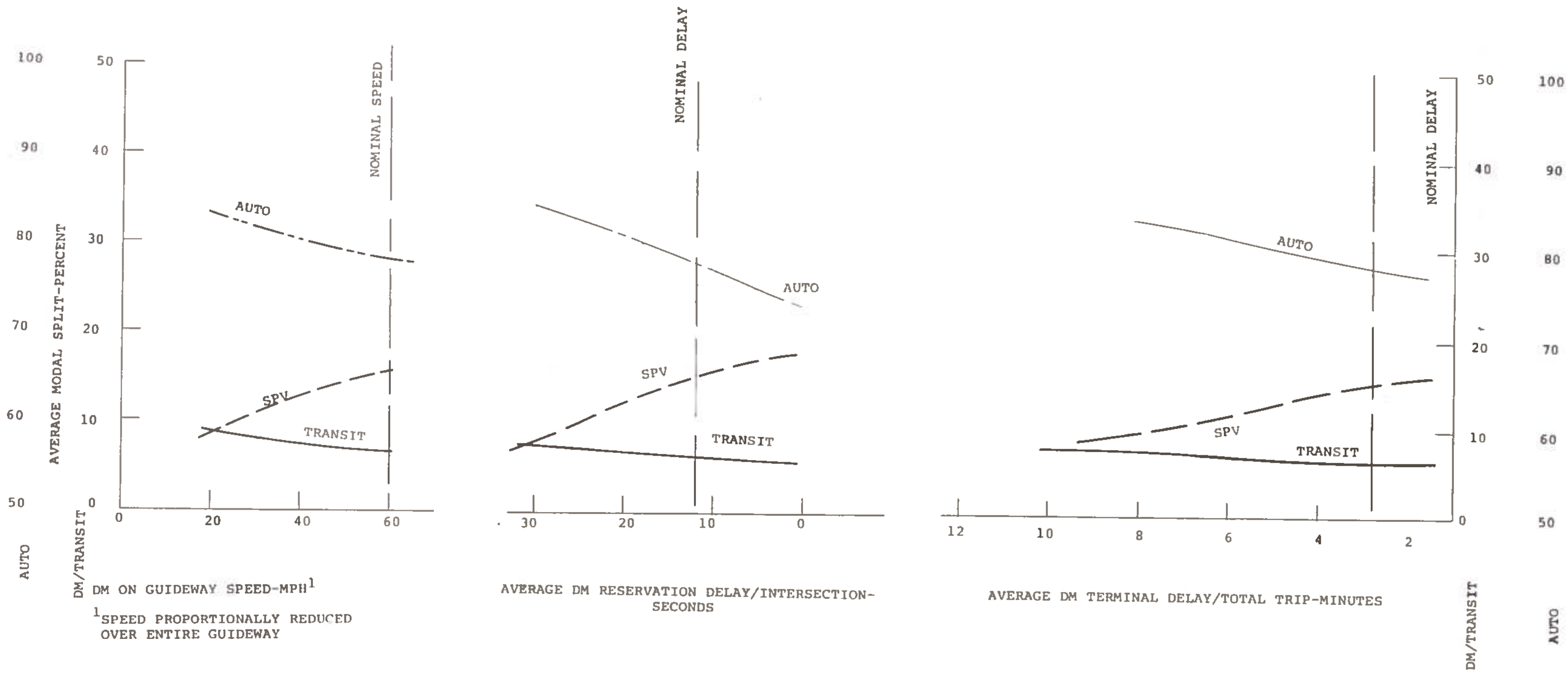


Figure 3-44 Effects of Varying System Operating Characteristics on Small Personal Vehicle Modal Split

auto. No system parking was provided. A modal split curve for the minibus is not shown on the charts since it was essentially unaffected by the small personal vehicle ridership variations.

3.4 SYSTEMS COMPARISONS

3.4.1 Service

In terms of effect on the regional transportation system, the new small vehicle baseline is the most significant Dual Mode alternative (Figure 3-45). It provides the fastest regional average trip speed, the greatest reduction of street congestion and the fastest Dual Mode average trip speeds of any of the baselines. Although the variations in these parameters among the baselines are not extreme, they are consistent and often significant. Two factors account for the regional travel time savings resulting from the presence of a Dual Mode baseline: the shorter travel times on the Dual Mode system itself and its ability to attract highway travelers and thereby reduce street congestion. On both counts the new small vehicle system is superior to the other baselines.

Figure 3-46 presents a number of comparative statistics for the vehicles in the various baselines. Of particular interest are the fleet sizes and utilization rates. The small personal vehicle fleet is the largest in size and the lowest in utilization. These characteristics are due to the fact that for the most part vehicle usage is similar to that of an automobile, with vehicles being used only for a couple of trips during the day and lying idle the remainder of the time. Since there is little common usage of the vehicles, quite a large fleet is necessary. The pallet, on the other hand, has the highest utilization of any of the vehicles. This is because pallets can service a large number of automobiles during the course of the day, particularly during the peak period.

	1990 Plan	Pallet System	Automated Highway Vehicle System	New Small Vehicle System
Route Miles	114 Highway[1] 29 Transit	249	249	261
Lane Miles		1138	966	1506
Dual Mode Daily Modal Split (%)		12	11	16
Transit Daily Modal Split (%)	10	6[2]	6[2]	6[2]
Peak CBD Modal Split (Dual Mode/Transit) (%)	46	22/35	21/36	53/21
Peak Period Surface Arterial Speed (mph)	15.8	17.7	17.5	18.6
Average Regional Trip Speed (mph)	16.1	18.4	18.1	19.1
Daily Regional Time Savings (years)		19.4	19.3	36.0
Average Dual Mode Trip Speed (mph)		24.0	23.8	25.3
Typical Dual Mode Trip Time Savings (min)		17	16	19

(1) Highway and transit miles not built when Dual Mode is constructed.

(2) Does not include the Dual Mode users transferring to transit at parking garages.

Figure 3-45 Comparative Service

VEHICLE	NO. PASS.	LIFE (YRS.)	FLEET SIZE	COST/ VEH.	AVERAGE LOAD FACTOR	HRS./ DAY (1)	MILES/ DAY(1)
SMALL PERS. VEH.	4	6	418,000	4,500	.38	1.29	37.2
MINIBUS	12	12	2,900	30,000	.44	3.29	79.2
PALLET	6	12	20,000	30,000	.25	6.41	364.0
DUAL MODE BUS	20	12	2,300	35,500	.41	3.23	86.0
DUAL MODE AUTOMOBILE	6	6			.25		
DUAL MODE BUS	20	12	2,300	35,500	.41	3.23	86.0

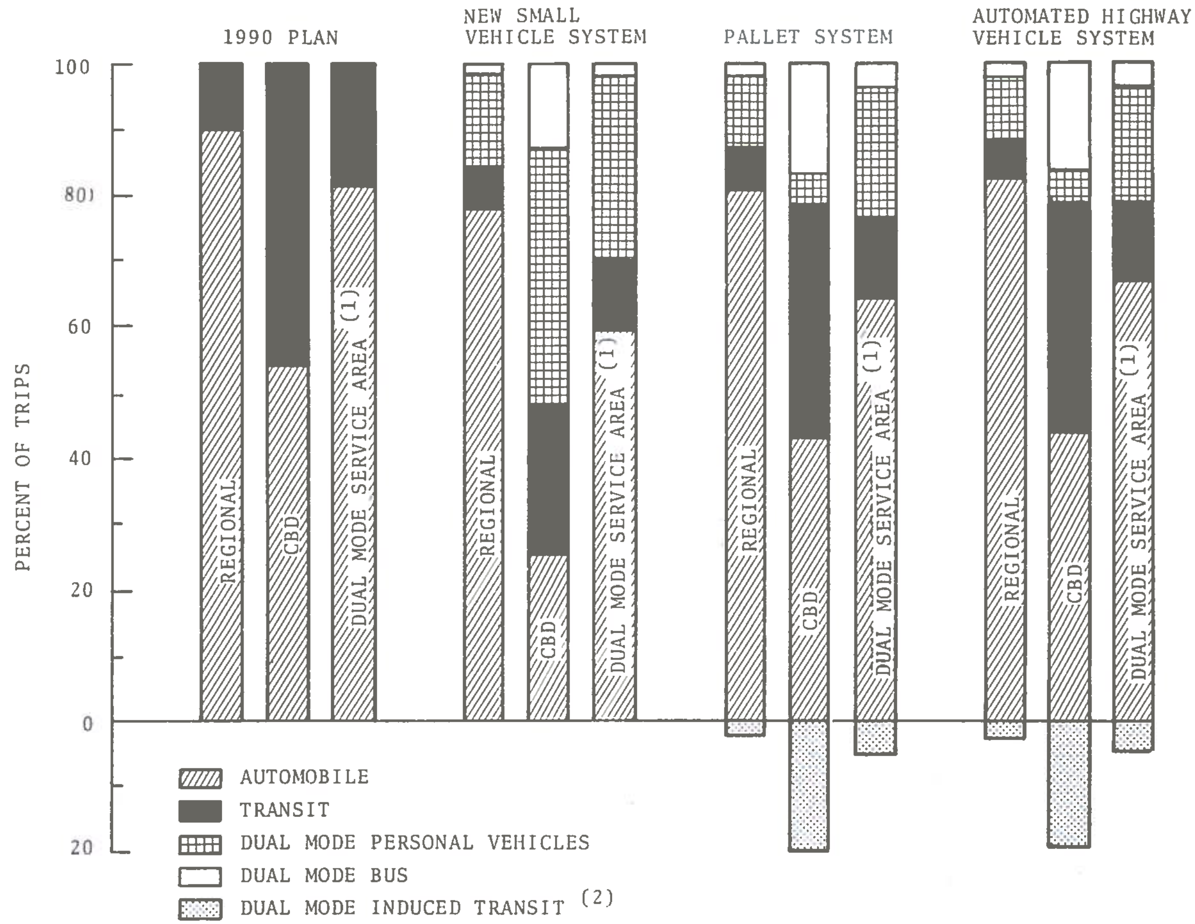
(1) SPENT IN REVENUE SERVICE

Figure 3-46 Dual Mode Vehicle Statistics

The utilization values for the various Dual Mode buses are all within the bounds represented by the small personal vehicle and the pallet. With the buses, the utilization is a function of the patronage, the assumed load factors, and the fleet size necessary to provide the desired service. Thus, the utilization figures represent the time and distance traveled if all the buses, loaded to the assumed load factors, made only the number of trips necessary to accomodate their passengers. The buses actually spend a good deal more time operating, but in a nearly empty condition.

The new small vehicle system attracts the largest ridership, as seen in Figure 3-47. The 1.7 million users represent almost a 30% greater ridership than the pallet system, its nearest competitor. On CBD trips the dominance of the new small vehicle system is even more pronounced. Its share of these trips (53%) is 140% greater than the pallet system's share. The new small vehicle system reduces regionwide automobile use by the greatest amount and, in particular, reduces auto trips to the CBD by 52% from the 1990 plan. Regionwide, transit also experiences a greater loss to the new small vehicle system (38%) than to the other baselines. Interestingly, because the pallet system and automated highway vehicle system connect with transit for CBD collection and distribution, they actually generate some transit ridership. For example, regionwide the pallet system induces enough transit ridership to make up 70% of the reduction it causes, and transit winds up with 60% greater patronage for CBD trips than it would have had in the 1990 plan, due to this induced ridership.

A comparison of various travel statistics among the Dual Mode baselines is presented in Figure 3-48. It is interesting to note the differences in speeds and trip lengths between the personal-type Dual Mode vehicles (pallet, Dual Mode auto and small personal vehicle) and the Dual Mode buses. The personal-type vehicles attract, on the average, longer trips than the Dual Mode buses. Thus they travel a relatively greater portion of total trip



(1) REFERS TO THAT PORTION OF THE REGION ACTUALLY SERVED BY DUAL MODE.

(2) REFERS TO THE DOWNTOWN COLLECTION AND DISTRIBUTION PERFORMED BY TRANSIT FOR THE PALLET AND AUTOMATED HIGHWAY VEHICLE SYSTEMS.

Figure 3-47 Patronage Comparisons

ALTERNATIVE	PASS. TRIPS/DAY (10^6)	AVE. TRIP LENGTH (MI.)	AVE. TRIP. SPEED (MI./HR.)	TRAVEL TIME SAVINGS PER TRIP(MIN.)
1990 PLAN				
HIGHWAY	9.7	5.5	17.8	-
TRANSIT	1.0	3.8	7.2	-
PALLET	1.1	15.0	24.7	14.1 (1)
DUAL MODE BUS	.2	8.9	18.0	45.1 (2)
DUAL MODE AUTO	1.0	14.6	24.6	13.6 (1)
DUAL MODE BUS	.2	8.9	18.0	45.1 (2)
SMALL PERS. VEH.	1.6	14.4	25.2	14.2 (1)
MINIBUS	.1	10.6	18.4	54.5 (2)

(1) COMPARED TO 1990 PLAN TYPICAL AUTO TRIP OF SAME LENGTH
(2) COMPARED TO 1990 PLAN TYPICAL TRANSIT TRIP OF SAME LENGTH

Figure 3-48 Comparative Travel Statistics distance on the guideway than the buses, resulting in a relatively high average trip speed. Significant increases in average trip length and speed occur for both the personal-type Dual Mode vehicles and the Dual Mode buses over their non-Dual Mode counterparts in the 1990 plan. In both cases, longer trips are attracted to the inherently faster Dual Mode systems.

The effect of Dual Mode ridership on peak period surface arterial speed is shown in Figure 3-49. For a given daily Dual Mode ridership level, the differences between surface arterial speeds for the various baselines is due to the number of people taking Dual Mode buses compared with the number using the personal vehicles. Although the personal Dual Mode vehicles are on the local streets (and thus adding to congestion) only during the off-guideway portion of their trips, the variation in their number among the baselines is sufficient to noticeably affect the peak period surface arterial speed. The automated highway vehicle baseline has more Dual Mode bus riders than the other baselines and, consequently, fewer automobiles on the local streets.

3.4.2 Impacts

Figure 3-50 presents data on selected impacts for the 1990 plan and the three Dual Mode alternatives.

A. CBD Parking Spaces

The Boston CBD area has about 55,000 automobile parking places at the present time. By 1990, if the current rate of usage continues, approximately 80,000 will be required. With the pallet system, nearly the same number of automobiles will be coming into the area. However, some of the pallet-transported automobiles will be parked in stations located on the periphery of the CBD, even though their occupants are headed for the CBD itself. Therefore, although the total number of spaces remains approximately the same, within the CBD only about 70,000 parking spaces (for Dual Mode and conventional vehicles) are required. The automated highway vehicle baseline requires slightly fewer CBD parking spaces since it does not attract as many trips away from transit as does the pallet system. The new small vehicle baseline results in the biggest reduction in CBD parking spaces, since the small personal vehicles attract a large number of automobile travelers and the vehicles themselves need no parking facilities within the CBD. In fact, the 39,000 spaces required by this baseline are less than are now available in the CBD.

B. Energy Consumption

According to the gross energy consumption data in Figure 3-50, all of the Dual Mode systems result in greater daily regional energy requirements than does the 1990 plan. This is partially because a trip via Dual Mode is often longer, due to guideway layout, than the same trip by conventional means, and partially because of the higher average speeds attained by the Dual Mode vehicles. The pallets further adversely affect the regional energy consumption owing to their large size and weight.

A measure of the energy efficiency of a transportation system is the ratio of passenger miles generated to energy consumed. Figure 3-51 compares Dual Mode baselines and the 1990 plan in terms of energy efficiency, as well as their effect on the overall passenger transportation system of the area (trucks are not included in the system results). The dashed vertical line on the figure is aligned with the 1990 plan system results for purposes of comparison. It might be noted that in all the baselines, the standard automobile efficiency is very nearly (slightly less than) that of the overall system results for the 1990 plan, hovering around 0.5 passenger miles/1,000 BTU's.

The vehicles with higher speeds suffer in energy efficiency when compared with slower ones since the power required to overcome aerodynamic resistance increases with the cube of the vehicle's velocity. Thus, the Dual Mode vehicles in general are lower in energy efficiency than their non-Dual Mode counterparts,

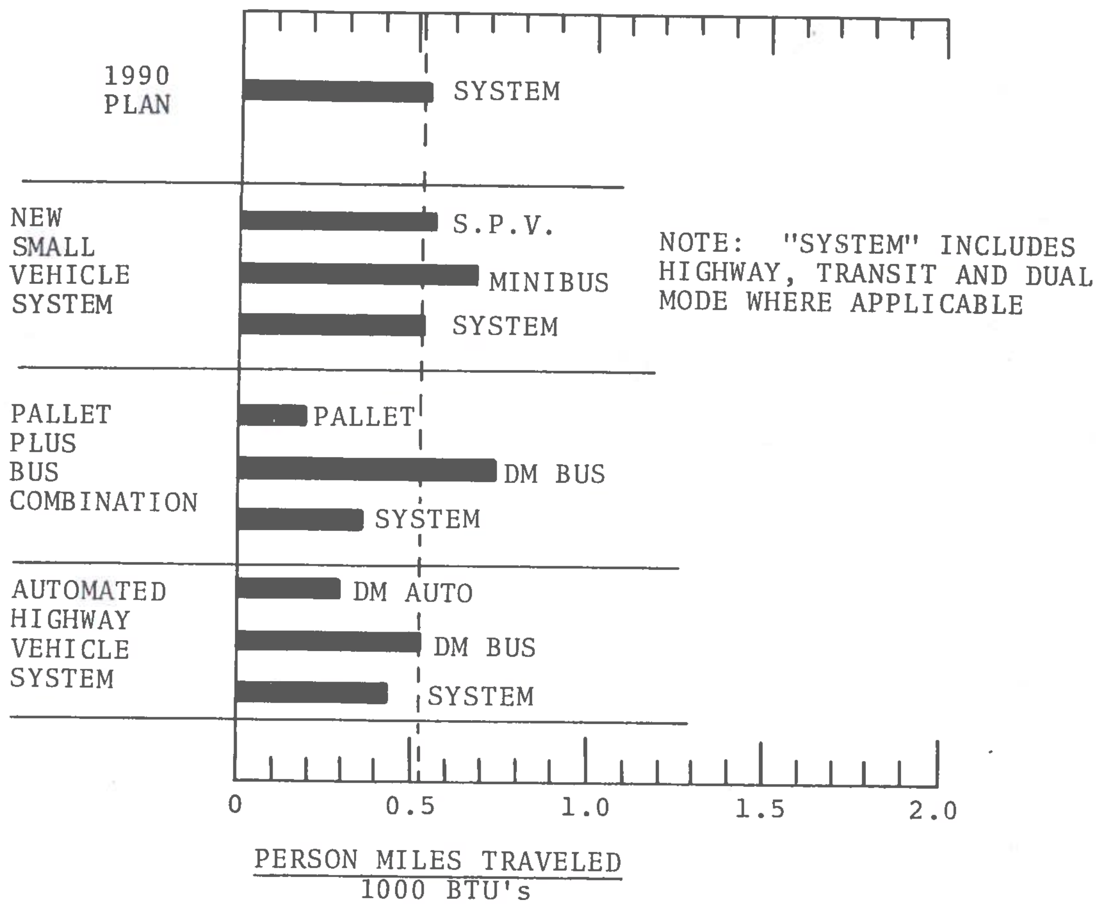


Figure 3-51 Energy Consumption Comparisons

as exemplified by the Dual Mode automobile in the automated highway vehicle baseline, which has approximately 60% the efficiency of the standard automobile.

Besides speed, the other factors influencing energy efficiency are vehicle weight, frontal area, aerodynamic drag coefficient, and propulsion system efficiency. The pallet, because of its high weight and large frontal area, yields a very low energy efficiency. The diesel-powered Dual Mode bus in the automated highway vehicle baseline comes out with a lower efficiency than does the identically-sized electrically powered Dual Mode bus in the pallet baseline. This is attributable to the the lower efficiency of a diesel engine in converting fuel to energy as compared with an electric power plant. The personal Dual Mode vehicles generally are poorer in energy efficiency than larger Dual Mode buses, because each one carries so few passengers and thus generates relatively few passenger miles per vehicle mile. The small personal vehicle, because of its light weight, small frontal area, and efficient aerodynamic design, is quite good in energy efficiency when compared to other automobile-type vehicles, in spite of its relatively high average cruising speed.

In general, except for the pallet and the automated highway vehicle baselines, Dual Mode does not significantly impact the overall transportation system energy efficiency. A greater patronage on the Dual Mode vehicles would have resulted in a larger effect on the system average, with the nature of the effect being dependent upon their indivudual efficiencies. The energy consumption calculation for standard automobiles was based upon average automobile speed; however, the fuel wasted due to traffic congestion and stop-and-go driving was not taken into account, and this factor can be expected to improve the standings of the Dual Mode vehicles in comparison.

C. Air Pollution

From a pollution standpoint, the various Dual Mode systems present a mixed picture. It should be kept in mind, however, that the results presented here depend on the assumptions made concerning the pollution emission characteristics of the various systems. These assumptions and their implications are discussed in Volume III, chapter 6.1.

From the standpoint of person miles generated per pound of total pollution produced, the small personal vehicle and electrically-powered Dual Mode buses are quite attractive, while the pallet, Dual Mode automobile and diesel-powered Dual Mode bus do not fare so well. Figure 3-52 shows the relative standings. The electrically-powered systems in general emit less pollution than do the ones powered by internal combustion engines, as exemplified by the Dual Mode buses in the pallet and automated highway vehicle baselines. The pallet, because of its size and weight, consumes a good deal more energy per mile of travel than does the small personal vehicle and consequently causes a greater pollution emission. The Dual Mode buses in general cause less pollution than the smaller, personalized vehicles. This is due to the fact that the buses carry more people per vehicle mile than the smaller vehicles. Again, the diesel-powered bus in the automated highway vehicle system is an exception, being a relatively prodigious producer of pollution. The small personal vehicle baseline significantly increases the pollution efficiency of the regional transportation system compared with the 1990 plan, the pallet baseline significantly decreases it, and the automated highway vehicle system has little effect on it.

If the dollar costs of the various species of pollutants are considered, the picture is somewhat different, as indicated in Figure 3-53. As explained in Volume III, Chapter 6.1, the particulates and sulfur dioxide produced by electrically-powered systems impose a far greater unit cost than do the other constituents. This accounts for the relatively low values of passenger miles per dollar cost of pollutants achieved by the electrically-powered Dual Mode systems. The diesel-powered Dual Mode bus in the

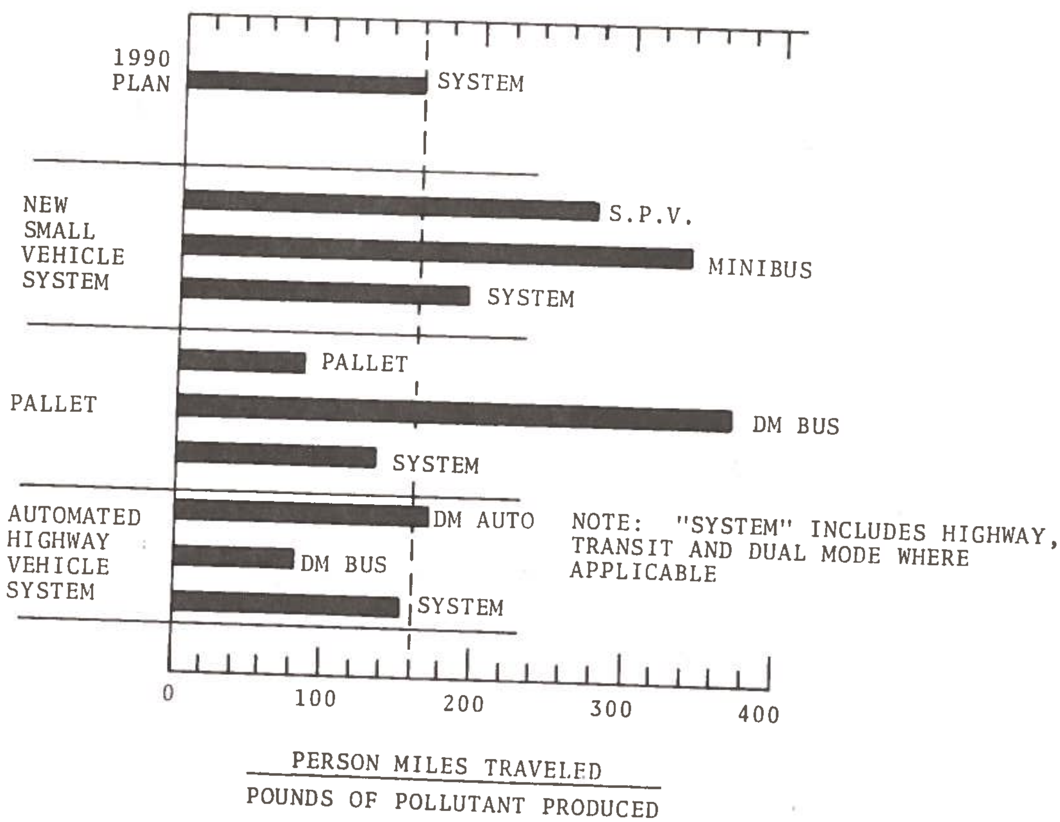


Figure 3-52 Pollution Output Comparisons

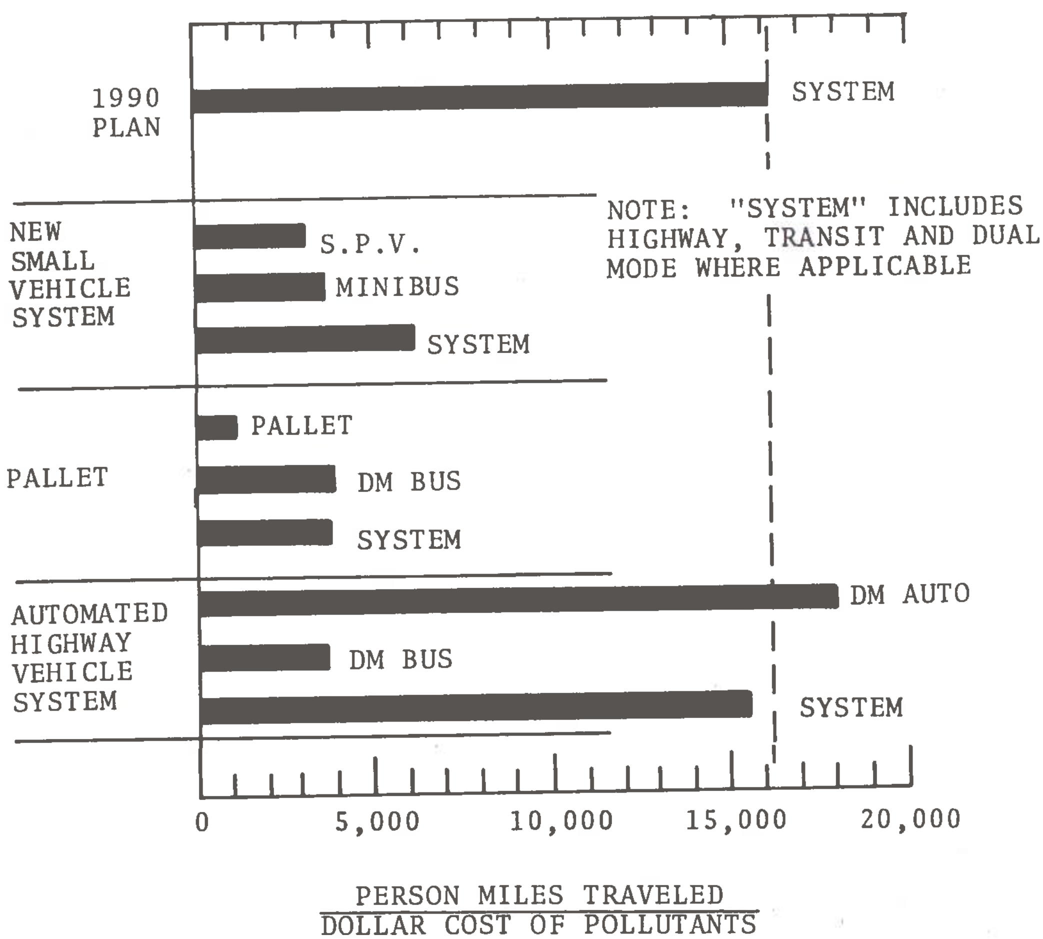


Figure 3-53 Pollution Cost Comparisons

automated highway vehicle baseline and the electrically-powered ones in the other baselines yield about the same dollar efficiency. Although the diesel powered bus produces far more pollutants per passenger mile than the electrics, its pollutants are considerably less costly on a unit basis. The pallet, which makes a poor showing on a pollution quantity basis, depresses the regional transportation system average even more on the pollution cost basis. In fact, all of the electrically-powered Dual Mode systems depress the regional system average below that of the 1990 plan. In the automated highway vehicle system, on the other hand, the Dual Mode automobile is relatively innocuous from a pollution cost standpoint. It draws travelers from electrically-powered rail transit and from diesel buses, thus helping to improve the system average, but the negative effects of the Dual Mode diesel bus cause a net reduction in the system average, nevertheless.

D. Safety

As can be seen from Figure 3-50, all three Dual Mode systems result in a decrease in regional annual traffic accidents, with the percentage reduction ranging from 7.9 to 14.2%. All three alternatives likewise bring about a reduction in regional fatalities (7.5 to 15.6% decrease).

These results are based on the assumption that accident and fatality rates on the guideway are equivalent to the very low rates (per vehicle mile) experienced by certificated air carriers*; however, a parametric analysis of on-guideway rates (varying accident and fatality rates through a range including those of air carrier, rapid transit, highway, and bus systems and the idealized accident-free case) revealed that Dual Mode systems result in fewer traffic accidents than the 1990 plan if on-guideway travel is as safe as

*The rationale for this assumption appears in Section 3.1.2.

current-day travel by airlines and rapid transit systems, and that they result in comparatively fewer deaths if the fatality rate is as low as that achieved by airlines and, in certain cases, buses. The reason for Dual Mode's superior safety record compared to the 1990 plan is that some of the travel that would otherwise take place on highway and transit facilities is diverted to Dual Mode, which has an on-guideway component which is assumed to be safer than highway and transit travel. The baseline which performs the best from a safety standpoint is the new small vehicle system, which diverts the largest percentage (about 16%) of highway and transit travel.

E. Noise Effects

Figures 3-54 and 3-55 show the number of households adversely impacted by noise from the 1990 plan and the three Dual Mode alternatives. During the daytime, when people's tolerance to transportation noise is relatively high (10), Dual Mode operations on the 249 route miles of guideway (261 for the new small vehicle system) adversely affect only 0.8 to 2.5% the number of households impacted by traffic noise from the 144 miles of highway and transit additions for the 1990 plan. At night, the comparative advantage of Dual Mode systems over the 1990 plan is even greater; the noisiest baseline, the automated highway vehicle system, results in only 1.1% the impacted households associated with the 1990 plan. In general, the reasons for the negligible noise impact of Dual Mode systems compared to the planned highway and transit additions are the smaller number of lanes (3 for Dual Mode vs. 6 for highways), more extensive and effective use of barriers (every Dual Mode lane has a 32" barrier on either side, whereas highways are only assumed to have barriers between the median strip and the inner lanes), and the location of at least 80% of the Dual Mode guideway along existing transportation right of way. In the case of right of way accommodating operative facilities, the noise level due to conventional modes usually masks the presence of Dual Mode

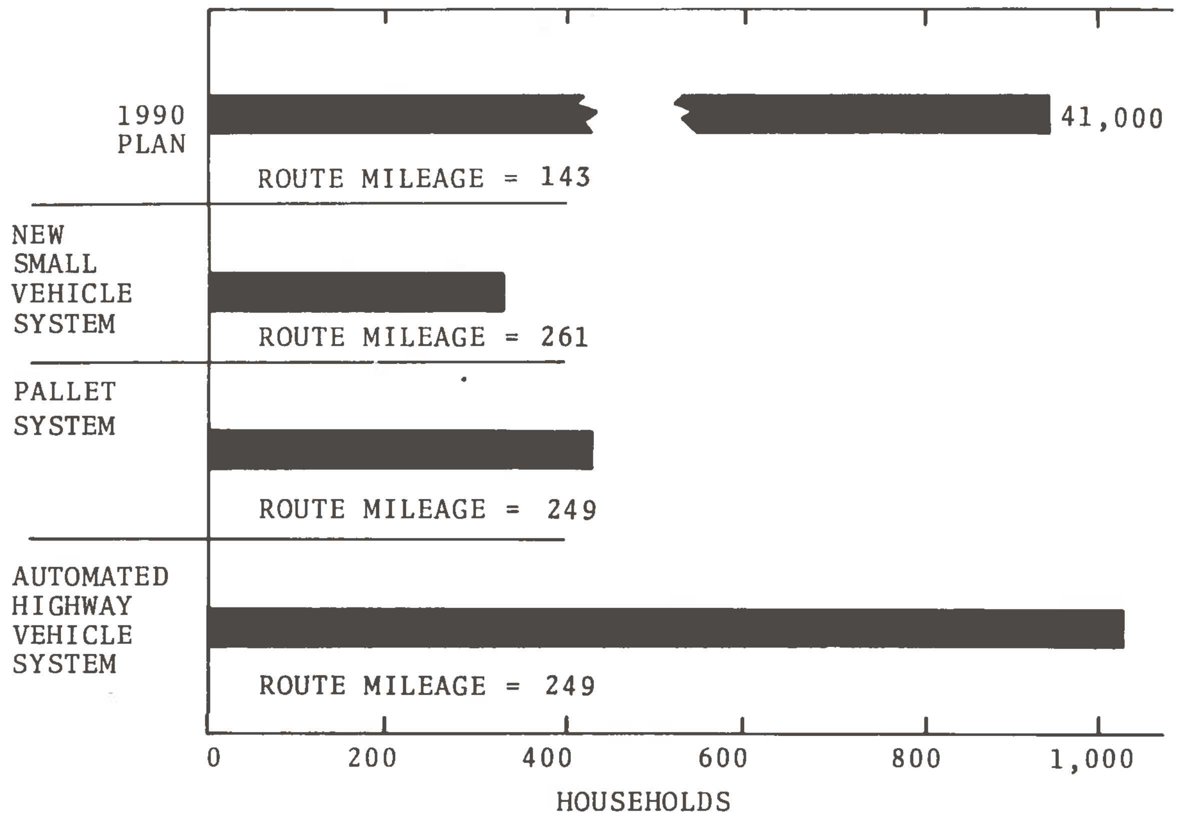


Figure 3-54 Noise Impacted Households* - Daytime

*Associated with new transportation facilities.

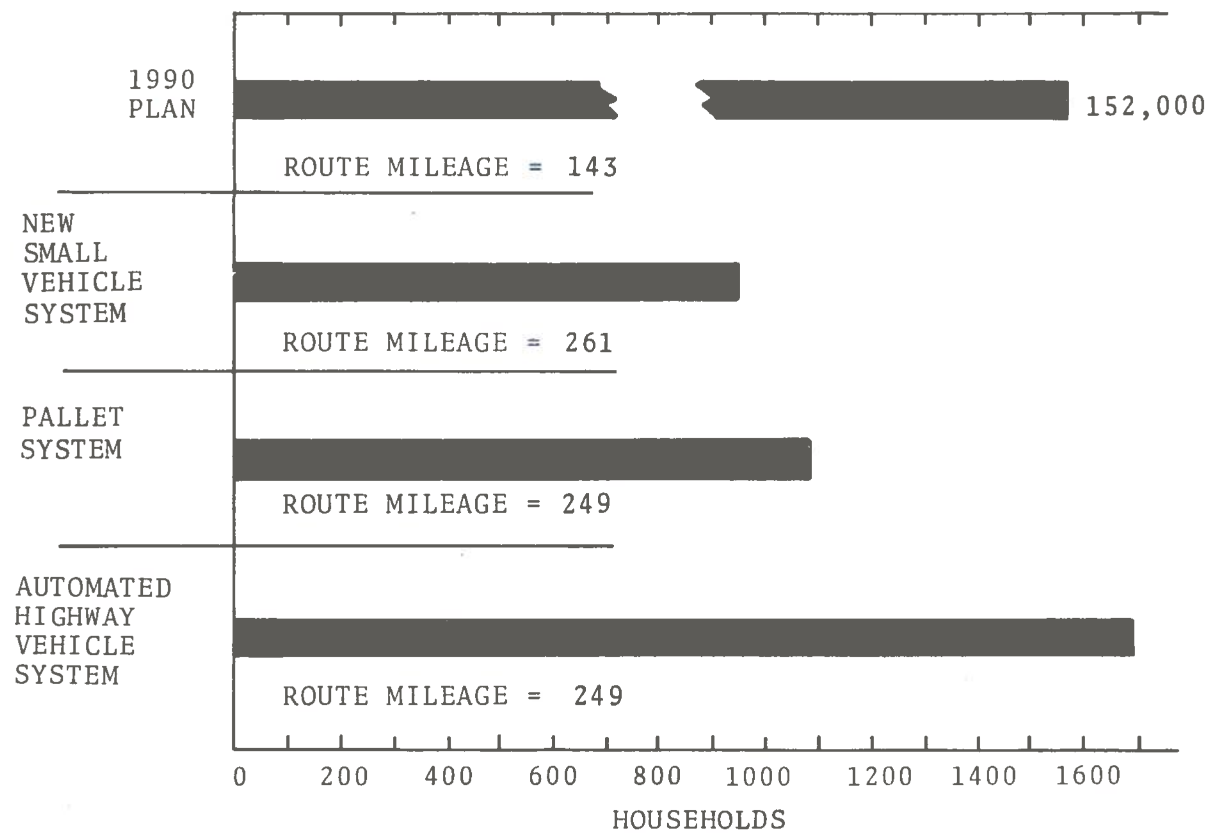


Figure 3-55 Noise Impacted Households* - Nighttime

*Associated with new transportation facilities.

vehicles; in the case of abandoned rail lines, there is no masking effect, but the relatively large right of way width (60 to 99 feet) provides additional buffer space between the Dual Mode noise band and the nearest houses. The variation between the Dual Mode baselines is explained by such factors as vehicle noise output, number of vehicles per hour per lane, network length, and extent of tunneling. For instance, the downtown network and its approaching links are tunneled for the new small vehicle system, whereas for the other baselines they are largely at-grade. This contributes to the relative quietness of the new small vehicle baseline. All baselines but the automated highway vehicle system involve electrically-powered vehicles, which are quieter than vehicles powered by internal combustion engines. (It should be noted, however, that regardless of the propulsion method, tires are the predominant noise source, especially at high speeds.)

There is no doubt that electrically powered systems are to be preferred from a noise standpoint over the automated highway vehicle baseline, whose automobiles and buses are powered by internal combustion engines. However, it is difficult to pinpoint a "best" electrically powered baseline, especially since the idiosyncracies in network design are partially removed by presenting the number of noise impacted households on a route mile basis. But this should not be a source of concern; in view of the very dramatic improvement which Dual Mode systems (including the automated highway vehicle system) represent over the 1990 plan, it is perhaps unnecessary to attempt to identify a preferred baseline.

F. Displacements

Dual Mode systems perform almost as well compared to the 1990 plan from a displacement standpoint as from a noise standpoint. Although the Dual Mode network has nearly double the route mileage of the planned highway and transit additions, household displacements are only 9 to 10% of those required by the 1990 plan, and business displacements are only 6 to 8% the number required by these additions. The reason for the low number of displacements is twofold: first, Dual Mode systems can satisfy the same regional travel needs as the 1990 plan with far less right of way (only 3,200 to 3,800 acres, depending upon the system, as opposed to 19,100 acres for the 1990 plan). (To illustrate why the Dual Mode right of way requirements are so much smaller, the guideway is only 3 lanes, or 36 feet wide, whereas the planned highway additions are around 6 lanes, or 150 to 200 feet wide; a 60-mph Dual Mode interchange takes up 115 acres of land, while a 60-mph highway interchange requires 138 or 571 acres, depending on design.) More important, the Dual Mode network makes extensive use of existing transportation right of way (e.g., abandoned rail lines), while the planned highway and transit additions are located almost entirely on new right-of-way.

Differences among baselines in the number of displacements can be largely attributed to variations in station size. The pallet and automated highway vehicle baselines require the largest stations, since loading docks and parking spaces must be provided for cars. The new small vehicle system has the smallest stations, because parking facilities are not required.

G. Tax Revenue Losses

Tax revenue losses due to land acquisition for Dual Mode are only 17 to 21% of the amount associated with the 1990 plan, and the rank ordering of the baseline variants is the same as for displacements. The explanation given for the displacement results holds for tax losses, except that the extensive use of existing transportation right of way is a much less important factor: a large portion of this existing right of way consists of abandoned rail lines, which are privately owned property and hence a current source of tax revenues.

H. Accessibility

Figure 3-56 shows comparative accessibility to four major activity centers -- the CBD, a centrally located university complex, the airport, and a suburban shopping center -- during peak

Major Activity Center		1990 Highway & Transit	Pallet System	Automated Highway Vehicle System	New Small Vehicle System
People Within 40 Minutes of:					
CBD	- Peak	2,290	2,900	2,900	3,150
	- Off Peak	3,110	3,480	3,480	3,510
University	- Peak	2,120	2,320	2,320	2,750
	- Off-Peak	3,460	3,600	3,600	3,760
Airport	- Peak	1,790	2,220	2,220	2,200
	- Off-Peak	2,660	2,740	2,740	2,740
Sub.Sh.Center	- Peak	1,210	1,810	1,810	1,760
	- Off-Peak	2,720	2,720	2,720	2,720
		1990 Transit			
CBD	- Peak	2,200	2,250	2,250	3,150
	- Off-Peak	1,680	1,680	1,680	3,110
University	- Peak	1,720	1,720	1,720	2,750
	- Off-Peak	998	1,020	1,020	2,700
Airport	- Peak	1,730	1,730	1,730	2,200
	- Off-Peak	1,000	1,000	1,000	1,990
Sub.Sh.Center	- Peak	634	634	634	1,520
	- Off-Peak	293	293	293	1,290

Figure 3-56 Comparative Accessibility of Major Activity Centers (Thousands of Persons)

and off-peak periods. The first column of the table indicates the number of people who would be within 40 minutes of these areas if the 1990 plan were implemented, and subsequent columns show how many persons would be within a 40 minute range if Dual Mode were introduced; in the upper half of the table, all forms of Dual Mode (public and private) are compared to 1990 highway and transit, while in the lower half, the comparison is limited to public Dual Mode systems vs. transit. Figure 3-57 depicts peak-period accessibility to the CBD in the form of iso-travel time contours; while this method of presenting results gives a better idea of which areas of the region stand to benefit from Dual Mode service, it would seem that numerical results are needed in order to assess the impact of Dual Mode in terms of the number and socio-economic background of people served.

Comparing Dual Mode systems to 1990 highway and transit, it can be seen that the comparative advantage of Dual Mode occurs during the peak period, when highway mobility is curtailed by congestion, but Dual Mode mobility is relatively unimpaired because guideway speeds are unchanged. The percentage increase in accessibility to the four activity centers is as much as 50% during the peak period, vs. a maximum of 13% during off-peak hours.

The relative ranking of the baselines is somewhat different for the CBD and university than for the airport and suburban shopping center; in the case of the former major activity centers, the new small vehicle system provides slightly better accessibility than the pallet and automated highway vehicle systems, reflecting the denser downtown network and the elimination of the need for parking and transfers to transit. Access to the airport and the suburban shopping center is not so dependent on a fine-grained CBD network, so the pallet and automated highway vehicle system come out ahead of the new small vehicle system.

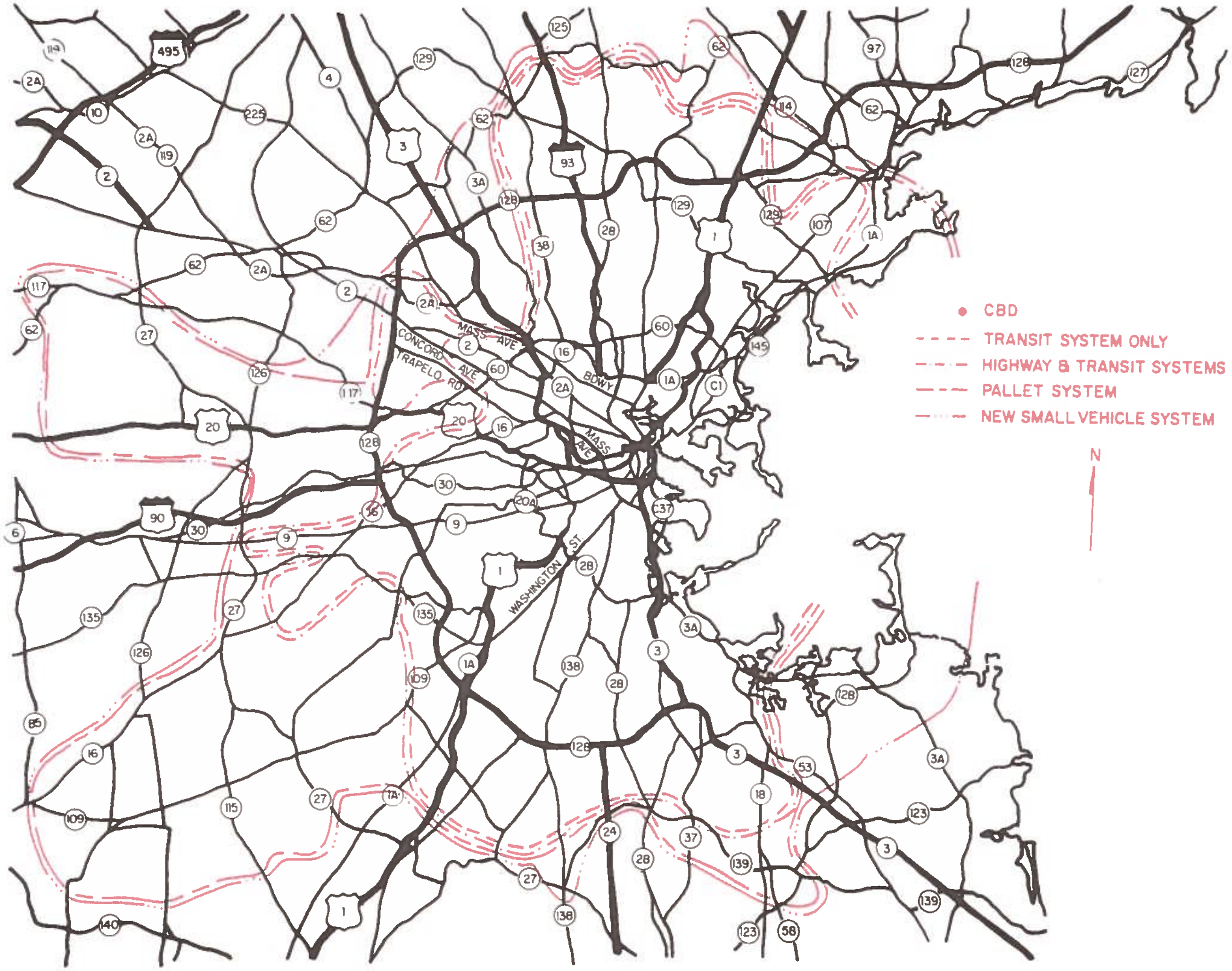


Figure 3-57 Peak Period 40-Minute Travel Time Contours Around CBD

Comparing the "public" components of Dual Mode systems to 1990 transit, one notes that the new small vehicle system performs far better from an accessibility standpoint than the other two baselines; this is because the minibus and especially the small personal vehicle provide far better service than the bus components of the pallet and automated highway vehicle systems. During the peak period, the percentage increase in the number of people who can reach the four activity centers within 40 minutes by the new small vehicle ranges from 27 to 140%; during off-peak hours, the percentage increase ranges from 84 to 339%. The comparative advantage of this baseline thus occurs during the off-peak period, when transit service is greatly curtailed (longer headways, fewer express runs, possibly smaller service area) but small personal vehicle travel time and service are unchanged. In the case of the CBD and the university zone, the new small vehicle system provides off-peak service to all the areas affected by the cut-back in transit service, so that the total number of people within 40 minutes travel time is the same during peak and off-peak periods; in the case of the other two destinations, Dual Mode service does not quite absorb the slack in transit service, with the result that fewer people can reach these areas during the off-peak period.

Regarding accessibility benefits to the 167,000 blacks, 36,000 other minority persons, and 75,000 low-income families projected to be living in the Boston region in 1990, Figure 3-58 shows the percentage of each ethnic and income group of the population within 40 minutes of the CBD during the peak period by 1990 highway and transit vs. Dual Mode. It is interesting to note that the minority and low-income groups are better served than white, middle- to upper-income groups whether or not Dual Mode is built. The introduction of the pallet or automated highway vehicle baseline brings another 4.0% of the regionwide black population, another 10.3% of the remaining minority population, and an additional 3.5% of low-income families within a 40-minute travel time range of the CBD; the percentage increments in

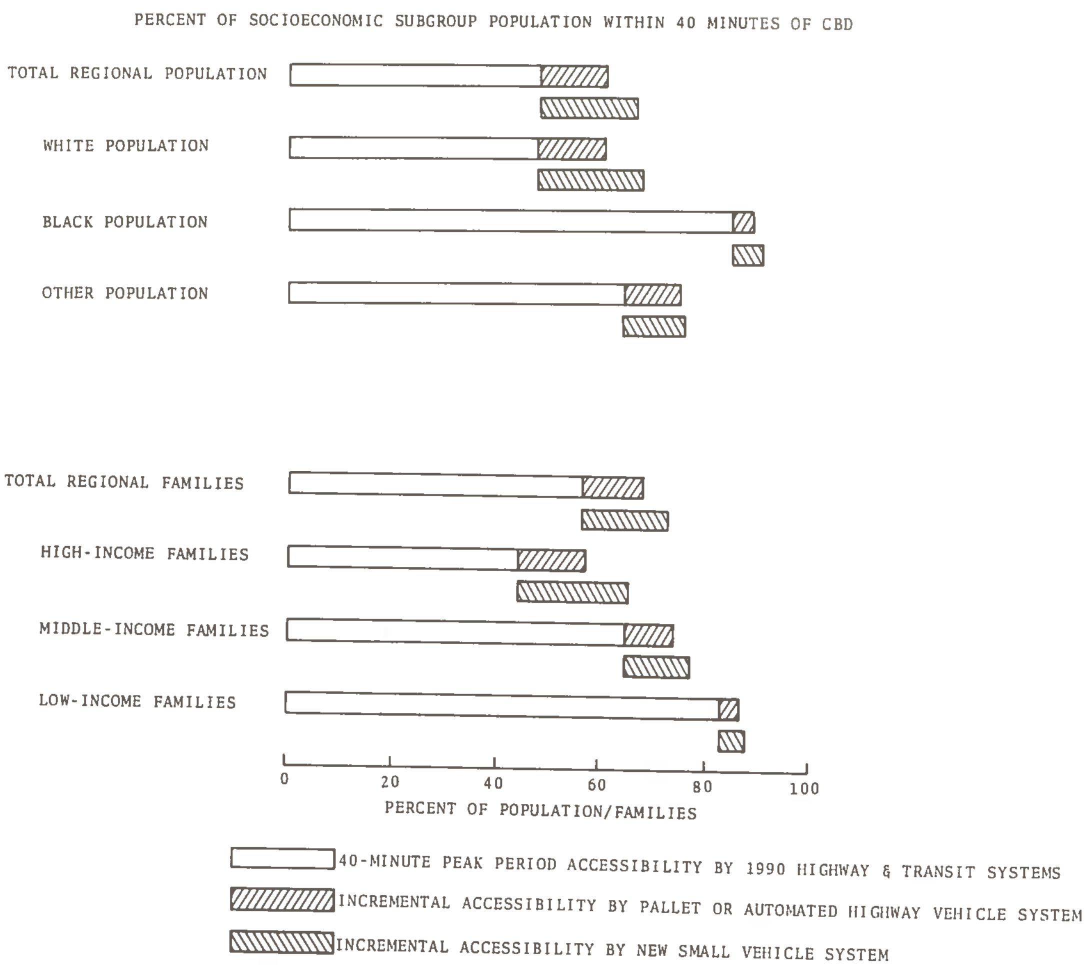


Figure 3-58 Comparative Peak Period Accessibility by Dual Mode vs. 1990 Plan - CBD

accessibility due to the new small vehicle system are higher--5.7%, 12.1%, and 4.6%, respectively. Although the percentage increments for the white population and for high- and middle-income families exceed those for minority groups, the latter groups still have relatively better access to the CBD.

As can be seen from Figure 3-59, the percentage improvements in mobility are greater for minority groups than for the rest of the population when the 40-minute accessibility contour is generated around a suburban location. The explanation is that the travel time savings due to Dual Mode extend part of the contour toward the center city, where most of the minority persons live. The introduction of the pallet or automated highway vehicle system brings another 21.0% of the black population, an additional 16.5% of the other minority population, and another 15.0% of low-income families within a 40-minute range of the suburban shopping centers; the corresponding percentage point gains for the new small vehicle system are 19.5%, 15.2%, and 20.3%.

Figure 3-60 presents results on low-income people's access to job opportunities and elderly and teen-age people's access to nonwork activities by alternative public modes of transportation. The small personal vehicle system qualifies as a public mode for the poor, who are generally able to drive but unable or unwilling to purchase vehicles outright; however, this system is not considered a true public option for the young and the elderly, who would perhaps be unable or unwilling to drive small personal rented vehicles. Aside from the small personal vehicle component of the new small vehicle system, which provides a moderate improvement (26 to 30%) in the number of blue-collar jobs accessible to the central and suburban poor and a 93% increase in the number of nonwork destinations accessible to the ghetto zone, Dual Mode systems provide little or no improvement in the mobility of the transportation-disadvantaged. In particular, the young and the elderly are still isolated from most of the commercial, recreational, medical, and educational facilities located throughout

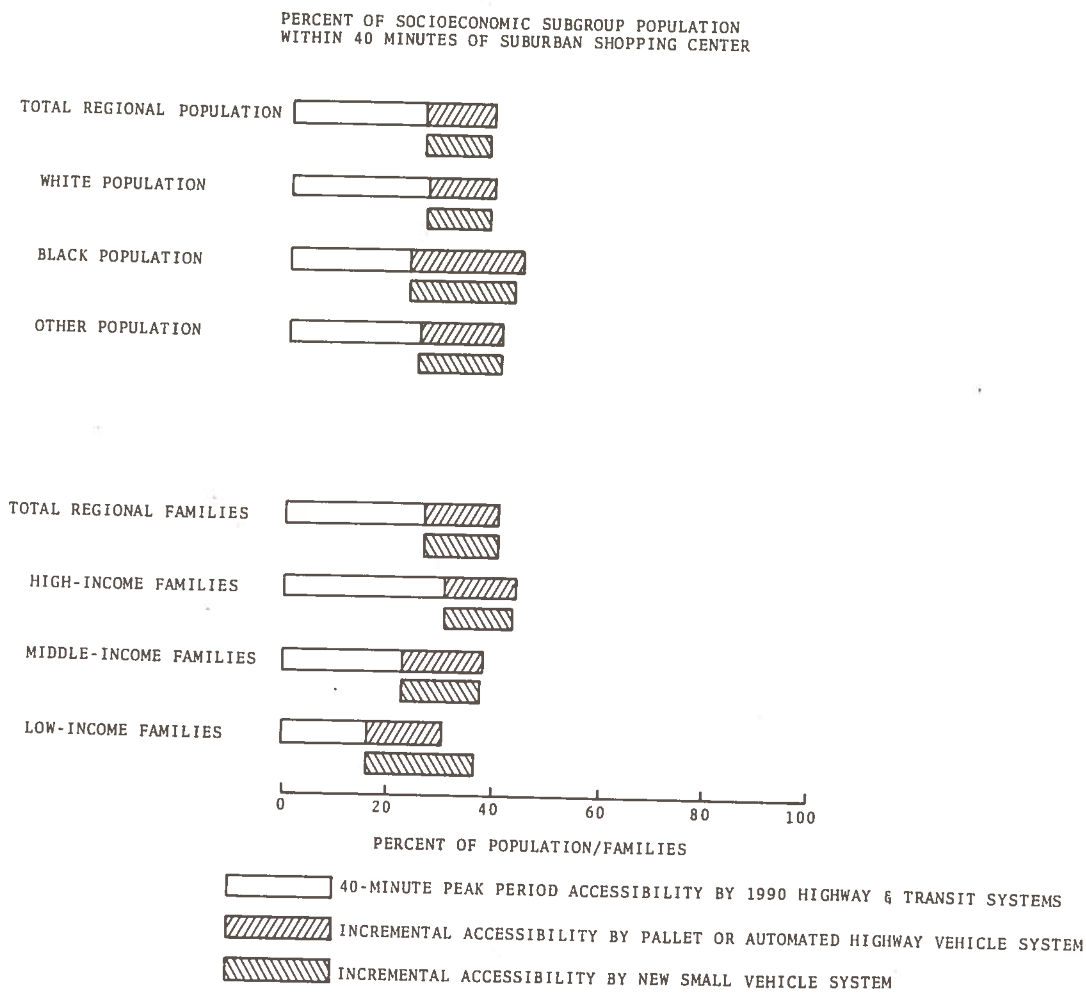


Figure 3-59 Comparative Peak Period Accessibility by Dual Mode vs. 1990 Plan - Suburban Shopping Center

Parameter/Analysis Zone/ Time Period	1990 Transit System	Pallet System (Bus Portion)	Automated Highway Vehicle System (Bus Portion)	New Small Vehicle System (1)
Blue Collar Positions Within 40 Minutes (Peak Period) of:				
Poor, Suburban Zone	366	366	366	477
Ghetto Zone	438	438	438	553
Nonwork Trip Ends (Including School) Within 40 Minutes (Off-Peak Period) of:				
Ghetto Zone	2,200	2,240	2,240	4,240
Young, Central Zone	1,330	1,330	1,330	1,330
Young, Suburban Zone	488	488	488	488
Nonwork Trip Ends (Excluding School) Within 40 Minutes (Off-Peak Period) of:				
Old, Central Zone	1,630	1,630	1,630	1,630
Old, Suburban Zone	1,550	1,550	1,550	1,550

(1) Based on small personal vehicle travel time in the case of poor suburban and ghetto zones; based on minibus travel time in the case of zones with predominantly young or or old populations.

Figure 3-60 Comparative Mobility from Special Analysis Zones (Thousands of Jobs/Trip Ends) the metropolitan area. The reasons that the bus components of Dual Mode systems perform so poorly compared to the small personal vehicle component of the new small vehicle system are the limited network and/or service area, the relatively long transfer times to transit (for all systems but the minibus), and the fairly long headways during off-peak hours.

In addition to the 40-minute results discussed above, accessibility was examined for the 20-minute travel time range. Dual Mode systems generally provide little or no improvement in mobility for shorter trips due to the overall granularity of the network: since the average access/egress time to the network is rather high for some baselines (e.g., 8 minutes for the pallet, or 16 minutes for off-guideway travel per trip), it is unlikely that a person can travel any farther by Dual Mode than by conventional modes within a 20-minute period. The new small vehicle system does perform somewhat better than the other baselines; its more extensive coverage downtown approximately halves the off-guideway travel time, making Dual Mode more attractive even for short trips.

I. Potential of Dual Mode for Serving the Handicapped and Elderly

According to TSC estimates (26), the elderly and handicapped comprised about 13 percent of the total U.S. population in 1970. The numerical breakdown of elderly (over-65) and handicapped persons is shown below:

Total Elderly	20,100,000
Handicapped	6,990,000
Non-Handicapped	13,110,000
Total Handicapped	13,390,000
Elderly	6,990,000
Non-Elderly	6,400,000
Total Elderly & Handicapped (with no double counting)	26,500,000

For the elderly non-handicapped, the handicapped non-elderly, and in particular for the 7 million elderly who are also physically handicapped, lack of mobility constitutes a serious problem. In the first place, the level of auto ownership and usage among the handicapped and elderly is rather low (only 28% of the former group and 32% of the latter group use automobiles), owing to physical and/or financial impediments to driving.* Thus those without access to an automobile must depend on some form of public transportation to get around. In general, public modes of transportation are characterized by high cost, physical inconvenience (crowding, difficulty of access to vehicles/stations, jerky vehicle movement), and inadequate service (in terms of coverage, frequency, and reliability)--attributes which are merely annoying to a young, able-bodied, employed person (who may as a result opt for traveling by auto) but which constitute barriers to travel for the handicapped and elderly (who have no alternative except for the prohibitively expensive taxi).

In view of the potentially high dependence of the handicapped and elderly on public transportation, it is appropriate to examine the degree to which Dual Mode might improve the ease and extent of mobility of these groups. The accessibility analysis described above showed that the three Dual Mode systems analyzed in this study provide no improvement in the accessibility of zones containing high concentrations of elderly people. In particular, it was noted that the bus portions of these systems are no better than the 1990 plan's transit system from the standpoint of the number of nonwork destinations (e.g., medical and recreational facilities) within 40 minutes of the two "elderly" analysis zones during off-peak hours.

* Related to the financial obstacle to car ownership is the fact that 59% of the handicapped and 25% of the elderly have annual incomes below the poverty level.

However, the preceding statement must be qualified in several ways. First of all, the elderly reside throughout the metropolitan area; although the two zones singled out for analysis have the highest percentage of persons over 65, they are by no means the only places where this subset of the population lives. The handicapped are likewise dispersed over the entire region, and furthermore have a need to travel to work during peak periods. Thus, additional measures of accessibility which reflect urban-wide mobility at all times of day must be considered. As can be seen from the lower part of Figure 3-56, which shows the accessibility of four major activity centers during peak and off-peak periods, the bus components of the three Dual Mode baselines provide some increase in the number of people who can reach these centers within 40 minutes;* the handicapped and elderly constitute some percentage of these additional people and hence share in the accessibility gains. Nevertheless, the rather unspectacular performance of the transit portions of these systems (even when accessibility is analyzed from a more regional standpoint) must be attributed to the operating policies adopted in this study--the rather limited service area of buses,** the relatively long transfer times to transit (for all systems but the minibus), and the fairly long headways during off-peak hours. Clearly, these bus systems <u>could</u> be designed to improve the quantity and quality of transportation services provided to the handicapped and elderly.

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* The "new small vehicle" column reflects small personal vehicle rather than minibus travel times. However, the minibus portion of this baseline provides accessibility increases comparable to those achieved by the bus components of the other two baselines.

**Point-to-point routes were only provided where a demand existed, thereby precluding the possibility of inducing the latent demand of transportation disadvantaged persons who have turned to automobile or taxis or have curtailed their travel.

Still another qualification of the accessibility results is that a significant number of handicapped and elderly persons who are unwilling or unable to drive conventional automobiles would be able to use small personal vehicles. For example, a handicapped or elderly person too poor to purchase a car might wish to rent a small personal vehicle from time to time. An elderly person afraid to drive an automobile downtown via the freeway network might feel capable of making the trip in a Dual Mode vehicle, since the high-speed line-haul portion of the journey would occur under automatic control. If the small personal vehicle is assumed to be a viable option for this subset of the elderly and handicapped, then the gains in mobility are very significant.

The final qualification which must be added is that zone-to-zone travel time (the basis of the accessibility analysis) may not be such an important aspect of travel to the non-working handicapped and elderly as comfort and convenience. Thus, although the Dual Mode bus systems do not increase the number of places within a specified time range of the "elderly" zones, they may make travel to the initial set of destinations more pleasant and thereby induce certain elderly people to take trips who would otherwise stay at home. This induced demand among the older members of society (the same phenomen could occur with the handicapped) certainly would constitute an increase in mobility, even though not related to faster travel times.

Aside from the actual and potential accessibility gain discussed above, Dual Mode buses (and, for certain persons, small personal vehicles) have a number of potential quality-of-service advantages over conventional transit. These are listed below, along with the particular travel problems of the handicapped and elderly which they would serve to alleviate:

1. Front-door pick-up of passengers (for the dial-a-ride minibus; could be incorporated into bus components of pallet and automated highway vehicle baselines) -- eliminates walk to and wait at transit stop, which is often unsheltered.
2. Direct routing between suburbs and downtown -- eliminates transfers and associated walking and waiting.
3. Greater schedule reliability (due to predictable guideway travel time) -- minimizes waiting time, uncertainty.
4. Smoother, safer travel (for on-guideway portion of a trip) -- eliminates jerky motions related to acceleration, deceleration, lateral sway; lessens fear of accidents.
5. Provision of seats for all passengers -- eliminates crowding, fatigue due to standing.
6. Incorporation of design features aimed at ease and comfort of travel -- e.g., special steps for getting on and off buses, escalators or elevators in stations, ramps for wheelchairs, wide aisles.

Many of the above items are not necessarily unique to Dual Mode bus systems -- for instance, conventional transit systems could institute more direct-route service and could improve the reliability of their service. However, it seems more probable for a new system to incorporate these features from the start than for an existing system to overcome its inertia sufficiently to adopt the needed changes.

It should also be pointed out that even these features will be inadequate to handle the very special requirements of the severely handicapped. Nevertheless, the above-mentioned advantages of Dual Mode over conventional transit will make travel possible for some who would otherwise be homebound and will make travel easier and more comfortable for the handicapped and elderly who are presently captive users of public transportation.

J. Qualitative Impacts

The quantitative and, in some cases, monetary assessment of the impact of Dual Mode on users and the community has provided a fairly adequate case for deciding which, if any, Dual Mode alternative(s) should be implemented. However, it is also appropriate to consider the qualitative side of the impact picture, since numbers, and in particular, dollars cannot possibly convey the scope or complexity of Dual Mode's influence on the urban area. Comparative effects of Dual Mode vs. conventional systems on land values, employment levels, retail sales, driver/occupant convenience, neighborhood quality, and future metropolitan development are among the criteria which must be evaluated outside the framework of cost-benefit analysis. Unfortunately, many barriers stand in the way of doing a definitive and comprehensive analysis of these impact areas: for example, state-of-the-art limitations and uncertainties about the future make it impossible to predict exactly which parcels of land would increase in value; it is difficult to measure changes in employment levels and identify the industries which would be affected by the implementation of Dual Mode without a thorough knowledge of future production techniques and power sources; in the absence of detailed system design specifications (in particular, relating to the physical appearance of the guideway, terminals, and vehicles) which can form the basis of a public opinion survey, one cannot foresee whether users and people living near the guideway would consider Dual Mode an aesthetic or unattractive addition to the environment. Nevertheless, it is worthwhile to examine these benefits/disbenefits even in a cursory fashion, basing comments and conclusions on the results of the Dual Mode displacement, air pollution, noise, and accessibility analyses and on the findings of previous transportation impact studies.

As stated in the Northeast Corridor Transportation Project report External Costs and Benefits Analysis (20, pp. 37-38) "there are two types of effects of transportation facilities on property and land values:

- an accessibility effect, which makes the area surrounding the transportation facility more productive, and is sometimes reflected in changes in land uses in the affected areas; and
- a neighborhood disturbance effect, which is characterized by increases in noise, air pollution, and aesthetic and safety effects on the adjacent area."

Chapter 6.3.1 of Volume III of the Dual Mode report contains a brief critique of the Northeast Corridor Study approach of measuring noise effects of alternative transportation systems solely in terms of decreases in the value of adjacent residential land and presents reasons for the inadequacy of the procedure for the Dual Mode noise analysis. However, although land value changes are considered an insufficient means of quantifying accessibility and neighborhood disturbance effects, the converse does not apply: knowledge of a transportation system's impact on accessibility, noise, air pollution, and neighborhood stability and appearance can be used to predict the geographic distribution and overall magnitude of land value changes.

Several findings of the Dual Mode analysis suggest that Dual Mode would have a far more beneficial effect on land values than the 1990 plan. In the first place, Dual Mode systems generally provide increased accessibility to central and suburban locations compared to conventional modes, with the largest percentage increases occurring during the peak period. These accessibility improvements can affect the value of land positively or negatively: on the one hand, "Because land buyers are willing to pay for savings in vehicle operating costs, time, and the other components of accessibility, the value of these expected future benefits is capitalized into land prices" (12); on the other hand, the addition to the supply of land at, say, 40-minutes from the CBD may in certain situations (at least in the short run) depress the value of land already at that distance. In the Boston scenario, with an anticipated population growth of about 25% by 1990, and a corresponding increase in the demand for new housing, the latter phenomenon seems unlikely to occur, so that the incremental accessibility associated with Dual Mode systems could be expected to enhance land values. For the cost-benefit portion of this study, land value increases have been estimated on the basis of changes in accessibility to the CBD. However, it is also worthwhile to venture further and consider the probable geographic distribution of the land value changes. As in the case of highways, Dual Mode-induced changes in land value and land use would probably tend to be concentrated in the vicinity of the facility (particularly at stations), where minimum access/egress time to the high-speed guideway is required. This concentration would be far less pronounced for the components of the baselines which provide direct door-to-door service (e.g., small personal vehicle, Dual Mode auto, minibus) than for the bus components of the systems which involve transfers to automobile or transit. Again extrapolating from the highway experience, it is probable that industrial or vacant land near Dual Mode stations would undergo a greater percentage increase in value than similarly situated commercial and residential land, reflecting the greater potential of the former land categories for being upgraded to higher (more intensive) uses. Although accessibility improvements due to Dual Mode are generally larger for the CBD than for the other major activity centers studied (reflecting the predominantly radial, as opposed to circumferential, orientation of the Boston network), the CBD would not necessarily experience the greatest changes in land value, because of the predominance of commercial and residential land.

The Dual Mode analysis findings relating to noise likewise support the assertion that Dual Mode would be preferable to the 1990 plan from the standpoint of land value effects. As was discussed above, Dual Mode operations adversely affect only a fraction of the households impacted by traffic noise from planned highway and transit additions. There is no doubt that noise impacts from the 1990 plan would result in a severe reduction in property values along the facilities, since as many as 152,000 households would be affected within a noise band as wide as 3,000 feet for highways and 4,700 feet for rapid transit (these are nighttime values; the corresponding daytime figures are 41,000 households, 1,100 and 1,350 feet). However, it is not certain whether the noise band for Dual Mode systems (maximum of 84 feet during the day and 102 feet at night for the automated highway vehicle system) would be sufficiently obtrusive to effect a decrease in property values. Residential property directly abutting the guideway would probably decline somewhat in value, but on the whole, noise from Dual Mode systems could be expected to have a negligible impact on land values. Thus it is possible that the land value loss savings calculated for the cost-benefit comparison slightly understate the true magnitude of the incremental benefit of building Dual Mode, since they are based on the difference between noise impacted households for Dual Mode vs. the 1990 plan rather than on the total impacted households for the plan.

The pollution costs computed for each baseline reflect damage to property, vegetation, and health caused by the various pollutants, so that to calculate pollution-induced changes in land value would be double-counting. However, it should be noted that the geographic distribution of these land value changes would differ depending on the type of power source: for the two electrically powered baselines, the only area which might experience a pollution-related decrease in land value would be the vicinity of the fossil-fuel burning plant; for the automated highway vehicle system, all of the land straddling the guideway would be subject to decreases in value.

The final reason why Dual Mode would have a more beneficial impact on land values than the 1990 plan is the comparatively low number of displaced households. Land value is very much dependent on people's attitude toward their property and the surrounding area, which in turn is influenced by the physical appearance, safety, and stability of the neighborhood. It would seem that a transportation system which minimizes the uprooting of households (particularly those inhabited by people who would hardly benefit from the transportation improvements) would have a less detrimental effect on residents' attitudes and hence land values than one which requires extensive right-of-way acquisition. The planned highway and transit additions in Boston involve the acquisition of over 19,000 acres, 8,700 of which are residential; in contrast the Dual Mode systems occupy only 3,200 to 3,800 acres of land, most of which are on existing transportation right of way. Even in areas where the Dual Mode system must displace households, the impact on the land value of remaining property would be minimal because the guideway interchanges and terminals can be designed to be visually unobtrusive.

In the absence of accurate knowledge about future technological and economic conditions, it is extremely difficult to predict the employment effects of Dual Mode vs. the 1990 plan. Accordingly, some broad generalizations will have to suffice. Within the metropolitan area, improved accessibility due to Dual Mode should indirectly lead to increased employment by enlarging the market area of commercial establishments and encouraging a better allocation of underemployed labor resources. Moreover, to the extent that decreased highway congestion results in truck travel time savings, the resultant improvements in productivity of manufacturing and distribution activities should in time spur expansion of these types of firms. If Dual Mode were eventually to be used for freight transportation, the economic and employment benefits would be even greater, since goods could travel directly on the highspeed guideways.

It is unlikely that the introduction of Dual Mode in just one city would have any noticeable impact on employment in raw material and manufacturing industries. However, implementation of either the pallet or new small vehicle Dual Mode system in several cities throughout the country could have rather significant effects on the petroleum, coal or uranium, and automobile industries. The substitution of travel in electrically powered Dual Mode vehicles for travel in automobiles equipped with internal combustion engines would lead to a reduced demand for gasoline and an increased demand for coal, fuel oil, or uranium (depending on whether electricity is produced in fossil-fuel or nuclear power plants), with corresponding changes in employment in these industries. The effect of the introduction of Dual Mode on employment levels in the automobile industry would depend on the degree to which Dual Mode vehicles would substitute for or supplement conventional autos: systems which provide good connectivity during peak and off-peak periods (e.g., the new small vehicle) could cause a reduction in the number of second car purchases and thus result in decreased employment in the automobile industry; on the other hand, the pallet system could cause a net increase in employment, since the number of cars per family would be unchanged and pallets would be produced in addition to automobiles.

The effect of Dual Mode on the volume and geographic distribution of retail sales is primarily a function of accessibility and travel time changes. Sales activity in the CBD could be expected to increase as a result of decreased congestion on arterials leading to the CBD and improved circulation within the CBD. In particular, the convenient CBD distribution system (interfacing with transit where necessary), coupled with a ban on parking Dual Mode vehicles downtown, would alleviate the frustrating aspect of highway trips to the CBD -- stop-and-go traffic conditions and a tedious search for a parking space followed in many cases by a long walk to one's destination. The new small vehicle system would be especially conducive to CBD shopping trips, since the fine-grained downtown network would allow no-transfer service to one's initial destination and also provide convenient intra-CBD service from one commercial district to another. Sales volume in suburban shopping centers would likewise increase somewhat with the introduction of Dual Mode service.

With respect to driver/occupant comfort and convenience, there is no question that Dual Mode systems would be preferable to conventional modes. Since guideway travel would be fully automated, the driver of a private vehicle would be free to read, engage in conversation, knit, or merely sit back and enjoy the scenery -- a pleasant contrast from the usual constraint on him to survey the road continually.* Other advantages over conventional modes which likewise can be attributed to the guideway portion of Dual Mode trips (accounting for approximately 60% of all Dual Mode VMT) would be a faster, smoother ride (because of constant 60 mph speeds with no stopping and starting and the absence of bumps and sharp curves on the guideway) and greater reliability of arrival time (reflecting the low probability of vehicle breakdown and the lack of congestion on the guideway). Comparing the various Dual Mode baselines, it would seem that the bus component of the baselines would be somewhat inferior to the private vehicle portions from the standpoint of safety, privacy, and convenience. The absence of a bus driver during the on-guideway portion of a trip might encourage vandalism, theft, and injury to patrons. Moreover, 12- or 20-passenger buses, no matter how well designed on the interior, could not compare with 4- to 6-passenger vehicles in terms of privacy and a person's freedom to do and say what he wants while traveling. From the standpoint of convenience, the small personal vehicle in combina-

*Elsewhere in this report, this benefit is monetized into driver relief savings (one half the dollar value per hour of travel time savings).

tion with the minibus would be superior to the other baselines, because of its ability to provide direct, no-transfer service (individual vehicle or dial-a-ride service in the suburbs, dense circulation system in the CBD). The pallet and automated highway vehicle systems would rank next highest in convenience, since the downtown distribution system is not so fine-grained.

There would not seem to be any significant differences among baselines or between Dual Mode and conventional systems with respect to the cleanliness, comfort, and physical appearance of the vehicles and stations. Certainly the technological means exists at the present time to create a pleasant micro-environment for the traveler; thus the key requirements for a comfortable and attractive transportation system are the willingness of system operators to provide such an environment and the cooperation of users in preserving it. The degree to which these requirements are met would probably be no different for conventional private automobiles vs. Dual Mode personal vehicles, or for transit vehicles vs. Dual Mode buses.

Dual Mode systems would undoubtedly have a more positive or less negative effect on neighborhood appearance, stability, and quality than the 1990 plan. In the first place, Dual Mode requires far fewer household displacements than the planned highway and transit additions, thus minimizing the disruption of closely knit established communities throughout the region. Since the downtown network is tunneled or elevated, Dual Mode causes minimal dislocation of low-income and minority families, who tend to live in or near the center city. Not only does the system owner/operator save money by not having to pay relocation costs for displaced families (valued at $1,604 per dwelling unit), but individuals are spared the inconveniences and phychological disturbance associated with adjusting to a new home, neighborhood, school, and friends (valued at $20,000 per dwelling unit for purposes of cost-benefit analysis). In addition to these social benefits of Dual Mode vis-a-vis the 1990 plan, equally significant environmental benefits are anticipated. Most of the Dual Mode guideway is located within existing transportation right-of-way (e.g., the median strip of a highway) and is therefore inconspicuous from the standpoint of noise, vibration, and physical/spatial intrusiveness. Regarding the portions of the Dual Mode network situated on new right-of-way, there is no question that their impact on the surrounding area is far less adverse than that of a freeway system designed to provide comparable service. This is because Dual Mode causes a much lower noise output, is built on a smaller scale (i.e., fewer lanes, absence of medians and shoulders), and can be designed so as not to detract from the visual quality of the environment (in fact, the Dual Mode guideway and stations could be designed so that they might in many cases enhance the appearance of the area).

The final topic to be covered is the effect of Dual Mode vs. the 1990 plan on future metropolitan development -- in particular, the influence of these systems on the long-term viability of the CBD and on the tendency toward urban sprawl. Again drawing from the result of the accessibility analysis, it would seem that Dual Mode has every potential for maintaining or even increasing the vitality of the center city (to a greater extent than the 1990 plan), since accessibility improvements are largest for trips having one end in the CBD. The decreased time and hassle involved in traveling to the CBD not only would result in increased sales activity, but also can be expected to increase the attractiveness of the center city for cultural and recreational activities and for businesses which are contemplating relocation in the suburbs because of excessive congestion but which would really prefer to remain in a central location with proximity to a high concentration of related firms and services. On the other hand, families and business establishments desiring a surburban location for space, tax, educational, or environmental reasons could decentralize and yet be assured of quick and convenient access to the CBD for work or other purposes. By shrinking the metropolitan area through improvements in travel time and travel convenience, Dual Mode would thus provide a much wider range of choice than the 1990 plan in the temporal and spatial distribution of individual and business activities.

Of course, the possibility exists that any mobility-related shrinkage of the region would be counteracted or even overweighed by geographic expansion of the metropolitan area. The highway has often been attacked as the primary catalyst of urban sprawl, which can be defined as "...a haphazard intermingling of developed and vacant land on the urban-rural fringe and the siting of houses on lots of ever larger size" (18) and which is generally considered undesirable because it results in extravagent consumption of scarce vacant land and causes inefficiencies in the public service sector of the urban economy. The question thus arises as to whether Dual Mode, anticipated to provide travel time savings in 1990 roughly equivalent to those afforded by the freeways built in the 1950's and 1960's, would likewise encourage urban sprawl. It would seem that this does not necessarily have to be the case, since the 1990 public will undoubtedly be much more conscious of environmental quality and more receptive to comprehensive regional planning than the 1960 public. Thus the implementation of Dual Mode could be coordinated with land use and zoning policies, urban renewal programs, public service plans, and other transportation improvements, with the result that Dual Mode could tend to be associated with orderly metropolitan development rather than uncontrolled growth.

3.4.3 Costs and Benefits

Comparative cost data is presented in Figure 3-61 for the various baselines, as well as the 1990 plan. The total capital cost of the urbanwide systems studied in the Boston scenario ranged from 1.6 billion dollars to more than 4 billion dollars. These represent multi-year investments in an extensive transportation system. Just over 1 billion dollars of proposed construction in the 1990 plan (in the form of 114 miles of highway and 29

	1990 PLAN	PALLET SYSTEM	AUTOMATED HIGHWAY VEHICLE SYSTEM	NEW SMALL VEHICLE SYSTEM
Total Capital Cost ($\$x10^6$)	1,020 (1)	2,630 (2)	1,620 (2)	4,200 (2)
Dual Mode Vehicle Capital Cost ($\$X10^6$)		682 (3)	83 (4)	1,970 (5)
Annual Door-to-Door Dual Mode Capital and Operating Cost ($\$x10^6$)		724	625	972
System Operator Annual Capital Cost ($\$x10^6$)		308	180	681
System Operator Annual Operating Cost ($\$x10^6$)		254	46	291
Dual Mode Private Vehicle User Annual Cost (In Addition to Fare) ($\$x10^6$)		162	399	0
Dual Mode Annual Net Revenue ($\$x10^6$) (Revenue Minus Operating Cost)		-4	72	113
Dual Mode Door-to-Door Cost per Passenger Trip ($)		1.83	1.81	1.90
Regional Door-to-Door Cost per Passenger Mile (¢)	12.6	13.4	13.3	14.0

NOTES: (1) Highway and transit extensions that are not built if Dual Mode is put in.
(2) Dual Mode system only.
(3) Pallet and bus portion of the total capital cost.
(4) Bus portion of the total capital cost.
(5) Minibus and small personal vehicle portion of the total capital cost.

Figure 3-61 Comparative Costs

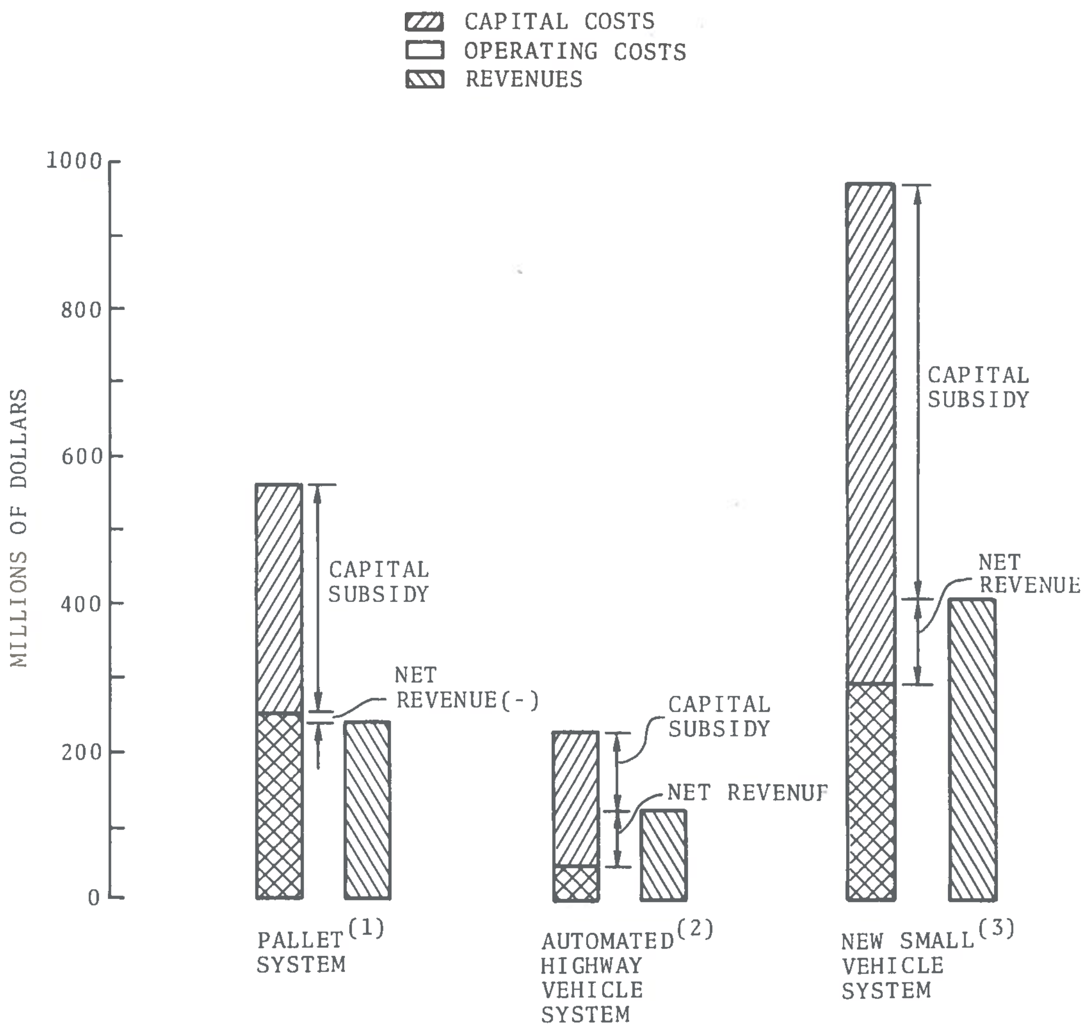
miles of rapid transit extension) would not be built if Dual Mode were installed. This, in effect, represents a capital cost savings incurred by the adoption of a Dual Mode system. The rest of the 1990 plan was assumed to be built and operate in conjunction with the Dual Mode system.

The relationship between annual costs and revenues for the various baselines is presented in Figure 3-62. The new small vehicle system incurs the greatest costs but has the greatest net revenue (excess of revenues over operating costs).

Revenue variations with changes in fares are shown in Figure 3-63. The pallet system is the most sensitive in this respect and the automated highway vehicle system the least. In Figure 3-64 are shown the fares charged for the vehicles in the various baselines, the fares necessary to cover operating costs, and the fares necessary to cover both operating and capital costs (with the assumption of constant ridership). With the exception of the pallet, the fares charged cover operating costs for all vehicles, but none of the vehicles could cover operating and capital costs with the existing fare structure.

A comparison of annual costs and benefits relative to the 1990 plan is shown for the three baselines in Figure 3-65. Costs and benefits were determined as described in Sections 3.1, 3.2, and 3.3. The new small vehicle system has the greatest costs, the greatest total benefits, and the greatest net incremental benefits and the greatest benefit/cost ratio of all the baselines. The automated highway vehicle system has the lowest costs, lowest total benefits and lowest net incremental benefits. All of these systems have benefits considerably in excess of costs and have nearly equal benefit/cost ratios (based on the assumes dollar valuation of benefits), and thus are generally equally good investments. Therefore, the return on capital investment is not a dominant consideration in the choice of systems.

In order to gain perspective on how the projected cost and service levels of Dual Mode systems compare with the actual experience of conventional rapid transit systems, a survey was



(1) Does not include capital and operating costs borne by private vehicle owners for the off-guideway portion of Dual Mode trips.

(2) Does not include capital and operating costs borne by private vehicle owners for Dual mode Trips.

(3) Total door-to-door transportation costs.

Figure 3-62 Annual Costs and Revenues Accrued to Dual Mode System Operator

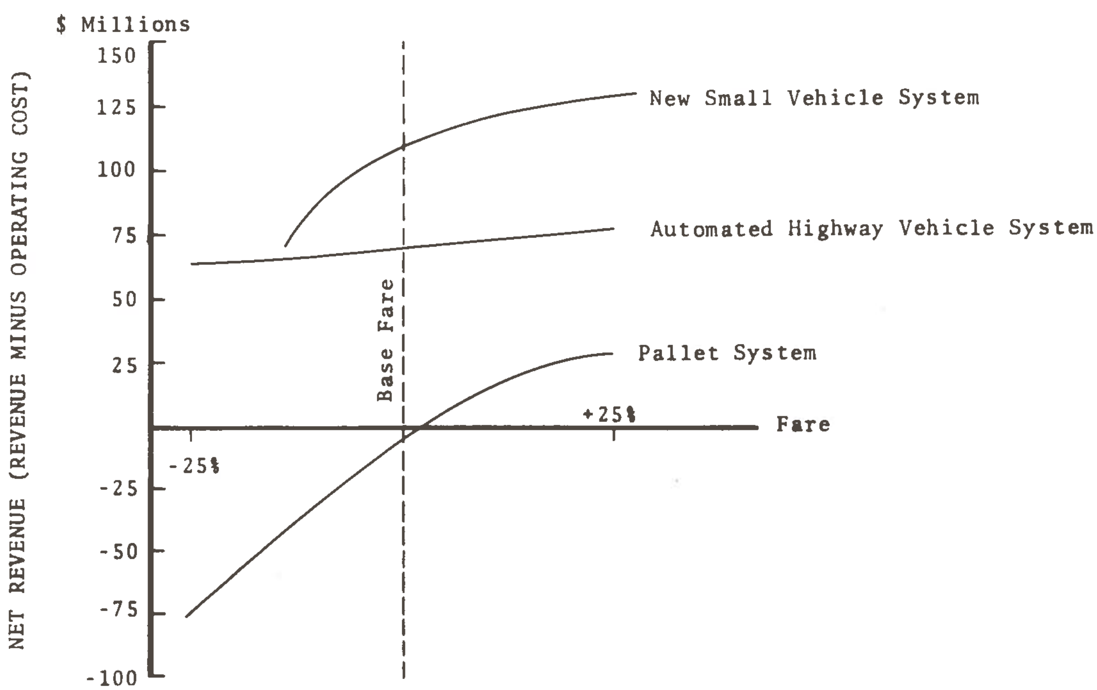
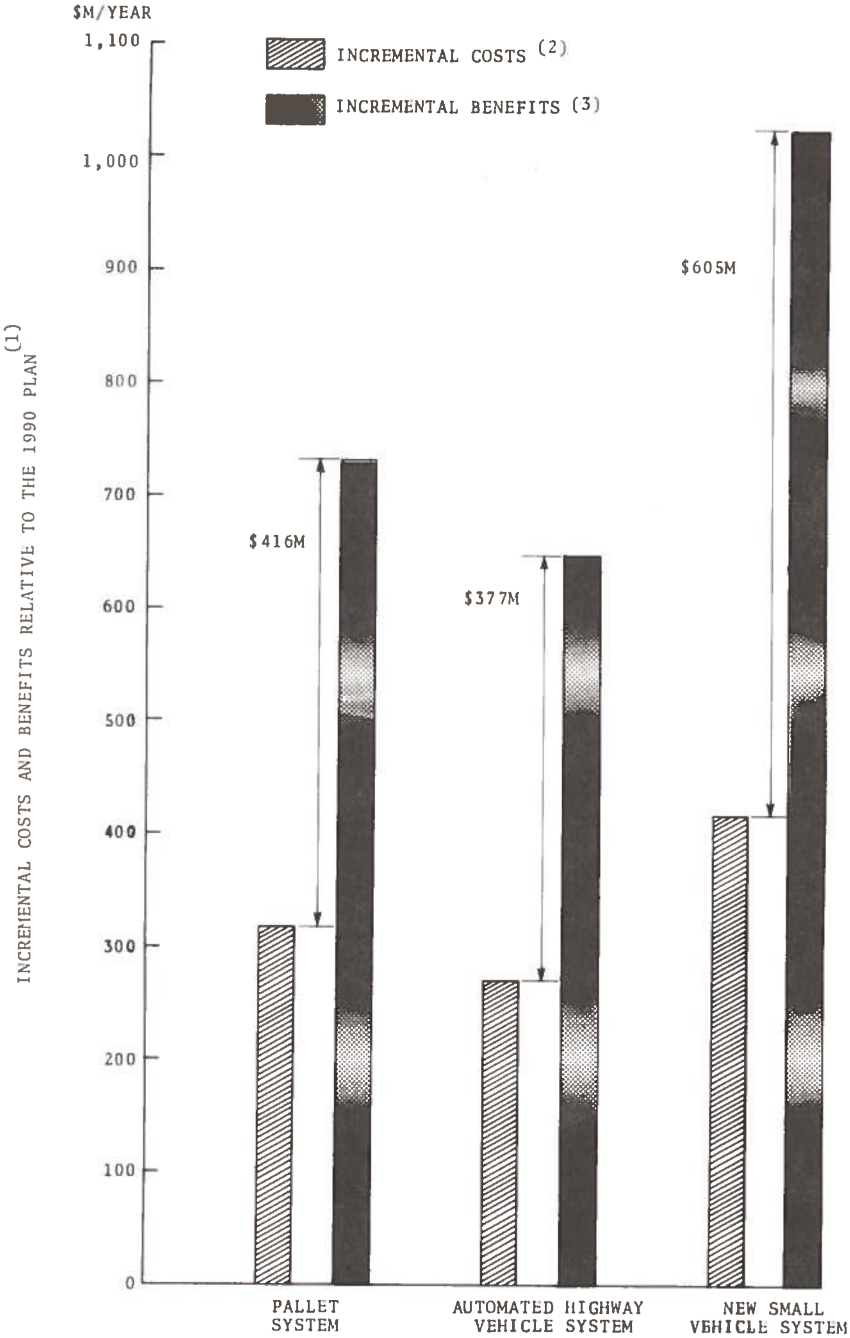


Figure 3-63 Profit/Subsidy vs. Fare Variation (Operating Costs)

ALTERNATIVE	FARE($)	FULLY ALLOCATED SYSTEM-OPERATOR COST ($)	
		OPERATING	OPERATING & CAPITAL
SMALL PERSONAL VEHICLE MINIBUS	.08/VEH. MI. .90/PASS. TRIP	.056/VEH. MI. .845/PASS. TRIP	.197/VEH. MI. 1.485/PASS. TRIP
PALLET DUAL MODE BUS	.10/VEH. MI. & PKG .50/PASS. TRIP	.121/VEH. MI. .407/PASS. TRIP	.273/VEH. MI. .746/PASS. TRIP
DUAL MODE AUTO DUAL MODE BUS	.04/VEH. MI. & PKG .50/PASS. TRIP	.014/VEH. MI. .438/PASS. TRIP	.100/VEH. MI. 1.08/PASS. TRIP

Figure 3-64 Dual Mode Cost/Fare Comparisons



(1) Includes costs and benefits to all users of highway, transit and Dual Mode systems relative to those associated with the 1990 plans.
(2) Includes total Dual Mode capital costs plus operating costs, minus 1990 Plan capital and operating cost savings.
(3) Includes dollar valuation of time savings, relocation savings, accident savings, changes in pollution costs, changes in land values and tax revenues relative to the 1990 Plan.

Figure 3-65 Dual Mode Annual Incremental Costs & Benefits (Relative to 1990 Plan) made of capital and operating costs as well as ridership for the major rapid transit systems in existence or under construction in North America. Information on these systems was obtained from an American Transit Association report (2), the report Economic Characteristics of the Urban Public Transportation Industry (7), articles from various periodicals, and from the transit companies themselves.

Figure 3-66 presents comparative cost and ridership data on a route-mile basis for the three Dual Mode alternatives and the 12 rapid transit systems considered. All cost figures are in 1970 dollars. The annual capital cost of each system was calculated assuming a 10% interest rate and appropriate system component lifetimes. It can be seen that the Dual Mode systems fall within the range of capital and operating costs experienced or projected by transit systems. The automated highway vehicle baseline is in the lower end of the range, the pallet baseline falls in the middle, and the new small vehicle system is in the upper portion of the range. All three systems have lower capital costs per route mile than the five rapid transit systems proposed or under construction. These findings are significant in view of the fact that Dual Mode costs generally reflect the provision of direct (no transfer) door-to-door service (the exception being the personal vehicle components of the pallet and automated highway vehicle baselines, whose off-guideway operating costs are not included in the table). Rapid transit systems, on the other hand, provide such service only to people residing within one-quarter mile of the network; those living farther away must either drive or take a bus to a rapid transit station--a process that involves a transfer and possibly the parking of an automobile.

As shown by the ridership per route mile in the last two columns of Figure 3-66, Dual Mode systems again appear to be comparable to transit systems, in spite of their more extensive networks. Thus Dual Mode systems are capable of serving a much

System	Rte. Mi.	Total Cap. Cost Per Rt. Mi (millions)	Annual Oper. Cost[1] Per Rt. Mi. (millions)	Annual Cap. & Oper. Cost Per Rt. Mi. (millions.	Daily Pass.[2] Per Rt. Mi.	Annual Pass-Mi. Per Rt. Mi. (millions)
Dual Mode (Boston):						
Pallet System	249	10.6	1.0[3]	2.3[3]	5,300	22.5
Automated Highway Vehicle System	249	6.5	0.2[3]	0.9[3]	4,600	19.0
New Small Vehicle System	261	16.1	1.1	3.7	6,500	27.8
Rapid Transit (Existing)						
N.Y.C.T.A.	237	38.0[4]	1.9	5.8	14,500	33.4
Chicago T.A.	107	N.A.	0.5	N.A.	2,700	10.6
•Extension	14.7	8.1	0.5	1.4	N.A.	N.A.
MBTA (Boston)	65	19.2[4]	0.6	2.6	4,300	5.2
•Extension	6.2	13.1	0.6	2.0	N.A.	N.A.
SEPTA (Phila.)	47	N.A.	0.4	N.A.	3,700	6.9
PATH (N.Y.-N.J.)	14	13.4	1.4	2.7	7,600	13.9
PATCO (Lindenwold)	14.5	6.4	0.3	1.0	1,600	4.2
Cleveland T.S.	23.1	4.6	0.2	0.7	2,000	5.3
• Extension	4.1	4.5	0.2	0.7	N.A.	N.A.
Montreal	16	22.3	1.0	3.3	11,300	25.3
Rapid Transit (Proposed or Under Construction)						
BART (S.F.)	75	19.3	0.4	2.4	1,900	N.A.
METRO (Washington)	98	21.7	0.4	2.6	7,700	N.A.
MARTA (Atlanta)	56	17.8	0.2	2.1	5,000	N.A.
Baltimore	28	16.1	0.3	2.0	3,900	N.A.
N.Y.C.T.A.--2nd Ave. Line	4.7	88.3	N.A.	N.A.	N.A.	N.A.

(1) Excludes depreciation and interest payments.
(2) Annual passengers divided by 365.
(3) Cost to system operator (excludes off-guideway operating cost for automobile).
(4) Based on estimated replacement cost.
N.A. - Not available.

The full names of the above systems or system operators are in the order of their occurrence:

New York City Transit Authority
Chicago Transit Authority
Massachusetts Bay Transportation Authority
Southeastern Pennsylvania Transit Authority
Port Authority Trans-Hudson Corp.
Port Authority Transit Corp. of Pennsylvania and New Jersey
Cleveland Transit System
Montreal Urban Community Transit Commission
Bay Area Rapid Transit Authority
Washington Metropolitan Area Transit Authority
Metropolitan Atlanta Rapid Transit Authority
Metropolitan Transit Authority (Baltimore)

Figure 3-66 Cost and Ridership per Route Mile for Dual Mode Systems vs. Selected Rail Rapid Transit Systems larger area and population than rapid transit systems on a door-to-door basis and yet can attain comparable network utilization rates (as measured by passengers or passenger-miles per route mile) and relatively low capital and operating costs per route mile.

4. LEGAL AND ADMINISTRATIVE ISSUES

4.1 INTRODUCTION

This essay is a first step in the assessment of administrative and legal issues raised by proposed Dual Mode transportation systems. It identifies potential difficulties in the establishment and operation of a Dual Mode system, and suggests alternative solutions. Because it represents only a preliminary analysis, it should not be considered either a comprehensive catalogue of issues,[1] or a complete compilation of solutions.

4.2 NATIONAL REGULATION V. LOCAL CONTROL OF DUAL MODE SYSTEMS

A preliminary issue in the establishment of a Dual Mode transportation system is the necessary degree of centralized control over system design, construction, or operation.[2] If a uniform nation-wide system were envisaged, a greater degree of centralized control over design and operation would be required than if several discrete systems were planned.

4.2.1 The Need for Uniform Nation-Wide Control

In general, the need for uniformity in both design and operation of a Dual Mode system is determined by the number of separate guideway networks on which a vehicle is expected to operate, and by the degree of interaction between vehicle and guideway in a particular system. For example, it is

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[1] Omitted from this discussion, for example are issues relating to financing of Dual Mode systems. Should they be paid for out of general tax revenues, special purpose bonds, a trust fund supported by user charges, etc.?

[2] It is assumed throughout this essay that the Federal Government would exercise control over a uniform nation Dual Mode system either directly, through a Federal administrative agency, or indirectly, through a Comsat-like public-private corporation, or through detailed regulation of private industry.

unlikely that a Dual Mode bus would need to operate on a guideway configuration other than its own system's and so there would be little need for uniformity among all Dual Mode buses and their guideways except for production considerations by the manufacturers. On the other hand, Dual Mode automobiles could be expected to operate on guideways anywhere in the country, and therefore vehicle and guideway design and operation should be uniform nationwide. If a Dual Mode system required only that vehicles ride passively on a moving guideway, a pallet system, for instance, vehicles would need to meet only minimal design standards (e.g. wheel base, axle length, height, etc.). But if vehicles must interact actively with the guideway in the automatic mode, all Dual Mode vehicles must be standardized throughout the system.

Policy arguments weigh for and against uniform design and centralized operation of Dual Mode systems. First, production of uniform vehicles and guideway should result in scale economies and rapidly provide a large body of knowledge on the workings of that system. It can be argued, however, that only through installation of systems of various designs can it be known which system, or which combination is best. Second, centralized control could exclude States and localities from control over this new system; this would represent a departure from other Federally-assisted transportation construction and operation programs, which have heavily involved the States. Federally aided highway projects,[3] for example, are initiated, planned, and developed by the States.[4] States supervise project construction[5] and assume responsibility for

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[3]The four Federal-aid highway systems are the primary, secondary, Interstate, and urban systems. 23 U.S.C.A. 103(a).

[4]23 U.S.C.A. §§105, 302.

[5]23 U.S.C.A. §114.

maintaining completed projects;[6] the Federal role is limited to technical review of project plans[7] and disbursement of funds.[8] Urban Mass Transportation projects are likewise initiated and planned by States and local public bodies, subject to Federal approval.[9] Furthermore, complete Federal dominion of Dual Mode bus systems seems particularly inappropriate for local collection-and-distribution route determinations. Federal control is also inconsistent with current administration policies favoring local autonomy and revenue sharing with States and localities to fund transportation improvements.[10]

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[6] 23 U.S.C.A. § 116.

[7] 23 U.S.C.A. §§ 105, 106, 109.

[8] 23 U.S.C.A. §§ 120, 121.

[9] Urban Mass Transportation Act of 1964, as amended, 49 U.S.C.A. §§ 1602-1603.

[10] See, e.g., President Nixon's special message to Congress, "Revenue Sharing for Transportation," H. R. Doc. No. 92-71, 117 Cong. Rec. H. 1750, 1751 (daily ed. March 18, 1971).

> "The hard fact is that the best mixture of transportation modes is not something that remote officials in Washington can determine in advance for all cities, of all sizes and descriptions, in all parts of the country. Nor do the Federal officials who grant money for specific projects understand local needs well enough to justify their strong influence over how local projects should be planned and run.....
>
> Community organizations, concerned individuals and local units of government should not have to shout all the way to Washington for attention. Community standards and community transportation goals are changing and some of those who only five years ago welcomed the prospect of a new highway or airport are now protesting in front of bulldozers. Transportation planning and appropriations mechanisms must be flexible enough to meet the challenge of changing community values. This flexibility can best be achieved by concentrating more decision making power in the States and the localities."

4.2.2 Requirements for Centralized Control

If system-wide operational uniformity were required, it would probably entail detailed control far exceeding existing regulation of ground transportation vehicles and guideways. The sophisticated electronic equipment necessary for safe automatic operation of Dual Mode systems would be much more complex than, say, mandatory safety and air pollution emission equipment now required on automobiles.[11]

To regulate vehicle design, the Dual Mode central administrator could issue detailed specifications for vehicles to be constructed by private manufacturers.[12] As long as vehicles conformed to these requirements, they could be built in various models differing only in non-essential features. If more control were needed, the administrator could create limited monopolies by licensing qualified producers to make standardized vehicles. Only vehicles built by licensed manufacturers could then be allowed on the Dual Mode guideway. Or, the administrator could fabricate vehicles himself. Parallel degrees of control are available to regulate guideway construction.

[11] See, National Traffic and Motor Vehicle Safety Act of 1966, 15 U.S.C.A. §§1381-1410, and implementing motor vehicle safety standards 101-301, 49 C.F.R. §571.21. These standards establish requirements for control switch identification and location, windshield wiping and defrosting mechanisms, brake systems, lights, tires, mirror, crash impact protection, etc.

See also, "National Emissions Standards Act," 42 U.S.C.A. §1857f-1, authorizing establishment of exhaust emission standards for new motor vehicle engines.

[12] See, e.g., 32 C.F.R. §255 (Department of Defense Policies and Procedures for Assuring the Quality of Production of Complex Supplies and Equipment):

> "Complex supplies and equipment must be produced under regulated conditions if adequate assurance of quality is to be realized. Systematic control of manufacturing processes by the producer is an essential prerequisite for assuring the quality of such items. Likewise, it is essential that the Government verify systematically that such control is, in fact, established and exercised by contractors." 32 C.F.R. §255.3.

The administrator could issue detailed guideway construction standards which States must follow,[13] or personally direct guideway construction.

4.2.3 Precedents for National Regulation

Current Federal transportation regulatory and aid programs supply precedents for various degrees of centralized (Federal) control of specific transportation modes. Federal control of civil air transportation provides one example of extensive centralized control of facilities design and operation (but not necessarily the most appropriate administrative method for exercising control). That control, exercised by the Civil Aeronautics Board and the Federal Aviation Administration over private industry and individuals, determines terminals and intermediate cities,[14] reviews tariffs,[15] regulates air traffic,[16] prescribes minimum safety, design, materials, performance and maintenance standards for aircraft,[17] establishes pilot certification requirements,[18] and in all other aspects assures the safe and efficient utilization of the airspace.[19] The Dual Mode central administrator could be given comparable authority

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[13] The Secretary of Transportation now has authority to establish minimum guideway standards for other transportation modes. See, e.g., Natural Gas Pipeline Safety Act of 1968, 49 U.S.C.A. §§ 1671-1684. Section 1672 (b) requires the Secretary to adopt minimum Federal Safety standards covering "design, installation, inspection, testing, construction, extension, operation, replacement, and maintenance of pipeline facilities."

See also, 23 U.S.C.A. § 109 (b), authorizing the Secretary of Transportation to set geometric and construction standards for the Interstate highway system.

[14] Federal Aviation Act of 1958, as amended, 49 U.S.C.A. § 1371(e)(i).

[15] 49 U.S.C.A. § 1373.

[16] 49 U.S.C.A. § 1348(c).

[17] 49 U.S.C.A. § 1421(a).

[18] 49 U.S.C.A. § 1422.

[19] 49 U.S.C.A. § 1348(a).

over the Dual Mode system. The Federal highway aid program presents a model for regulation of a Dual Mode system with less centralized control. As described above, States carry out Federally aided highway construction projects in compliance with minimum Federal technical standards (e.g., geometric configuration, capacity to handle predicted traffic volume, construction techniques, and regulatory, informational and safety markings).[20] States control the basic matters of project location and design, project construction, and maintenance.[21] Finally, if nationwide design and operational uniformity for Dual Mode systems were not necessary, Federal participation could be limited to construction of a variety of Dual Mode system demonstrations. Local governments could then decide whether or not to construct a Dual Mode system, where to put it, and which one best suits their needs.

4.3 ROUTINE OPERATIONAL ISSUES

Operation of a Dual Mode system will pose several administrative problems. First, who should be allowed access to the automated portion of the system? If entry were at all complicated, safe and efficient operation would dictate that vehicle operators be trained to bring their vehicles into the system properly. This issue is of particular importance in systems open to large numbers of potential vehicle operators, for example, systems involving some variant of today's automobile. If the system were national in scope, a nationwide driver training and licensing program should probably be

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[20] 23 U.S.C.A. §109.

[21] 23 U.S.C.A. §§105 (planning), 106 (design), 114 (construction), and 116 (maintenance).

required.[22] Training should be given to all persons above a minimum age, or at least to all persons holding licenses to drive today's manually-controlled automobiles.

Before vehicles were permitted to enter the automated portion of the system, they should be required to conform to necessary safety standards. (This requirement could be relaxed in pallet Dual Mode systems, where vehicles would be passive and would not interact with the guideway.) If Dual Mode vehicles were under the control of the system administrator, as Dual Mode buses and rental vehicles would be, it should not be difficult to maintain and inspect them periodically.[23] Coercing private owners of Dual Mode vehicles to maintain them and have them inspected might present a problem, however. Automated pre-entry electrical and mechanical inspection of all vehicles would provide an incentive to adequate maintenance of privately owned vehicles. Any vehicle failing this inspection would not be permitted on the guideway. In addition to this quick check, more frequent vehicle inspections than the one or two per year required for automobiles would also be

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[22] In 1926, the National Conference of Commissioners on Uniform State Laws promulgated a proposed uniform statute to govern licensing of motor vehicle operators. Uniform Motor Vehicle Operators' and Chauffeurs' License Act. 11 U.L.A. 77-97 (1938). By 1949, 20 states had adopted this uniform code. The commissioners declared the law obsolete and withdrew it in August, 1943. 11 U.L.A. (1949 pocket supp. at 7). The National Committee on Uniform Traffic Laws and Ordinances issued their version of a uniform driver license law in 1968. Uniform Vehicle Code and Model Traffic Ordinance 69-92 (rev. ed. 1968). Section 6-110 requires the state department of motor vehicles to examine each applicant for a driver's license to determine eyesight, reading ability, knowledge of traffic laws and safe driving practices, and driving ability.

[23] Firms renting automobiles now follow elaborate vehicle inspection procedures to avoid liability for accidents involving their cars. See, e.g., Clarkson v. Hertz Corp., 266 F. 2d 948 (C.A.5, 1959); Stevenson v. Hertz Corp., 356 Mass. 723, 252 N.E. 2d 212 (1969); Anno.: Liability of bailor of automotive vehicle or machine for personal injury or death due to defects therein, 46 ALR 2d 404, 443-46 (1956).

necessary.[24] These inspections should include complete checkout of the Dual Mode mechanism, as well as testing of conventional safety features--brakes, tires, etc. Inspectors could attach computer-coded stickers to each vehicle complying with inspection standards to indicate the date of the inspection, thoroughness (i.e., was it a major or minor inspection), possible trouble areas to be watched, etc. Vehicles without proper inspection stickers, detectable by the central computer as they enter the automated portion of the system, could be barred from the guideway or even made subject to criminal sanctions, just as violators of existing auto inspection regulations now are.[25] A system-wide network of maintenance (and inspection) stations would be necessary to check Dual Mode vehicles regularly. To insure mechanics' and inspectors' qualifications, the Dual Mode system administrator could supervise training these personnel and either license maintenance and inspection stations or operate them himself to insure necessary quality standards.

4.4 NON-ROUTINE OPERATIONS: THE COST OF ACCIDENTS

Thus far the discussion has assumed routine operation of the Dual Mode system. The system is assumed to be designed in such a manner as to minimize the chance an accident will occur. While the possibility of an accident may be remote, should one occur, it could impose enormous dollar and non-dollar costs on the operators and occupants of the high-speed, close headway, automated Dual Mode vehicles involved. Planners should therefore evaluate alternative accident liability and compensation schemes appropriate for each type of Dual Mode system; schemes

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[24] See, e.g., Mass Gen Laws c. 90, § 7A, requiring semiannual inspection of automobiles; New York Vehicle and Traffic Law §301, requiring only annual inspection of motor vehicles.

[25] See, e.g., New York Vehicle and Traffic Law §§306, 512; Mass. Gen. Laws c. 90, §§ 2, 23. Computerized detection and review of inspection stickers should result in better enforcement of vehicle inspection laws than now available.

which would compensate accident victims for their losses, deter future accidents, satisfy social needs to penalize wrong-doers, all without deferring use of the Dual Mode system.[26] Without such policy guidance, courts in each jurisdiction in which a Dual Mode system operates will be forced to allocate accident costs on a case-by-case basis, adapting and applying traditional legal theories. As courts grope for a satisfactory body of law to apply to Dual Mode accident litigation, their missteps may result in grossly inequitable accident costs distributions in individual cases.[27] "Furthermore, the particularistic nature of the case law system is at best a form of 'incremental planning' with minimum integration into general rules that can guide the future actions of individuals, industries, and government agencies."[28] The following discussion applies alternative accident compensation schemes to the different types of Dual Mode systems, and evaluates their efficiency as allocators of accident costs.[29]

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[26] See, Harper and James, The Law of Torts 743 (1956 ed.).

[27] Green, Technology Assessment and the Law: Introduction and Perspective, 36 Geo. Wash. L. Rev. 1033, 1036 (1968).

[28] See, Note, The Role of the Courts in Technology Assessment, 55 Cornell L. Q. 861, 872, (1970). But see, Judge (now Chief Justice) Warren Burger, Seminar: The New Biology and the Law, 21 U. Fla. L. Rev. 427, 433 (1969): "The law's assignment in society is not one to anticipate needs. The law responds after a problem arises, and that is as it should be."

The suggestion that planners actively review alternative accident cost distribution schemes should not be construed to intimate that common law theories are inadequate to deal with Dual Mode accident litigation. But the decision to opt for the traditional approach should be a conscious one made after all alternatives are considered.

[29] Much of the discussion which follows relies on analysis developed by Professor Guido Calabresi of Yale. See Calabresi, Some Thoughts on Risk Distribution and The Laws of Torts, 70 Yale L. J. 499 (1961); Calabresi, The Decision for Accidents: An Approach to Nonfault Allocation of Costs, 78 Harv. L. Rev. 713 (1965); Calabresi, Fault, Accidents and the Wonderful World of Blum and Kalven, 75 Yale L. J. 216 (1965).

4.4.1 Accident Compensation Schemes for Bus and Pallet Dual Mode Systems

1. Accident Cost Allocation Under the Fault System.

To recover accident costs under existing common law principles of fault and negligence, an injured bus or pallet passenger must initiate a law suit against persons who may be legally liable to him. Candidates for liability include the Dual Mode system operator, who is responsible for automated operations and perhaps for vehicle and guideway design and construction, the bus or pallet manufacturer, the guideway builder, electronics fabricators, or makers of component parts for any of these manufacturers. The injured plaintiff must prove the following elements of his action to establish each defendant's liability: (1) A legal duty or obligation requiring the defendant to conform to a certain standard of conduct (in general, to act reasonably); (2) Defendant's failure to conform to that standard; (3) A causal connection between the conduct and plaintiff's injury; and (4) Actual losses.[30] Injured passengers on Dual Mode Buses or pallets would most certainly sue the Dual Mode system operator, the only entity they have dealt with directly in connection with Dual Mode operations. Because pallet and bus Dual Mode systems provide passenger service to the public akin to existing passenger common carrier service,[31] Dual Mode accident victims may take advantage of several special rules of law designed to

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[30] Prosser, The Law of Torts 143 (4th ed. 1971).

[31] A "common carrier by motor vehicle" is defined by the Interstate Commerce Act, 49 U.S.C.A. § 303 (a)(14), as "any person which holds itself out to the general public to engage in the transportation by motor vehicle in interstate of foreign commerce of passengers...for compensation, whether over regular or irregular routes...." A bus or jitney is a common carrier. 13 Am. Jur. 2d Carriers § 14 at 570.

facilitate accident victims' recovery from common carriers of passengers.

a. Duty of care. Instead of the duty to act reasonably which the law imposes on most individuals, common carriers of passengers are held to a higher standard of care. Passenger carriers holding themselves out to serve the general public owe their patrons the highest duty of care consistent with operation of their service.[32] If courts applied this rule to Dual Mode bus or pallet system operations, it could be argued that the absence of a driver or attendant aboard the bus or pallet in the automated mode constitututed evidence of negligence. The system operator could respond to this argument by contending that his Dual Mode system was designed to maximize safety without the need for human interference, and that a driver aboard the vehicle would be unable to respond to emergencies quickly enough to be of use. The presence of a human driver would therefore constitute a safety hazard, the system operator would conclude. Plaintiffs could respond that the failure to provide for human control was evidence of negligence itself.

b. Defendent's failure to conform to his duty of care. Establishing the precise manner in which a defendant common carrier's conduct deviates from the duty owed can be a difficult or impossible burden on an injured plaintiff. He lacks information as to proper modes of operation, proper maintenance methods, etc. To overcome this problem of proof, plaintiffs may employ the doctrine of res

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[32] The general rule has been summarized as follows:

> "A majority of courts uphold an instruction to the jury which exacts of a common carrier of passengers for hire the highest degree of care and forethought toward the passenger, consistent with the practical operation of the business." [Footnotes omitted.]

Harper and James, op. cit. supra note 26, at 947, and cases there cited. See also, 14 Am. Jur. 2d Carriers, §916 (1964).

ipsa loquitur ("the thing speaks for itself") to establish a common carrier's liability. Under this doctrine, the occurrence of an accident involving an instrumentality within the defendant's control and without plaintiff's active participation creates a presumption (or at least permits a jury to infer[33]) that the accident resulted from the defendant's negligence.[34] The burden then shifts to the defendant to prove he was not negligent. "The conditions usually stated in America as necessary for the application of the principle res ipsa loquitur are as follows: (1) The event must be of a kind which ordinarily does not occur in the absence of someone's negligence; (2) It must be caused by an agency or instrumentality with the exclusive control of the defendant; (3) It must not have been due to any voluntary action or contribution on the part of the plaintiff."[35] Automated Dual Mode bus and pallet operations appear to satisfy these prerequisites. Automated operation of buses and pallets would be under the system operator's complete control, with no control on the part of the passengers.

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[33] In some jurisdictions, the res ipsa loquitur doctrine merely allows a trier of fact to infer a defendant's negligence, but does not require a finding for the plaintiff when defendant offers no rebuttal evidence. In other jurisdictions, res ipsa creates a presumption of negligence which requires the trier of fact to find for the plaintiff unless the defendant rebuts the presumption. Even in those jurisdictions in which res ipsa otherwise creates an interference, however, a special rule may obtain in common carrier cases which increases res ipsa's effect to create a presumption. See McCoid, Negligence Actions Against Multiple Defendants, 7 Stan. L. Rev. 480, 483-5 (1955); but see, Note, Torts-Application of Res Ipsa Loquitur to Carrier-Passenger Cases, 38 Marq. L. Rev. 278, 280 (1955).

[34] Historically, the presumption of liability established by res ipsa loquitur was available only in actions by passengers against a common carrier. Harper and James, op. cit. supra note 26, at 1083-84

[35] Prosser, op. cit. supra note 30, at 214

According to representations of system designers, accidents are most unlikely to occur; if one does happen, it seems reasonable to presume it was caused by negligence. Further, the system operator would have easy access to technical information concerning the system to rebut the presumption (or interference) created by res ipsa.

Despite the availability of these special plaintiff-serving rules, it is difficult to predict the outcome of plaintiff's suits against the system operator. On the one hand, application of the common carrier standard of care and the res ipsa loquitur doctrine should facilitate accident victims' recovery from the system operator. If the injured plaintiff can point to a specific action by the system operator which caused his injury, he should have little trouble establishing that the action breached the high duty of care owed by the system operator as a passenger common carrier. (As passengers gain experience with use of the system, they should become adept at spotting specific deviations from standard practice, excess speed or too-rapid acceleration, for example.) Difficulties in proving adherence to the common carrier's high duty of care with respect to each of the myriad possible accident causes within the system operator to rebut the res ipsa presumption (or inference).[36] On the other hand, actual litigation experience in the airline industry indicates that any plaintiff's advantage created by the common carrier standard of care and by res ipsa may be fleeting. Courts and juries are often to find that airline accidents resulted from weather phenomena or other uncontrollable causes for which defendant air carriers are not liable regardless of the high duty owed. Procedural rules in some jurisdictions require plaintiffs to base their case either on res ipsa or to allege a specific act of negligence

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[36] See note 33, supra as to the effect of the res ipsa doctrine on the allocation of the burden of proof.

but will not permit plaintiffs to use both concurrently.[37] If a plaintiff suing an airline elects to rely on res ipsa, "The evidence adduced by the airline...tends to nullify whatever advantage the doctrine might afford the plaintiff. The defendant airline presents an elaborate display, consisting of maintenance, inspection and pilot experience records, which usually convinces the jury that there could not have been a failure to exercise reasonable care and that this must have been one of those 'mysterious mishaps of the air.'"[38] No doubt Dual Mode system operators would be capable of amassing similarly impressive displays shortly after systems began operations.[39]

Instead of suing the system operator, an injured plaintiff (or the system operator) could choose to bring suit against the manufacturer of the Dual Mode vehicle, the guideway fabricator, or perhaps the maker of component parts for alleged defects in their respective products. Cases now hold that "the seller of any product who sells it in a condition dangerous for use is strictly liable to its ultimate user for injuries resulting from such use,

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[37] See, Note, Domestic Commercial Aircraft Tort Litigation: A proposal for Absolute Liability of the Carriers, 23 Stan. L. Rev. 569, 571 (1971).

[38] Note, Liability of Airlines for Injuries to Passengers, 31 So. Cal. L Rev. 319, 321 (1958)

[39] Increased public familiarity with Dual Mode transportation systems could result in a more critical, less awestricken attitude on the part of juries to defendant system operators' evidentiary displays, giving renewed value to res ipsa loquitur. See Note Liability of Airlines for Injuries to Passengers, supra note 38, at 324.

although the seller has exercised all possible care, and the user has entered into no contractual relation with him."[40] Problems of proof, however, may make such suits difficult for plaintiffs to win. First, plaintiffs would have trouble identifying defective products after the accident occurs. A defendant could argue that the accident rendered its product defective, and that it was in satisfactory condition prior to the accident. Even if a product were shown to have been defective, it could be difficult to show the defect caused the accident. Plaintiffs could not use res ipsa because these products would not be under a single defendant's control.

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[40] Prosser, The Assault Upon the Citadel (Strict Liability to the Consumer), 69 Yale L.J. 1099, 1112 (1960)

The rationale behind this rule of strict liability for defective products has been explained as follows:

> Since the early days of the common law those engaged in the business of selling food intended for human consumption have been held to a high degree of responsibility for their products. As long ago as 1266 there were enacted special criminal statutes imposing penalties upon victualers, vintners, brewers, butchers, cooks, and other persons who supplied "corrupt" food and drink. In the earlier part of this century this ancient attitude was reflected in a series of decisions in which the courts of a number of states sought to find some method of holding the seller of food liable to the ultimate consumer even though there was no showing of negligence on the part of the seller. These decisions represented a departure from, and an exception to, the general rule that a supplier of chattels was not liable to third persons in the absence of negligence or privity of contract. In the beginning, these decisions displayed considerable ingenuity in evolving more or less fictitious theories of liability to fit the case....

Instead of attempting to establish liability based on defendants' fault, an injured plaintiff could choose to proceed on a contract legal theory by charging defendants with breach of an implied warranty of merchantability and fitness required of sellers of goods by nearly all states' law.[41] Because the fields

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40(cont'd).

> Recent decisions, since 1950, have extended this special rule of strict liability beyond the seller of food for human consumption. The first extension was into the closely analogous cases of other products intended for intimate bodily use, where, for example, as in the case of cosmetics, the application to the body of the consumer is external rather than internal. Beginning in 1958 with a Michigan case involving cinder building blocks, a number of recent decisions have discarded any limitation to intimate association with the body, and have extended the rule of strict liability to cover the sale of any product which, if it should prove to be defective, may be expected to cause physical harm to the consumer or his property.
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> On whatever theory, the justification for the strict liability has been said to be that the seller, by marketing his product for use and consumption, has undertaken and assumed a special responsibility toward any member of the consuming public who may be injured by it; that the public has the right to and does expect, in the case of products which it needs and for which it is forced to rely upon the seller, that reputable sellers will stand behind their goods; that public policy demands that the burden of accidental injuries caused by products intended for consumption be placed upon those who market them, and be treated as a cost of production against which liability insurance can be obtained; and that the consumer of such products is entitled to the maximum of protection at the hands of someone, and the proper persons to afford it are those who market the products.

Restatement (second), Torts 348-50 (comments to §402A) (1965)

[41]Uniform Commercial Code §2-314. The Uniform Commercial Code has been adopted in all States except Louisiana.

of liability-based-on-fault and contract law shade into each other in this area of liability for defective products,[42] plaintiffs may experience many of the same problems of proof described in the preceding discussion. For example, a plaintiff would still have to establish which defendant breached its implied warranty by selling a defective product. Employing a contract liability theory carries with it its own drawbacks. Although the requirement is slowly being abandoned,[43] some states still require plaintiffs to show "privity of contract," that is, a contractual relationship between plaintiff and defendant. Even when the privity requirement is relaxed, courts could still limit plaintiffs' actions against remote suppliers of component parts.[44]

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[42] It is beyond the scope of this essay to denote the niceties and limitations of each body of law as applied to products liability. See, e.g., James, Product Liability, 34 Texas L. Rev. 44, 192 (1955); Franklin, When Worlds Collide, 18 Stan. L.R. 974 (1966).

[43] While some jurisdictions continue to require privity of contract (i.e., a contractual relationship) between plaintiff and defendant, it will be assumed here that no showing of privity will be necessary. This assumption is not unwarranted. See, e.g., Greenman v. Yuba Power Products, 59 Cal. 2d 57 (1963); Goldberg v. Kollsman Instrument Corp., 12 N. Y. 2d 432 (1963); Kessler, Products Liability, 76 Yale L. J. 887 (1967).

[44] The issue of how far back along the production chain should liability for breach of warranty extend was decided in the circumstance of an airline crash in Goldberg v. Kollsman Instrument Corp., supra note 47. Plaintiff, whose daughter was killed when an American Airlines aircraft in which she was a passenger crashed, brought suit against the airline, Lockheed, the manufacturer of the aircraft, and Kollsman, the manufacturer of the aircraft's allegedly defective altimeter. The action against the latter two defendants was based on breach of an implied warranty of merchantability and fitness. The court below dismissed plaintiff's action against these defendants. On appeal, the New York Court of Appeals, Desmond, Ch. J., traced the demise of the privity requirement and dispensed with it as to the defendant Lockheed only: Dismissal of plaintiff's action against Lockheed was reversed, but dismissal of Kollsman as a defendant was affirmed.

See also, Hall v. E.I. DuPont De Nemours & Co., Inc., 40 U.S.L.W. 2787 (U.S.D.C. E.N.Y., May 30, 1972), extending liability for a defective product to an entire industry.

How well would the liability-based-on-negligence fault system satisfy the purpose of an accident compensation scheme? To the extent that injured plaintiffs lost their lawsuits, the fault system would not provide compensation for accident losses. (As indicated above, it is difficult to predict what portion of plaintiffs will or will not recover.) The fault system would provide incentives toward accident cost avoidance: The costs of defending lawsuits and the cost of lawsuits lost should induce the Dual Mode system operator and product manufacturers to curb activities which contributed to their legal liability. Balanced against this accident deterrence effect, however, is the possibility that Dual Mode product manufacturers might absolutely refuse to participate in the system rather than risk being held liable for all costs of an accident. Holding the system operator of product manufacturers liable for those accidents for which he is proven to be "at fault" should satisfy social needs to punish wrongdoers. But, to the extent that the operator or manufacturer escapes liability due to difficulties of proof in cases in which one or another is believed to be "at fault", the fault system would frustrate this social need. (If the system operator were to escape liability on too many occasions, a legislative judgment could be made to "sock it to him" for all his wrongs "once and for all" by closing the system, or by imposing a system of enterprise liability (discussed below) on its operation.)

2. <u>Enterprise Liability as an Accident Cost Allocator</u>

Dual Mode bus and pallet system operations could be held liable for accident costs in all cases through application of enterprise or strict liability, parallel legislative and judge-made legal theories which have grown alongside the traditional liability-based-on-negligence fault system. These doctrines recognize that many beneficial activities will inevitably cause accidents, and that the costs of these accidents may prove catastrophic to individual victims who cannot protect themselves against them. Rather than leave these costs where they lay, or where the fault system redistributes them, enterprise liability requires the activities themselves to bear their accident costs.[45] Placing the burden of these costs on the enterprise is thought to provide incentives to reduce accident cost-producing activities. The enterprise is generally prohibited from bringing lawsuits to pass on accident costs to related activities which otherwise might be liable for them. Accident costs which cannot be eliminated are distributed by the enterprise in the form of higher prices so that all users share these costs equally.[46] The statutory scheme found in most states for compensating victims of work-related accidents, workmen's compensation, is an example of enterprise liability. "The basic philosophy of such legislation is that loss from these (job related) accidents is a cost of the enterprises that entail them, and should be borne by the enterprises or their beneficiaries."[47] Strict liability for defective products, mentioned earlier,[48] is a case law doctrine which results in holding manufacturing activities liable for their accident costs.[49] And a similar result is obtained in non-manufacturing areas through the theory of strict liability for ultra-hazardous or "abnormally dangerous"[50] activities: "One who carries on an abnormally dangerous activity is subject to liability for harm to the person,

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[45] See James, General Products - Should Manufacturers Be Liable Without Negligence? 24 Tenn. L. Rev. 923 (1957).

[46] For refutation of these policy justifications, see, Plant, Strict Liability of Manufacturers for Injuries Caused by Defects in Products - An Opposing View, 24 Tenn. L. Rev. 938 (1957).

[47] Harper and James, op. cit. supra note 26, at 731.

[48] See text at note 40.

[49] See Prosser, supra note 40.

[50] This change in terminology is recommended by the drafters of the second Restatement of Torts. Restatement (second), Torts, Tentative Draft No. 10 at 56 (Reporter's note to§520) (April, 1964).

land or chattels or another resulting from the activity, although he has exercised the utmost care to prevent such harm."[51]

If the rationale underlying enterprise and strict liability and the result they produce appear to make these theories desirable methods for allocating Dual Mode bus or pallet system accident costs, they can be implemented directly, by legislation, or gradually, as accident victims press the courts to extend strict liability to the sale of Dual Mode transportation service. (It would seem unfortunate for Dual Mode system operators if courts branded their systems "Ultrahazardous activities" to justify imposing strict liability. In its early days, aviation was included with the category of ultrahazardous activities.[52]) If the latter case-by-case approach were followed, however, it could be some time until courts were persuaded to hold the system operator strictly liable for accidents without proof of negligent acts. And, under strict liability, the system operator could still attempt to redistribute this liability by initiating his own breach-of-warranty actions against Dual Mode equipment makers whose products appeared to have caused the accident.

Enterprise liability appears to satisfy the requirements of an accident compensation scheme better than the fault system. First, it would provide compensation to all Dual Mode bus or pallet accident victims. Individuals should be more willing to become Dual Mode bus or pallet passengers because they would not face the risk of unreimbursed accident costs. Enterprise liability would impose accident costs on the system operator who would be in the best position to change equipment, conditions, and procedures to avoid future accidents. Requiring the system operator to pay accident costs should not deter his operation of the system.[53]

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[51] Restatement (second), Torts, Tentative Draft No. 10 at 52 (§519(1)) (1964).

[52] See, Note, Tort Liability in Aircraft Accidents, 4 Vand. L. Rev. 857, 861 (1951), and cases there cited.

[53] If the system operator did act to curtail Dual Mode activities, his judgement implicit in such actions should induce critical re-thinking of the viability of the system.

The system operator could self-insure or purchase insurance to cover the cost of unavoidable accidents, and distribute these costs to all users in the form of increased fares.[54] Further, making the system operator bear accident costs should satisfy the need to punish the wrongdoer because, as between accident victims and the system operator, the latter more likely would be the cause of accidents.

Placing accident costs on the system operator through strict liability could produce results which, on balance, make it somewhat less satisfactory than legislated enterprise liability as an accident cost allocator. While permitting the system operator to sue his suppliers could induce them to produce better products, it could also intimidate tham from participating in the system.[55] With enterprise liability, on the other hand, such lawsuits could be barred by the enabling statute; the system operator would then be limited to economic pressures against suppliers to obtain accident-free products. The system operators' search for better (i.e., accident-cost-reducing) products under enterprise liability should induce new manufacturers to enter Dual Mode markets; the risk of bearing redistributed accident costs under strict liability could serve to eliminate them.

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[54] The system operator may wish to arrange for Federal reimbursement of accident costs which exceed a certain minimum level during the system's first years of operation. Such an arrangement would assure that an especially costly accident in the early days of Dual Mode service did not bankrupt the system. A few years' operation should provide the system operator with sufficient data to calculate the amount of insurance necessary, and to adjust rates accordingly. See generally, Morris Enterprise Liability and the Actuarial Process - The Insignificance of Foresight, 70 Yale L. J. 554 (1961).

[55] See discussion on page 25, *supra*.

3. <u>An Aside on Procedural Problems Incident to Fault and Strict Liability Accident Compensations Systems</u>

Both liability-based-on-negligence and strict liability require persons injured in accidents to initiate lawsuits to recover their accident costs.[56] Procedures governing these legal actions could be mofified to reduce administrative costs and time delays. For example, all accident victims could be required to join together to litigate defendants' liability instead of subjecting each defendant to multiple lawsuits.[57] Once liability were established, victims' recoveries could be as broad as permitted under present law - pain and suffering, lost earnings, lost earning capacity, medical expenses, property damage, and incidental expenses.[58] Or, legislation could limit recovery to a percentage of each of these expenses, or could deny recovery altogether for certain expenses.[59] Alternatively, a judicial arbitrator or damages adjuster agreed to by the parties could fix each victim's loss according to a predetermined compensation formula. Standards

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[56] If a system of enterprise liability for Dual Mode operations were established by legislation, the statute should include an administrative mechanism for making payments to accident victims. See generally, Note, Workmen's Compensation, 56 <u>Mich. L. Rev</u>. 827 (1958).

[57] Fed. Rules Civ. Proc. rule 20, 28 U.S.C.A., now authorizes Federal trial courts to permit voluntary joinder of several plaintiffs' actions arising out of a common occurrence.

[58] See generally, Harper and James, <u>op. cit</u>. <u>supra</u> note 26, at 1299-1360.

[59] Massachusetts has taken the lead in limiting personal injury recoveries in automobile accidents. No person may bring suit for pain and suffering unless his medical expenses exceed $500., or unless he suffers specific types of injuries. Mass. Gen. Laws c. 231, § 6D. Recovery for lost wages is limited to 75% of the victim's average wage. Mass. Gen. laws c. 90, § 34A.

from workmen's compensation statutes could be used to supply the basis for computation of Dual Mode accident victims' recovery.[60]

4. Social Insurance Accident Compensation Plans

Social insurance - direct payments to accident victims from general tax revenues - constitutes the last and least satisfactory method of allocating the accident costs of Dual Mode bus or pallet operations. The prime advantages of this scheme would be that it would compensate accident victims, and would certainly not discourage either the system operator, Dual Mode product manufacturers, or individual passengers from selling or purchasing Dual Mode transportation services. Social insurance would not, however, provide direct economic incentives to reduce accident costs, because neither the system operator nor product manufacturers would be liable to pay for them. Only if these costs skyrocketed to a politically unacceptable level would the system operator receive exhortations to reduce accident-causing activities from anxious politicians, concerned about high expenditures or the number of constituents injured by Dual Mode operations. In addition, social insurance would not punish the moral wrongdoer behind each accident. Unless Dual Mode accident costs were or were expected to be so high that the other schemes described above could not accommodate them, and/or unless Dual Mode bus or pallet transportation appeared so socially desirable that all society should bear its accident costs, it would seem reasonable to reject social insurance as a method of accident compensation.

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[60]Massachusetts requires employers' insurers to furnish eligible injured employees "adequate and resonable" medical and hospital services, Mass. Gen. Laws c. 152, §30, death benefits to dependents, §31, burial expenses, 53, payments for total and partial incapacity to the employee §§34, 34A, 35, and to dependents, §35A, and lump-sum payments for certain injuries, §36. Limitations of injured workers' recovery to only those benefits provided by a workmen's compensation statute have been found constitutional. New York Central R. R. v. White, 243 U.S. 188 (1917) (New York's Workmen's compensation statute). See generally, Note, Workmen's Compensation, 35 Chi.-Kent L. Rev. 164 (1956).

4.4.2 Accident Compensation Schemes for Private Vehicle Dual Mode Systems

1. Accident Cost Allocation Under the Fault System

A scheme for optimal allocation of costs resulting from accidents on the automated portion of a private vehicle Dual Mode system is more difficult to develop than one for allocation of Dual Mode bus or pallet system accident costs. This difficulty arises because of the increased number of active participants in private-vehicle systems. The increased complexity which these participants add to the liability determination necessary under the existing caselaw fault system makes that system a poor choice for accident cost allocator for this Dual Mode system. The fault system, it will be recalled, requires an injured accident victim to bring suit against persons who may be liable to him, and to prove liability by showing the duty of care owed, a breach of that duty, causation, and damages.

Of these elements, plaintiffs should probably find it easiest to prove their damages resulting from the accident. Choosing defendants from among the many actors involved in the operation of a privately owned vehicle on the Dual Mode guideway would be quite difficult. Potential defendants might include the guideway operator, the vehicle manufacturer, the manufacturers of specific vehicle components, a supplier to the component maker, the mechanic who last serviced the vehicle, the most recent vehicle inspector, the vehicle in front, the vehicle behind, etc. The decision to sue a particular defendant should be based on that defendant's actions which proximately caused the accident. Given the complexity of the system and the shambles accident-damaged vehicles and guideway may be in after an accident, it would be very difficult to identify either a defective product or a specific negligent act.[61]

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[61] Similar problems arise in determining the cause of commercial airline crashes. See, e.g., Note, Domestic Aircraft Tort Litigation: A proposal for Absolute Liability of the Carriers, 23 Stan. L. R. 569, 571 (1971); see generally, Hardman, Aircraft Passenger Accident Law: A reappraisal, 1961 Ins. L. J. 688.

Even if a defendant's product were found to have been defective, or a defendant were found to have acted negligently, plaintiff must still prove that the defect (or negligent act) actually caused the accident.[62] Plaintiffs would not be able to use the res ipsa loquitur doctrine to create a presumption of negligence because no single defendant would have sufficient control to justify the doctrine's application.[63]

The net effect of the fault system's post-accident legal obstacles to injured plaintiffs' accident cost recovery most likely would be to block plaintiffs' attempts at cost redistribution. How well does this succeed as an accident compensation system? Plaintiffs' failure to win lawsuits would leave losses where they fell after the accident, on the Dual Mode vehicle owners involved.[64] Vehicle owners would have to insure against these losses. Occasionally, perhaps almost randomly depending on jurors' vicissitudes, one or more accident victims would succeed in pinning liability on a particular defendant, with disastrous consequences for that defendant. The bill for all costs of a major Dual Mode accident could bankrupt all but very wealthy defendants, and could exceed

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[62] If the accident were caused by a defective product, say, the vehicle or a vehicle component, plaintiff could employ the doctrine of strict products liability to hold the manufacturer liable for damages. If, however, the accident were caused by a defendant's action, perhaps the guideway operator's act or another vehicle owner's act, plaintiff would also have to prove that the act violated the standard of care to which that particular actor must adhere. The novelty of Dual Mode private vehicle operations might result in case-by-case development of either a higher standard of care (equivalent to that owed by a passenger common carrier), or a lower standard (equivalent to that owed a guest occupant of an automobile).

[63] See, Note, Res Ipsa Loquitur As Applied to Multiple Defendants, 43 Ky. L. J. 535 (1955).

[64] The guideway operator would incur accident costs to the extent the guideway were damaged in an accident. If he sought to redistribute these costs through fault or breach-of-contract litigation, he would face the same problems as other injured parties. The risk of liability for these costs should provide some incentives to accident cost reduction through better guideway design, improved maintenance, etc.

the limits of most vehicle owner's liability insurance policies. The risk of bearing this liability, no matter how remote, may deter individuals from using the Dual Mode system and manufacturers from building Dual Mode vehicles, components, and guideways. The allocation of accident costs to injured owner-victims or to an occasional damned defendant would create no effective incentives toward future accident deterrence. Individual vehicle owners have neither sufficient bargaining power to compel manufacturers to build better Dual Mode vehicles,[65] nor adequate expertise to discover on their own defects in vehicle design, construction or maintenance. The burden of accident costs could not produce better driving habits in vehicle operators because operators would have no control over vehicle movement during routine automated operation. (Even if emergency services were provided in the vehicle, chances are that an accident would occur before a human operator could accomplish even reflexive movements.) If the risk of liability did not deter manufacturers from the Dual Mode market altogether, they might well find it cheaper to invest in lawyers' services after an accident than to take elaborate precautions beforehand to reduce the chance of accidents. Finally, leaving accident costs where they lay would not serve to punish wrongdoers.

2. <u>Enterprise Liability and Private Vehicle Dual Mode Systems</u>

Enterprise liability--the legislative decision to hold an activity liable for its accident cost--would also be more difficult to apply to private vehicle Dual Mode systems than to bus or pallet systems because of the increased number of activities involved: vehicle ownership, guideway operation, vehicle manufacture, all of which could be under separate control. The question is, which activity should be held liable.[66] Since no candidate for liability

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[65] Owner's lack of bargaining power vis-a-vis large manufacturers is demonstrated by automobile purchasers' inability to compel auto makers to build safer cars, or to eliminate unwanted annual model changes.

[66] The problem is akin to that raised by railroad grade crossing accidents, or auto-pedestrian accidents: See, Blum and Kalven, Public Law Perspectives on a Private Law Problem - Auto Compensation Plans, 31 <u>U. Chi. L. Rev.</u> 641, 699 (1964).

stands out, it is necessary to estimate how well accident compensation goals would be satisfied when different Dual Mode activities are held liable.

If each vehicle owner were held liable for his own accident costs, the result for accident cost distribution would be similar to that obtained in the fault system when plaintiffs lose their cases. While victims could insure themselves to cover their accident costs,[67] this solution would provide little or no deterrence

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[67] Vehicle owners could be made liable for their own accident costs by requiring them to participate in a compulsory insurance scheme comparable to "no-fault" automobile insurance. See, e.g., Mass. St. 1970, c. 670, found constitutional in Pinnick v. Cleary, __Mass.__ (1971 Adv. Sh. 1129). A no-fault insurance accident compensation scheme for private vehicle Dual Mode systems could pose administrative problems. Vehicle owners may be required to purchase two types of insurance - one covering automated operation on the guideway and a second covering non-automated operations. If there were a single no-fault system covering all vehicles, whether equipped for Dual Mode operations or not, rates would have to be adjusted so that neither Dual Mode vehicle owners nor non-Dual Mode vehicle owners subsidized each others' insurance premiums. With single insurance coverage, rates for frequent users of the automated portion of the system should be relatively lower than rates set for infrequent users because of Dual Mode automation's predicted increases in safety. Each privately-owned Dual Mode vehicle could be equipped with meters to register miles traveled in each mode, or the guideway computer could keep track of each vehicle's operations in the automated mode. Rates would then be based on total miles driven, and miles driven in each mode. Such a rate determination process could become extremely burdensome to administer, however. And, if monitoring patrons' usage resulted in detailed computerized records of trip origins, destinations and times of travel, the fear of unauthorized disclosures of trip details could induce potential users to shun automated operations.

If owners of Dual Mode equipped vehicles were required to purchase two insurance policies, one covering automated operations and the other non-automated operations, when would one coverage begin and the other end? Unless clear and easily applied principles resolved this issue, both insurers could deny liability in close cases. One solution would require the automated operations insurer to assume liability as soon as the vehicle crossed an arbitrary entrance point, perhaps upon passing through an electronic beam at an entrance ramp. The electronic entrance registering device would record the vehicle's entry, and its record would be deemed conclusive evidence of of future accidents because victims could not bargain effectively for improved vehicles or guideways.[68] This cost distribution might also deter individuals' use of the system for fear of incurring accident costs. In addition, the result produced by this allocation would not satisfy social needs to punish wrongdoers.

A legislative decision to hold the guideway operator liable for accident costs would produce a more satisfactory result: victims would receive compensation for accident costs from a source well placed to deter future accidents. The guideway operator could self-insure or purchase insurance to provide funds for compensation of accident victims.[69] His control over the automated right-of-way would put him in a good position to reduce the possibility of future accidents.[70] He could, for example, improve accident-prone sections of the guideway. The guideway operator could license or establish vehicle inspection and maintenance

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67(cont'd) the vehicle's entry into the system. Alternatively, no vehicle could be considered to have begun automated operations until the Dual Mode central computer noted and recorded its presence on the guideway. The computer's record would again be considered conclusive as to when coverage began. As with single insurance coverage, combined automated and non-automated insurance premiums for vehicles usually operated in the automatic mode should be lower than rates for vehicles only occasionally operating automatically.

68 See text at note 65, <u>supra</u>.

69 For a discussion of administrative issues in connnection with victim compensation, see text at note 56, <u>supra</u>.

70 Instead of using his authority to reduce accident costs, the guideway operator could choose instead merely to increase all toll rates charged for use of the guideway to cover these costs. This result is especially likely if the guideway operator occupied a monopoly position, with little possibility that other guideway operators would arise to compete with him by lowering their rates to reflect their reduced accident costs. A monopolist guideway operator whose position was established by law, for example, could easily develop an entrenched bureaucracy unwilling to initiate accident-cost-reducing changes (except, of course, when pressed by politicians controlling the monopoly.)

stations and permit only qualified vehicles to enter the guideway. If the experience of several accidents and near-accidents indicated that certain vehicles were accident-prone, the guideway operator could increase the rates charged those vehicles for guideway use. This increased toll should deter purchase of accident-prone vehicles and create economic pressure on these vehicles' manufacturers to improve their products. The guideway operator could be further empowered to set vehicle specifications and allow only complying vehicles on the guideway.

Placing liability on vehicle manufacturers should result in some combination of accident-cost-reducing vehicle improvements and higher vehicle prices to reflect the burden of unavoided accident costs; the precise mix would depend on manufacturers' monopoly power. Vehicle makers could decide to establish maintenance networks to extend their control over vehicle-related accident causes. This allocation of accident costs would not deter accidents resulting from defective guideways. While it would be in their interest to persuade the guideway operator to reduce his accident-causing activities, vehicle manufacturers would probably lack leverage to compel changes in guideway operations. Holding vehicle makers responsible for accident costs could also deter potential entrants from the vehicle market, or quickly bankrupt the maker of inferior (accident-prone) vehicles.

This discussion indicates that an enterprise liability system in which the guideway operator is held liable for all accident costs appears to best satisfy Dual Mode private vehicle accident compensation requirements. Unlike the fault system, enterprise liability would provide reimbursement to all vehicles owners and drivers for accident costs. The guideway operator could distribute these costs to maximize economic pressures to reduce accidents and to minimize dislocations resulting from unavoidable accidents. This allocation of accident costs should discourage no one from participation in Dual Mode operations because no single individual - driver, owner, or manufacturer - would bear all costs of an accident. (If costs exceeded cash reserves or insurance, the guideway operator could be permitted to tap general tax revenues to pay all accident victims.) Finally, placing responsibility for accident costs on the guideway operator should tend to discourage the wrongdoing in most cases: the guideway operator could have, after all, avoided or pressed others to avoid the accident.

4.4.3 Accident Compensation Alternatives for Rental Vehicle Dual Mode Systems

The analysis developed for bus, pallet and private vehicle Dual Mode systems can also be applied to rental vehicle systems. The effectiveness of alternative accident compensation plans for this type of system will depend on the specific characteristics of the rental system: the identity of vehicle lessor(s) and the guideway operator (are they one and the same entity), the rental time period, and lessor's control over the vehicle during the rental. Under the fault system, for example, if the vehicle lessor were also the guideway operator, and if only short-term rentals were allowed, it could be argued that the lessor-operator was in effect a passenger common carrier vis-a-vis vehicle lessees. Lessees injured in accidents while on the automated portion of the guideway could then use the special rules applicable to passenger carriers to facilitate their recovery.[71] The risk of liability for accidents could result in substantive improvements in vehicles, guideway maintenance, and so on, or in higher rental or toll rates to cover accident costs. The pressure to avoid accident costs rather than merely redistribute them through increased tolls and rental charges would then depend on the extent of the lessor-guideway operator's monopoly power. If the lessor-guideway operator contracted with lessees to assume liability for all accidents, a result equivalent to strict liability of the lessor-operator would obtain.

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[71] Lessees could also employ breach-of-implied-warranty arguments to hold lessors liable for defects in the rental vehicle. See text at notes 41-44, *supra*.

To change assumptions, suppose now that lessors and the guideway operator were independent of each other, or that long-term vehicle leases exempted lessors from vehicle maintenance and inspection. Plaintiff-lessees would now face both the difficult decision, which person to sue - vehicle lessor, guideway operator, maintenance man, lessor of another vehicle, etc., and the problems of proof of liability discussed earlier.[72] Plaintiffs' chances for recovery would decline correspondingly with these additional complexities. Applying the fault system to rental vehicle Dual Mode systems designed around these assumptions would therefore yield an unsatisfactory accident cost distribution in most cases. If injured lessees failed to recover their accident costs in lawsuits, they would be forced to bear their own accident costs. Even worse from the perspective of an individual lessee would be the possibility of being held liable for another lessee's accident costs. This possibility could deter persons from renting Dual Mode vehicles, and would provide little effective deterrence of accident-producing activities. Lessees could be permitted to shift the burden of accident costs to vehicle lessors by purchasing accident liability insurance from lessors. But, if lessors were relatively small independent businessmen, the fear of being held liable for all costs of a single accident could altogether deter their participation in the vehicle rental business, instead of stirring them to avoid future accidents through purchase of better vehicles, improved maintenance, etc.

The analysis could continue, changing assumptions about the rental vehicle system and applying the different systems of accident compensation (fault, enterprise liability, social insurance) described earlier.

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[72]See text at notes 61-63, supra.

4.5 SUMMARY AND CONCLUSION

This discussion of Dual Mode accident cost allocation suggests that the goals of an accident compensation scheme could be satisfied for most Dual Mode systems when accident costs are distributed to the system operator (in bus or pallet systems), or to the guideway operator through an enterprise liability plan. The system or guideway operator should have, through purchased insurance or self-insurance, adequate resources to compensate accident victims. His control over automated operations places him in a good position to reduce future accident costs by requiring safer vehicles, guideway and operating procedures. Assessing accident costs against the system or guideway operator should not discourage system utilization, because neither passengers, vehicle owners, vehicle lessees, nor Dual Mode product manufacturers would face the crushing burden of accident costs. If fear of accident costs intimidated potential system or guideway operators from engaging in Dual Mode transportation activities, a social insurance plan could be employed to distribute society-wide accident costs exceeding a pre-determined level.[73]

The time has passed when new technology can be deposited on society's doorstep and unashamedly left there with the expectation that others would devise piecemeal solutions for each development's collateral consequences. Rational well-integrated solutions to the type of issues raised in this essay are essential to public acceptance of any major technological innovation. In the case of Dual Mode transportation systems, planners should be prepared to supply proposals for administration of proposed system and a description of the administrator's authority necessary for efficient and responsible operation. Planners should also have ready a method for allocation of accident costs on the system, or a rationale explaining why none is needed. Planners should further have available recommendations for modification

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[73] A mixed compensation system such as this would require, of course, a collective decision that Dual Mode transportation should continue despite anticipated accident costs.

of local communities' land use regulations to assist them in anticipating and channeling trends in land use patterns spurred by Dual Mode installation.

5. CONCLUSIONS

5.1 DUAL MODE SYSTEM CHARACTERISTICS

This analysis has shown that if a Dual Mode system is intended to serve an entire urban area, a fleet consisting of a mix of personal vehicles and Dual Mode buses is considerably more attractive than either of these types of vehicles operating separately. These combination fleets attract a greater ridership than either type of vehicle individually and therefore defray the capital costs associated with the guideway network over a larger user group. The larger number of riders of the combined system also provide greater revenues to the system. The convenience provided by the personal vehicles contributes to a large diversion from the highway, while the bus portion provides service to those unable or unwilling to drive (for instance, the young, the old, the handicapped). The combined fleet also provides the flexibility to changing demand patterns as land use and transportation preferences change.

For all systems examined the ridership and resulting revenues generated over a range of fares were sufficient to equal or exceed the operating costs of the system. Although the capital costs per route mile were equivalent to or lower than those of rail rapid transit systems recently completed, currently under construction, or planned for the near future, it seems unlikely that revenues would be large enough to cover the full debt service. Thus capital subsidies to the system from some source are required and can be justified by benefits which accrue both to system users and to non-users. Increased land values and tax revenues as well as reduced travel time, highway congestion, noise, and displacements are some of the benefits to the community. Based on the assumed monetary valuation of quantitative impacts, the benefits of the Dual Mode systems investigated were greater than twice the costs.

A significant benefit associated with the implementation of Dual Mode systems is travel time savings. Diversion of highway travel onto Dual Mode guideways increased peak period surface arterial speeds by an average of 13%. Typical Dual Mode travelers reduced their trip time by 15 to 20 minutes. These two factors caused a 15% increase in average regional trip speed and travel time savings of up to 36 years per day. Thus the Dual Mode system provides increased travel speed not only to its users, but through diversion of highway traffic and consequent reduction in congestion, to other urban travelers as well.

Most of the route miles (about 80%) of the systems analyzed in this scenario were accommodated on existing rights of way or were tunneled. Thus, although the Dual Mode systems have up to 83% more route mileage than the 1990 plan highway and rapid transit that they replace, dislocations are only about 10% of the number of households displaced by the 1990 plan. Further, by using large amounts of existing right of way, additional neighborhood disruption and division is minimized. Of those displacements which are required, less than 5% are blacks or other minority groups and less than 7% are low-income families. Thus these systems in this scenario minimize the impact upon the traditional victims of new transportation system construction.

It is because of the high capacity of the automated guideway (which permits relatively large traffic volumes per lane) that existing rights of way could be used so extensively and so effectively. Currently community pressures are making acquisition of new right of way for transportation systems into a sensitive political issue, and it is becoming increasingly difficult - virtually impossible in many cases - to disrupt communities and displace families in order to provide new transportation. Thus this particular characteristic of Dual Mode systems may be more than a benefit; it may be a requirement for any transportation improvement. To the extent that communities are placing increasing value on minimizing these impacts and to the extent that noise pollution - reduced from the level of the 1990 plan by better than a factor of 100 by Dual Mode - is of ever greater concern to the populace, these benefits become more significant in support of the case for Dual Mode systems.

Of the systems analyzed the new small vehicle alternative has the greatest total benefits, the highest net incremental benefits, and the highest ratio of benefits to costs. This system also attains the greatest ridership and generates the largest excess of revenues over operating costs. It incurs, however, the highest capital cost of any baseline and requires the biggest capital subsidy. As noted in Chapter 3, the size of the capital investment is very sensitive to the unit cost of the small personal vehicles. In spite of the fact that benefits are on the order of 2-1/2 times the costs, the requirement still exists to invest about 4 billion dollars - over a period of years - into building an urban network of this extent and populating it with vehicles. Clearly a less extensive system could have correspondingly lower investment requirements.

The costs determined for the Boston system probably represent the upper bound of costs of urbanwide Dual Mode systems in any U.S. city except New York, Chicago, and Los Angeles. It is expected that examinations of these baselines in other scenarios would yield lower costs. It should also be emphasized that every attempt was made in this analysis to adopt a conservative position. The tendency, therefore, was to overstate the costs in question. The sensitivity of these assumptions is discussed in Chapter 3.

The capital investment by the system operator is 2.5 billion dollars for the pallet system analyzed in this study and 1.5 billion dollars for the automated highway vehicle system. For both of these systems an additional real cost is incurred by system users, who must individually purchase and operate their own vehicles in conjunction with the Dual

Mode system. For the new small vehicle system these vehicles are system owned, accounting in large part for the difference in total capital costs.

The new small vehicle system serves 45% more passengers than the pallet system at only a 30% higher annual capital plus operating cost. The automated highway vehicle system incurs 65% of the annual cost of the new small vehicle system while attaining 69% of the patronage level of that alternative. In fact, on either a passenger mile or a passenger trip basis the annual capital plus operating costs of all Dual Mode alternatives are practically the same.

The analysis has indicated potential benefits to minibus ridership by providing coordinated on-guideway PRT and off-guideway minibus (non-Dual Mode) dial-a-ride service. Thus there emerges the potential of a significantly better alternative: a Dual Mode new small vehicle system including captive PRT vehicles which coordinate with off-guideway conventional dial-a-ride minibuses as well as the Dual Mode small personal vehicles and Dual Mode minibuses. Both JPL and GRC have alluded to this conclusion that PRT and Dual Mode are complementary, rather than competitive systems. These projections are, of course, based only on data from a limited parametric analysis. Further detailed analysis would be required to verify the indicators.

This analysis has considered urban goods movement in only a peripheral manner - the time savings for highway truck travel. The potential cost savings for local freight movement on an automated guideway would appear to be a most attractive way to further defray the high costs of the fixed facilities. Utilization of the Dual Mode system for freight, particularly during off-peak periods, could contribute considerably to increasing the net benefits of the system.

5.2 POTENTIAL SYSTEM IMPLEMENTATION SEQUENCE

This analysis is of urban-wide applications of Dual Mode transportation systems and has indicated that for scenarios similar to Boston the ultimate urban-wide implementation goal is a new small vehicle system. Such systems will not, however, come into existence instantaneously. They will, rather, grow over a period of years. Because the network characteristics will change during this implementation period, different Dual Mode alternatives will provide the greatest effectiveness at particular stages. This implies that Dual Mode system designs should be sufficiently flexible so that they may accommodate these various forms during the implementation sequence.

Figure 5-1 depicts a potential implementation sequence for an urban area. Initial implementation of Dual Mode will probably occur in a high demand density corridor. The guideway will be of limited extent and will provide few alternative origins and destinations. A primary attraction of the Dual Mode system to the personal vehicle user is a diversity of possible destinations. Few people will be willing to invest in personal Dual Mode vehicles or make Dual Mode modifications to existing vehicles if only a few destinations are available for their use. Similarly, entering into rental agreements for system-owned vehicles is unlikely if only limited use can be made of them. Nor would the system operator wish to lease vehicles which would be seldom used. Thus if any personal vehicle system is to be used in a limited scale application, the pallet would appear to be the most appropriate alternative. A relatively high capital outlay for pallets would be required, and the higher operating cost per vehicle mile associated with pallet systems would be incurred.

However, it is precisely in this situation - a limited corridor with relatively high demand existing for a common set of origins and destinations - that bus systems are most effective. In such limited applications buses would probably attract a fair amount of ridership and would achieve

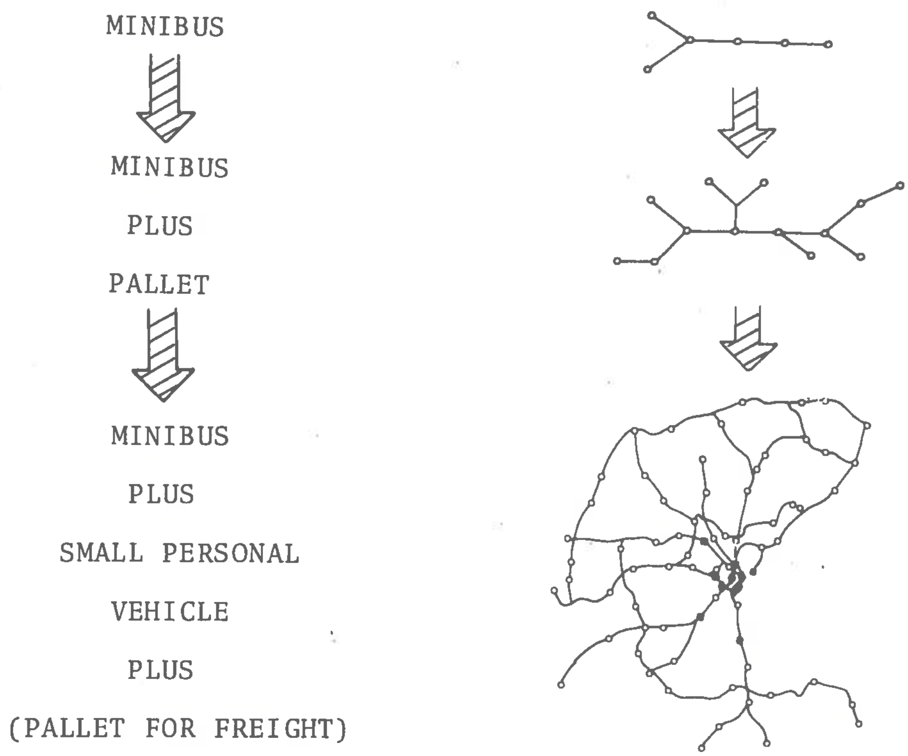

Figure 5-1 A Potential Implementation Sequence

high load factors. At anything above minimal load factors buses achieve the lowest vehicle capital and operating costs per passenger mile of any system. Thus, in a single corridor, implementation of a Dual Mode bus system provides the opportunity to install a working Dual Mode system at minimal cost and still achieve acceptable ridership. Moreover, because Dual Mode buses can be operated on guideways at relatively large headways compared to those required to move the same volume of people in personal vehicles, bus systems would appear ideal for the initial developmental stages of these systems, when command and control technology is in its early stages of maturity.

Of the bus systems examined, the minibus with dial-a-ride service achieved the greatest ridership. Since this high ridership would be desired to help defray the relatively large automation costs over the widest possible user base, the dial-a-ride minibus would appear to be the most suitable system for an initial limited corridor application of the Dual Mode concept. Personal vehicles could be introduced at a later date to increase utilization of the guideway, with the pallet being the most attractive candidate so long as a limited diversity of origins and destinations is available.

This analysis suggests that as the network expands and includes a greater number of stations, the new small vehicle alternative, in scenarios similar to Boston, provides the greatest benefits for the costs incurred. The total costs of a new small vehicle Dual Mode system are very high, however, and if such funds could not be made available, continued expansion of the pallet or introduction of the automated highway vehicle alternative may be preferred, despite their lower benefit/cost ratios. Were the new small vehicle system to be implemented, however, continued use of pallets or pallet-like vehicles for freight might be desired to further diversify system usage. The introduction, at a later stage, of a coordinated off-guideway bus feeder and on-guideway personal vehicle system has the potential to further increase ridership while decreasing costs per passenger trip through increased bus load factors. The evolution of an urban-wide application of Dual Mode transportation, therefore, would utilize a number of the concepts examined during its various stages of growth.

5.3 AREAS FOR FURTHER STUDY

The results presented here are for only one scenario and for urban-wide implementation of the concept. It is expected that different demand patterns, population densities, and urban forms would lead to some differences from the results obtained in this analysis. The rather extensive rail rapid transit system in existence in Boston, together with the extremely dense CBD having poor surface arterial circulation, forced the network design and operating policies for the alternatives examined to be considerably different from those which would be expected in other scenarios. The prohibition of Dual Mode vehicles from the CBD streets would probably not hold in cities with a lower population density and better CBD arterial circulation. The differentially-priced CBD and peripheral parking with transfer to transit would probably not occur elsewhere, nor would the extensive tunneling for the CBD network be required. In Boston the analysis examined Dual Mode and transit as complementary, but also competing modes. This would not be the case in cities which do not have an existing investment in rapid transit.

To place this analysis in the appropriate context, and to evaluate Dual Mode systems relative to alternative solutions to urban transportation problems, an analysis should be conducted of the various transportation options using a single technique, a fixed scenario, and consistent assumptions. For example, low capital cost bus systems with appropriate improvements and rapid transit, as well as innovative technologies, should be evaluated as alternatives.

As discussed in Section 5.1, parametric analyses have indicated potential for a combined PRT and Dual Mode system. The conclusion that PRT and Dual Mode are complementary, rather than competitive systems is potentially extremely important. Although other investigators, such as JPL and GRC, have obtained similar results, no concentrated study of the combined systems has been undertaken. It would appear that such a study may be of great significance to the future development of these two systems.

Urban goods movement is an area not examined in much detail in the current analysis. As indicated in Section 5.1, a significant increase in the net benefits of Dual Mode systems may result from the integration of passenger and freight operations in a single automated network. Further investigation of this subject would seem warranted.

Transportation systems exist as an integral part of an urban environment, and as such contribute to the economic, geographic, and demographic development of the region. This report has only commented qualitatively on a few of the impacts of Dual Mode systems upon urban growth. Land use modifications, industrial development, and changes in housing patterns as a result of new transportation implementation are some of the areas which should be examined in a more quantitative manner.

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NOTE: References for Chapter 4 appear in the text only.