Precursor Systems Analyses of Automated Highway Systems

R E S O U R C E   M A T E R I A L S

Commercial and Transit AHS Analysis

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FOREWORD

This report was a product of the Federal Highway Administration's Automated Highway System (AHS) Precursor Systems Analyses (PSA) studies. The AHS Program is part of the larger Department of Transportation (DOT) Intelligent Transportation Systems (ITS) Program and is a multi-year, multi-phase effort to develop the next major upgrade of our nation's vehicle-highway system.

The PSA studies were part of an initial Analysis Phase of the AHS Program and were initiated to identify the high level issues and risks associated with automated highway systems. Fifteen interdisciplinary contractor teams were selected to conduct these studies. The studies were structured around the following 16 activity areas:

(A) Urban and Rural AHS Comparison, (B) Automated Check-In, (C) Automated Check-Out, (D) Lateral and Longitudinal Control Analysis, (E) Malfunction Management and Analysis, (F) Commercial and Transit AHS Analysis, (G) Comparable Systems Analysis, (H) AHS Roadway Deployment Analysis, (I) Impact of AHS on Surrounding Non-AHS Roadways, (J) AHS Entry/Exit Implementation, (K) AHS Roadway Operational Analysis, (L) Vehicle Operational Analysis, (M) Alternative Propulsion Systems Impact, (N) AHS Safety Issues, (O) Institutional and Societal Aspects, and (P) Preliminary Cost/Benefit Factors Analysis.

To provide diverse perspectives, each of these 16 activity areas was studied by at least three of the contractor teams. Also, two of the contractor teams studied all 16 activity areas to provide a synergistic approach to their analyses. The combination of the individual activity studies and additional study topics resulted in a total of 69 studies. Individual reports, such as this one, have been prepared for each of these studies. In addition, each of the eight contractor teams that studied more than one activity area produced a report that summarized all their findings.

Lyle Saxton
Director, Office of Safety and Traffic Operations
Research and Development

NOTICE

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16. Abstract
The program described by this eight-volume report , a resource materials document type, identified the issues and risks associated with the potential design, development, and operation of an Automated Highway System (AHS), a highway system that utilizes limited access roadways and provides "hands off" driving. The AHS effort was conducted by a team formed and directed by the Calspan Advanced Technology Center. Primary Team members included Calspan, Parsons Brinckerhoff, Dunn Engineering Associates, and Princeton University. Supporting members of the team were BMW, New York State Thruway Authority, New York State Department of Transportation, Massachusetts Department of Transportation, the New Jersey Department of Transportation, Boston Research, Vitro Corporation, and Michael P. Walsh of Walsh Associates.
Calspan provided overall management and integration of the program and had lead responsibility for 5 of the 17 tasks. Parsons Brinckerhoff provided transportation planning and engineering expertise and had lead responsibility for 5 tasks. Dunn Engineering provided traffic engineering expertise and had lead responsibility on 2 tasks. Princeton supported the areas of transportation planning and automated control.
The 17 task reports (A through P plus Representative Systems Configurations) are organized into 8 volumes. This volume describes Commercial and Transit AHS Analysis (Task F). This task was performed as two independent and parallel efforts. Parsons Brinckerhoff performed the work reported in the main body of the report and Appendix A. That work was supervised by Marvin Gersten and supported by Jeanine Jankowski, both of Parsons Brinckerhoff. A separate and parallel analysis, performed by Princeton University, appears as Appendix B (with its own Executive Summary). This work was developed by Alain Kornhauser.

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VOLUME VII — COMMERCIAL AND TRANSIT AHS ANALYSIS (TASK F)

1.0 EXECUTIVE SUMMARY

As described in the Abstract of the Technical Report Documentation Page, this task was performed as two parallel efforts. The Executive Summary that follows only represents one of the studies. It summarizes the detailed report in sections 2.0 through 4.0 and Appendix A. Appendix B contains the results of the second and separate analysis effort, where the Executive Summary appears as section B.0.

1.1 GENERAL

If the implementation of AHS can result in improved highway travel time reliability, reduced delays, and lower accident rates for commercial vehicles as well as increased attractiveness of public transit for intercity as well as intra-urban travel, the potential benefits will also be accrued by passenger vehicle drivers and occupants who share these highway corridors.

1.2 COMMERCIAL VEHICLES

This brief ove rview of the trucking industry has revealed its enormous contribution to the nation's economy, employment, and productivity. Its diverse types of companies, commodities carried, vehicle types, haul lengths, labor concerns, competitive pressures, and government regulations indicate that the AHS program will need to address multiple trucking industry as well as competing mode issues and concerns. The basic question will be "what's in it for us?" Issues of primary concern to the trucking industry include environmental regulations, safety and health, taxes, labor and emerging technologies.

As the tractor-trailer combination truck appears to be the "workhorse" of the trucking industry, it must be decided whether this vehicle type should be the design standard for deployment and control. The integration of mixed and separate commercial vehicles within the traffic stream must also be considered. Analyses presented within Section 3.3 illustrate implications of trucks on the traffic stream for both rural and urban scenarios. If commercial vehicles are to be included, should all types, sizes, weights, and combinations be permitted, or should the AHS lane or lanes only allow smaller single unit trucks with dynamic characteristics similar to passenger vehicles?

While heavier and longer vehicles are viewed as needed by the trucking industry, what place do they have, if any, on the initial and subsequent AHSs that will be developed and constructed over the next decades? What, if any should the truck type and size restriction be? What are the cost implications for pavements and bridges? Should AHSs be designed only for passenger vehicles, vans, buses, and single unit trucks with a weight limit of 10,000 lbs, allowing the other commercial vehicles to remain on separate but non - instrumented sections of the Interstate System in both urban and rural areas? Or, should longer and heavier trucks be allowed, as is being lobbied for by the trucking industry. In theory, AHS will permit the drivers' tasks to be automated except for ingress and egress, and the risk of truck driver and / or passenger vehicle driver error leading to accidents will largely be eliminated.

The control and maintenance requirements needed for longer combination vehicles (LCVs), if they are permitted, need careful evaluation, in view of the greater accident potential of these commercial vehicles. The industry is, judging from the accident rate reductions achieved over the past decade, focusing on safety and proud of its accomplishments. It should, accordingly, be participating in the AHS efforts, to lend its expertise and experience in those vehicle and driver-related areas which will produce the most benefits in the early phases.

1.3 TRANSIT

AHS must be seen by the Local/Express Bus and Intercity transit industries as a cost effective, significant means to maintain current patronage and encourage new ridership.

The transit industry will need to demonstrate to the American public reasons for becoming competitive with personal autos. If AHS can provide the transit industry with the technology, service, reliability, frequency, direct routing (minimal transfers), at competitive costs with personal auto, there will be a demand for it. Contrary to the trends experienced over the last few decades, the emphasis in urban and suburban transportation is towards increased transit use, particularly based upon new federal legislation mandating change in travel habits by the public. The success of these new programs in accomplishing their goals will depend on transit's ability to provide more reliable, safe, and efficient transportation.

With AHS lanes or roadways available in high density travel corridors, buses, vans and qualifying high-occupancy vehicles will be afforded the opportunity to consistently meet on-time performance standards and schedules. Improved reliability and travel time will enhance customer service and attract 'choice' users from other modes.

AHS offers improved service and safety by reducing the potential for driver-related accidents. Removing the driver from the continuous operation of the vehicle and providing guidance and warning systems will enhance the performance of bus transit service on AHS facilities in high travel demand corridors. Continuous, predictable reliable service and well-maintained vehicles will eliminate excessive acceleration and deceleration rates which also cause numerous passenger injuries. The required increased maintenance practices would enhance vehicle operations and improve service reliability and safety.

Similar to the advantages of busways, buses and HOVs on AHS would include the following cost and service advantages:

1. Relatively low initial construction is required; i.e. convert HOV lanes to AHS, use existing central bus terminals, and expand as bus demand increases.

2. AHS transit lanes can be utilized by trucks during non-rush hour periods of the day.

3. Dual service buses provide manually driven feeder service, non- transfer trunk line AHS service, and downtown manually driven distribution service.

Expected time savings for HOVs can range from 0.5 to 2.0 minutes/mile. Carpooling has increased on HOV lanes in some cases up to 100 percent, and transit ridership has increased between 10 and 20 percent. The technology inherent to AHS would allow greater travel time savings and, potentially, higher ridership. In general, HOV lanes have shown good ridership growth and proven congestion mitigation. As travel demand grows and peak period capacity requirements outstrip available HOV lane capacity, AHS offers the next solution, with at least a doubling of vehicle carrying capability, and much greater multiples of person carrying capacity.

Improvements in the design of transit vehicles, and introduction of user-friendly transit information systems through IVHS programs, as well as additional government support through the mandates of the Clean Air Act Amendments and incentives introduced in ISTEA legislation, will lead to transit's evolution to a much more attractive alternative than it has been in the past. AHS offers the potential to make transit even more reliable, safer, and less time consuming. In light of the current legislation and support of transit by government policy to move people more efficiently, transit can be an integral, if not leading, component of initial AHS systems. Incorporation of transit into an AHS would allow transit agencies and their passengers to reap significant benefits, provided that the implementation and operating cost changes over existing conditions are viewed as worthwhile in terms of the benefits achieved. These potential benefits to the transit industry and its passengers Include:

- Increased ridership due to better customer service
- Reduced travel time: ability to compete with other, faster, modes of transportation
- Improved safety, reduced insurance costs, fewer third party claims from injuries sustained on-board buses, reduced fuel, energy consumption reduced bus down-time
- Reduced labor costs due to vehicle productivity increases
- Contribution to environmental goals of the CAAA, ISTEA.

Incorporation of AHS technologies into an existing High Occupancy Vehicle (HOV) lane or roadway would provide a cost effective transition from existing infrastructure. Transit vehicles and high occupancy vehicles would be among the first to benefit from AHS.

1.4 CASE STUDIES

From the analyses conducted for the Long Island Expressway, the New York State Thruway, and the New Jersey Turnpike, it is evident that each type of interstate highway, urban or rural, exhibits varying capabilities for incorporating AHS technology.

From the analyses, based on the stated assumptions, it appears that the most efficient travel will occur with passenger vehicles in separate AHS lanes, as well as all commercial and transit vehicles in separate AHS lanes.

AHS technology would be theoretically viable to alleviate congestion. The findings in the analyses for the LIE indicate that Option A for Scenario #4, with an ultimate capacity of 8,900 pcph, would be most beneficial for people-moving efficiency. These options also exhibit favorable average vehicle occupancies for compliance with the CAAA/ECO Progam goals. Along the east Spur of the New Jersey Turnpike Option A for Scenarios #1 and #4, with an ultimate capacity of 8,900 pcph, prove to be the most efficient. Option A for Scenarios #1 and #4 for the combined section of the Turnpike would also be relatively efficient in people-moving efficiency. These options would require carpools 2+ persons and aid in the effort to achieve the CAAA/ECO Program goals.

"No Build" conditions in 2024 on the New York State Thruway would not require excess capacity. An AHS could be implemented in this corridor for reasons of safety and efficiency. Option A, with one (1) AHS lane and two (2) GULs, would be the most effective option. None of the Scenarios/Options would meet CAAA/ECO Program goals.

2.0 INTRODUCTION

The dominant role of highways and the importance of trucks to the nation's economy is illustrated by the most recently available statistics [(1)] on freight transportation expenditures, indicating that 78 percent of the $375 billion spent in 1992 (6.3 percent of the $591 trillion GNP) was for over the road trucks, as compared to only 8 percent for railroads. By comparison, expenditures for passenger transportation by all modes were $638 billion (10.7

percent of GNP), and of this, $522 billion or over 80 percent was spent for private passenger vehicles. These two highway transportation system markets therefore account for a significant 17 percent of the GNP. By comparison, local and intercity passenger transportation, including bus, rail, and commuter rail accounted for only $24.5 million, or less than one half of one percent of the GNP. While these transportation costs include expenditures for equipment purchase, vehicle operation and maintenance, insurance, registration and licensing, they do not include the indirect costs of congestion, lost time, and accidents. If the implementation of AHS can result in improved highway travel time reliability, reduced delays, and lower accident rates for commercial vehicles as well as increased attractiveness of public transit for intercity as well as intra-urban travel, the potential benefits will also be accrued by passenger vehicle drivers and occupants who share these highway corridors.

2.1 DESCRIPTION OF ACTIVITY AREA

The Task F Activity Area has focused on identifying the potential commercial vehicle and transit industry roles, issues, and requirements for involvement and participation in the AHS Program. A comprehensive study of both industries has been made, identifying existing highway freight and transit passenger transportation markets, vehicle characteristics, roadway design criteria, accident patterns, existing and anticipated new technologies, and the expected impacts of operating these heavier and longer vehicle types on representative urban and rural AHS configurations, either mixed with AHS lane passenger vehicles, excluded from AHS lanes, or partially excluded by size/weight restrictions.

2.1.1 Purpose of Effort

The purpose of this task work effort has been to identify and discuss the specific market, industry, vehicle, roadway, operational, safety, and related issues and risks associated with the incorporation of commercial and transit vehicles into the various Representative Systems Configurations (RSCs) and scenarios addressed in this Precursor Systems Analysis.

2.1.2 Overall Approach

The initial Task F work was conducted as a research effort, including a literature search, review, and summary of relevant technical papers, statistical compilations, and commercial vehicle traffic characteristics data available from sources including: Transportation Research Board (TRB), Society of Automotive Engineers (SAE), American Trucking Association (ATA), National Private Truck Council (NPTC), U.S. Department of Transportation, Eno Foundation, various State Departments of Transportation and Tollroad Authorities; interviews with industry representatives; telephone conference discussions with other PSA Task F researchers; and discussions with members of the IVHS Commercial Vehicle Operations (CVO) and Advanced Public Transit Systems (APTS) Committees. The result of this effort was the Interim Report submitted in advance of the April 1994 Interim Results Workshop, at which its initial findings regarding Commercial Vehicle AHS issues were presented.

The subsequent work effort focused on completing the statistical market database by obtaining the national intercity freight shipment computer records and annual freight shipment records of the U.S. military to assess its relative importance; obtaining and evaluating hourly traffic volume classification counts for sections of urban and rural Interstate highways, including existing High-Occupancy Vehicle (HOV) roadways; and analyzing the impacts on these facilities of various RSC scenarios and AHS lane vehicle restriction alternatives by projecting existing passenger vehicle and truck traffic volumes thirty years ahead, to 2024. The results of these analyses have been used to provide input to the estimates of benefits and costs of operating commercial vehicles and transit on the selected AHS RSCs. This benefit cost analysis has been performed under PSA Task P, and the results are described in Section VIII of the overall report.

2.1.3 Guiding Assumptions

Given the rapid advances and price reductions in IVHS and vehicle engine and braking system technology, it is assumed that today's electronic computer engines, satellite communications systems, electronic data exchange, and cruise control will evolve quickly to widespread commercial acceptance of "intelligent" cruise control, collision avoidance devices, and ultimately, to "autopilot" type systems for commercial vehicle use, as the means for companies to retain their competitive edge. Transit operators will also implement these systems if they are seen as the means to control operating costs, retain existing passengers, and to attract new riders through improved service offered.

The present size, weight, and dynamic (acceleration, decel eration, braking, etc.) characteristics of existing truck and bus fleets are assumed to remain relatively stable over the next twenty years, although the trucking industry is actively seeking relaxation of current size and weight restrictions on large combination vehicles (LCVs). There will be a trend towards restriction of heavy vehicles in urban areas, but the resulting increase in smaller truck traffic may also prove to be objectionable. This study has, therefore assumed no major changes from existing truck or bus designs that would permit narrower lanes or lower vertical clearances to structures on AHS lanes or roadways. It has also been assumed that the passenger car equivalencies of trucks and buses will be the same on AHS facilities as they are now on Interstate highways.

3.0 TECHNICAL DISCUSSIONS

The evaluation of commercial and transit use of AHS followed the approach of identifying and studying the system parameters, or categories, of functional, operational and design issues and risks associated with this potential use. Relevant present and horizon year commercial and transit sector parameters were compiled and evaluated, and the results are described in the following sections of this Task Area F report. The sections have been structured into four parts: Section 3.1, Commercial Vehicles; Section 3.2, Transit; Section 3.3, AHS Scenarios With Commercial Vehicles and Transit. The Commercial Vehicle and Transit sections specifically address Functional/Market, Roadway Design/Vehicle, and Safety Characteristics and Issues. The AHS Scenario section identifies and analyzes alternative roadway deployment configurations for existing segments of urban, suburban, and rural Interstate highways, with several AHS lane use options for commercial vehicles, buses, and high occupancy vehicles (HOVs). The resulting estimates of vehicle miles, person miles and vehicle person hours of travel on each alternative and by each vehicle type have been provided to of these analyses to our team's economic analysts to quantify vehicle operating and capital costs, and to develop an "order of magnitude" estimate of benefits and costs of implementing each alternative as compared to the base non-AHS condition. Our conclusions and summary of critical issues and risks are presented in Section 4.

3.1 COMMERCIAL VEHICLES

3.1.1 Functional / Market Characteristics / Issues

3.1.1.1 The Commercial Trucking Industry

National Transportation Statistics for 1990 published by the U.S. Department of Transportation(2), and summarized in Appendix Table A-1 clearly illustrate the dominant role of highways and the importance of trucks to America's transportation system. Of the 189 million automobiles, trucks, buses, airplanes, and railroad cars and locomotives operating daily to serve the demands of moving people and goods, about 188 million are highway vehicles, and over 44 million of these, nearly 25 percent, are trucks. Over 3.7 million people are employed in the trucking industry, almost as many as employed in the automobile industry, (4.4 million). The railroad freight transportation industry employs less than 10 percent of the trucking industry, about 337,000. Comparative data on freight moved by rail vs truck indicate that while 26 million Class I rail freight car miles were operated in 1990, nearly 617 billion vehicle miles were traveled by trucks on the nation's highways, about 40 percent of which were on Interstates and other freeways and expressways. Trucks and the railroads moved approximately equivalent revenue ton-miles, 1.13 million and 1.03 million, respectively. The average haul distance for rail freight shipments is about double that of truck, 1,070 miles vs 570 miles, indicating that trucks carry nearly double the intercity tonnage carried by rail. Financially, the trucking industry generates ten times the annual revenue of the railroads, $272 billion vs $27 billion in 1990. Trucking dominates the market for all freight movements of less than 10,000 lbs, regardless of distance shipped, and for movements of up to 60,000 lbs for haul lengths of up to 500 miles. Rail competes with trucking for long haul shipments between 10,000 and 60,000 lbs, and for short hauls of over 60,000 lbs, as noted in "The Motor Carrier Industry in Transition", by Transportation Technical Services, 1993 (3).

The diversity of the trucking industry today can be seen in Appendix Figure A-1, prepared by Transport Topics, the National Newspaper of the Trucking Industry (4). It includes the "For Hire" Commercial Carriers, which are categorized as either Truckload, (TL), or Less-Than-Truckload, (LTL), Carriers. In addition, there are the Private Truckers and the Intermodal segment of the industry, which is growing rapidly.

For Hire Carriers: These companies are classified as interstate, intrastate, or local, the latter two subject to state or local regulation. They are either Contract Carriers; serving under contract to a small number of shippers with negotiated rates; Common Carriers who offer their services to any shippers and are subject to ICC approved commodity shipment rates; or Exempt Carriers, who transport special category goods, i.e. livestock, agricultural products, not subject to ICC regulations. Deregulation of the trucking industry by the Motor Carrier Act of 1980 broadened the areas in which these companies can compete for business, and they often overlap between the above classifications.

The For-Hire industry segments are comprised of the Truckload (TL) and Less -Than - Truckload (LTL) Carriers.

Truckload Carriers: These companies are characterized as follows:

- Single shipment between one shipper & one receiver
- Starting to compete in the short haul regional markets
- Heavily into Intermodal rail
- Constrained by driver shortages due to long hours away from home
- Strong market demand
- Non-Union drivers
- Dominated by J.B. Hunt, Schneider

Operating statistics for the 27 largest TL general freight carriers, presented in the August 1993 Commercial Carrier Journal (5), indicated total 1992 gross revenues of over $5.5 billion, 65 billion tons of freight moved and over 3.7 billion vehicle miles traveled. Two national carriers, J.B. Hunt and Schneider National, dominate this TL segment, each grossing over $800 million in 1992.

Less than Truckload Carriers: These carriers are characterized as follows:

- Single truck, multiple shippers, multiple stops
- Small shipments, 300-400 lb. packages
- Strong competition from UPS for small shipments, now up to 150 lbs
- Less driver problems than TL, drivers home most nights
- Unionized (Teamsters)
- Regional, Inter-regional, & National Network Carriers
- Trend is towards downsizing, streamlining
- Shippers reducing number of carriers used

Operating characteristics for the top 37 LTL common carriers were also presented in the August, 1993 Commercial Carrier Journal (6). These companies grossed over $27 billion in 1992, moving over 87 billion tons of general freight nearly 6 billion miles.

The dominant carrier in this industry segment is United Parcel Service, which grossed over $12 billion in 1992. United Parcel Service (UPS) is the world's largest freight carrier. Together with Federal Express, both gross over $25 Billion annually, about equal to the annual intercity freight revenue of the entire U.S. rail industry.

Private Carriers: The characteristics of this segment of the industry have been documented in Private Fleet Profile; 1993 (7), as well as garnered during discussions with industry sources. These fleets are owned and operated by companies who manufacture and ship their own goods. The trend in these companies is towards reducing costs by using for-hire carriers to supplement or replace their in-house fleets. They are represented by The National Private Truck Council, with over 1,100 members. The 1993 survey of these member firms provided the following information:

- One-way haul lengths range from 390 to 470 miles
- Average annual fleet miles range from 3.7 to 7.9 million miles
- Average number of stops on typical runs range from 4 for construction vehicles to about 30 for service vehicles
- Average percentage of empty miles operated: 27.1%
- Average annual tons hauled: 2.9 million
- Percent of vehicles, by type, operated in 1992:

light, class 1&2 (under 10,001 lbs) :	30.4
light / medium, class 3&4 (10,001-16,000 lbs) :	7.5
medium, class 5&6 (16,001-26,000 lbs) :	8.2
medium / heavy, class 7 (26,001-33,000 lbs) :	20.5
heavy, class 8 (33,001 & over lbs) :	35.3

- Average replacement of equipment: 7-8 years
- Method of driver payment

Hourly	56%
Mileage	28%
Salary & other	13%

The major concerns and Issues identified by the private fleet operators in the 1993 survey were: costing control, customer service quality, compliance with safety regulations, fleet justification, and compliance with environmental regulations.

3.1.1.2 Military Freight Shipments by Truck

During the search for a national database for truck freight shipment information, it was found that the U.S. Military Traffic Management Command maintains a Freight Information Systems (FINS) computer file of freight shipments by military service, mode and vehicle type, origin, destination, commodity type, weight, revenue, and date of delivery. As a comparable origin-destination database for civilian commercial freight movement is only in the planning stage by the U.S. Census Bureau, the military database, containing over 1 million records, of which some 600,000 were for trucks covering the period from February 1993 to January 1994, was obtained. Also obtained were the annual military data from FY 1984 through FY 1993 on the number, costs, and tonnages of military freight shipments by mode. These data, provided in Appendix Table A-2, indicated the significant role that trucks play in military goods movement, ranging from 81 to 85 percent of the shipments and 66-69 percent of the costs in that period. Only pipeline carried more weight, about 36-40 percent of the total annual tonnage shipped.

A comparison of revenues and tonnages of military truck freight with the civilian truck data provided in the previously noted ENO Foundation's 1993 edition of Transportation in America indicated that while trucking was the military's most significant goods movement mode, these shipments constituted less than 1 percent of the total civilian and military trucking tonnages and revenues over the 1984 to 1992 period for which that data was available. (See Appendix Table A-3). Based upon this comparison, it was decided not to sort the military origin-destination truck shipment database to identify its major shipping corridors, as the trucking volumes would likely be insignificant in comparison to the overall civilian truck shipment between major city pairs. It was concluded that the military, as a purchaser of freight transportation, will use AHS just as other civilian shippers will if it is cost effective to do so.

3.1.1.3 The Intermodal Industry

The characteristics of the Intermodal segment of the freight carrier industry are summarized below:

- Containers owned by large trucking companies, railroads, or shipping companies, moved large distances
- "Double stack" or "Railroader" rubber tire/ steel wheel container units
- Originated by the ocean shipping carriers, off-loading containers to double-stack railroad trains
- J.B. Hunt intermodal network transforming north american freight railroad system, with 39 terminal connections with at least 9 railroads
- Hunt is replacing entire trailer fleet with containers
- Current issues include linehaul & terminal capacity, equipment standards (Containers), railroads' capacity

- Predicted to grow by 8 percent in 1994, or to about 8 million containers
- Actual growth through June 1994 was 13.4 percent above comparable 1993 period.
- Competitive with trucking on long hauls (over 700 mi.), not short hauls
- Comparable system for considering AHS for commercial vehicles

In his 1994 paper, "Integrated Intermodal Freight Transportation Technologies in the 21st Century," (8) M. J. Vickerman described the growth of the Intermodal market, presenting the following statistics and information:

- Trailer and container on rail flatcar (TOFC/COFC) comprised 15 percent of the U.S. intercity freight moved over 500 miles and 3 percent of the total U.S. intercity freight moved in 1992
- This market generated $6 Billion in revenue in 1992, carrying 6.2 million loads and 16 percent of the total U.S. railroad freight volume.
- One-third of all shippers switched from truck to intermodal rail in 1992.

The significance of the Intermodal concept and its emergence as a long haul competitor to trucking is that it can also be viewed as an alternative to providing AHSs for heavy (LCV) trucks. Its advantages include safety, reduction of the need for drivers, reduction in heavy truck miles and infrastructure costs for highways and bridges to accommodate heavy vehicles, and reduced energy consumption. An April 1991 study, prepared for the U.S. Department of Transportation's Federal Railroad Administration (9), compared the fuel efficiency of rail freight movement with truckload freight movement in comparable corridors moving common and competitive commodities. The Measure of Effectiveness (MOE) used was Ton-Miles per Gallon. The results indicated rail to attain fuel efficiencies of 1.4 to 9 times greater than competing truckload service, ranging from 196 to 1,179 ton-miles per gallon of fuel consumed as compared to 84 to 167 ton-miles per gallon for trucks. The 43 different truck scenarios studied six different trailer types powered by a Cummins 350 truck engine. Truck distances ranged from 237 miles to nearly 2,100 miles. Six different train types were analyzed ranging from mixed freight in boxcars to doublestack. Rail distances, including switching and truck drayage for intermodal freight ranged from 311 miles to over 2,200 miles.

The November 1993 issue of "Progressive Railroading" was devoted to Intermodal Issues. An article by G. Carmichael, former FRA Administrator in the Bush Administration, entitled "J.B.'s Network" (10) depicted the national intermodal rail network developed by J.B.Hunt to serve his container freight shipments. If this network is superimposed on a map of the Interstate System and other rail corridors, it becomes evident that there are many unserved intercity corridors in which intermodal rail or AHS for trucks could potentially serve. Cost-benefit comparisons are recommended to assess the relative feasibility of AHS vs Intermodal Rail in specific intercity corridors during subsequent phases of this program. Evaluation of the terminal requirements at transfer points for rail containers vs direct access AHS commercial vehicles or future AHS containers would be a major part of these subsequent studies.

3.1.1.4 Summary & Conclusions

This brief overview of the trucking industry has revealed its enormous contribution to the nation's economy, employment, and productivity. Its diverse types of companies, commodities carried, vehicle types, haul lengths, labor concerns, competitive pressures, and government regulations indicate that the AHS program will need to address multiple trucking industry as well as competing mode issues and concerns. The basic question will be "what's in it for us?" The industry has identified it's "Issues of Concern" [4] as follows:

Environmental:

- Restricted operations in urban areas
- Stiffer emission standards
- Hazardous materials regulations

Safety and Health:

- Stringent government regulations
- Restrictions on CCV operations
- Health care costs
- Driver training, substance abuse
- Public perception

Taxes:

- Increasing fuel taxes
- ISTEA/MPO directed funding decisions
- New permit fees, times, penalties

Labor:

- Driver shortages
- Commercial driver's license requirements
- Mandatory drug testing

Technology:

- Pressure from shippers, suppliers, government to adopt new technology
- Competitive pressures for improved communications, computerization, vehicle components
- Growth of medium-duty trucks for short hauls

AHS has the potential to address many of these industry issues, particularly safety, driver task enhancement, and competitive pressure.

3.1.2 Roadway Design & Vehicle Characteristics

By defining the specific design and operating characteristics of trucks, including their sizes, weights, performance dynamics, impacts on roadway infrastructure and traffic operations, the issues to be addressed in assessing their role in the Automated Highway System program can be identified. This "Precursor" review has identified numerous design and operating issues which will have to be evaluated in detail as the Representative Systems Configurations which incorporate commercial vehicles are developed. Size and weight limitations, vehicle handling and stability, pavement and bridge design and maintenance requirements, geometric design requirements of ingress and egress ramps, are just a few of the relevant items which have been identified and discussed in the following sections.

3.1.2.1 Design Criteria

Roadway geometric design standards and criteria cover horizontal and vertical geometry and cross section elements including lane, shoulder, and clearance zone widths and heights. They are based upon design vehicle characteristics, including: vehicle height, width, length, driver eye height, vehicle headlight height, weight-to-horsepower ratio, braking distance, driver perception and reaction time, and acceleration and deceleration rates.

The American Association of State Highway and Transportation Officials, in its 1990 "Policy on Geometric Design of Highways and Streets", [11] has established the design vehicles and design standards used by state and local transportation agencies for urban and rural roadway design. The design vehicles include: Passenger Car, Single-Unit Truck, Single-Unit Bus, Articulated Bus, Combination Truck, "Double-Bottom" Truck, and Recreation Vehicle. The commercial vehicles included in the above design vehicles are further defined by symbol and description as follows:

COMMERCIAL VEHICLE TYPE	AASHTO SYMBOL
Single Unit Truck	SU
Combination Trucks:	
Intermediate Semitrailer	WB-40
Large Semitrailer	WB-50
"Double Bottom" Semi/ Full- Trailer	WB-60
Interstate Semitrailer	WB-62 (48' Trailer)
Interstate Semitrailer	WB-67 (53' Trailer)
Triple Semitrailer	WB-96
Turnpike Double Semitrailer	WB-114

These diverse types of trucks are illustrated in Appendix Figure A-2. Trucks are further defined by size / weight classifications ranging from Class 1, 6,000 lbs & less to Class 8, 33,001 lbs and over. Statistics published in the July 1993 Commercial Carrier Journal (12) show that nearly 47 million trucks were sold by U.S. truck manufacturers between 1978 and 1992. Of these, nearly 92 percent were Single-Unit, up to 10,000 lbs Gross Vehicle Weight (GVW). Only 4 percent were in the Class 8, Combination Vehicle category.

AASHTO design vehicle dimensions are provided in the above-noted 1990 "Green Book". The common design dimensions and criteria recommended for trucks of all categories are: Height - 13.5 ft.; Width - 8.5 ft.; Weight / Horsepower Ratio -300; Brake Reaction Time - 2.5-3.2 seconds; Driver Eye Height - 3.5 ft.; and Headlight Height - 2.0 ft. The pertinent AASHTO truck design dimensions are presented in Appendix Table A-4, along with the relevant vehicle performance characteristics.

All U.S. Transportation Departments are governed by these AASHTO standards, while the quasi - public Toll Road Authorities use their own standards, which may in some areas exceed the AASHTO values. These agencies include the New Jersey Turnpike Authority, New York State Thruway Authority, Delaware Turnpike Authority, Pennsylvania Turnpike Authority, and Massachusetts Turnpike Authority in the northeast.

Each of these agencies differ in their commercial vehicle classification systems, described as follows:

For toll collection purposes, the New Jersey Turnpike uses eight revenue vehicle classes, of which four (Class 3-6) are medium to heavy trucks, two (Class 5 & 6) are heavy trucks with five or more axles, and two (Class B-2 and B-3) are buses. Trucks comprise 12 percent of the annual traffic on the Turnpike.

The comparable classification system on the New York State Thruway includes seven truck classes, which comprise a low of 6 percent of total daily traffic in the Buffalo sections and 15 percent at its Yonkers Toll Plaza. By comparison, the New York State Department of Transportation uses thirteen vehicle classification codes for its statewide counting program. Codes F1 to F3 cover passenger vehicles, motorcycles, and 2 axle, 4-tire pickups, vans, and motor homes, while Codes F4 through F13 include buses and trucks ranging from 2 axle, 6-tire single unit to 7 or more axle, multi - unit vehicles.

Data obtained from the New York State classification counts on Interstate Highways in Rural and Urban areas have been analyzed to show the relationship between total daily traffic, total truck traffic (F4-F13), and four or less axle tractor-trailer truck traffic (F8-F10), excluding the multi-unit, double trailers (F11-F13) which comprise no more than one percent of the total daily traffic at all but two of the locations counted, where the percentages were less than two percent. (At trailer parking areas). The high proportion of tractor -trailer trucks to total trucks on both rural and urban Interstate highways is found throughout the range of total traffic volumes, as shown in Appendix Figures A-3 and A-4.

A similar graph, Appendix Figure A-5, was prepared for the NJ Turnpike (I-95). Although the Classification 3 includes both semi-trailers and 3 axle single unit trucks, it was included in the data shown in the graph to represent all tractor - trailers. These graphs as well as additional data obtained from the New York State Thruway Authority portray the over-representation of tractor - trailers in the total truck population of Interstate Highways and Toll Roads in urban and rural areas in the northeast, ranging from about 70 to over 80 percent.

Truck characteristics on urban freeway systems in California were investigated in the "Urban Freeway Gridlock Study: Decreasing the Effects of Large Trucks on Peak-Period Urban Freeway Congestion" [13]. The study covered freeway systems in Los Angeles, San Diego, and San Francisco. It found that large trucks averaged up to 5.5 percent of the morning, mid-day, and afternoon peak period traffic volumes on these freeways, and that 65 percent were tractors hauling single trailers, 20 percent hauled double trailers, 12 percent were single unit, straight trucks, and 3 percent were others. The authors noted that in Los Angeles, large trucks account for 80 to 90 percent of all truck miles on the freeways, most of which are five-axle, 18-wheel tractor-semitrailers. They also noted that California has a larger proportion of twin trailer trucks than most other states.

In summary, as this and subsequent sections of this report will indicate, the tractor-trailer combination truck appears to be the "workhorse" of the trucking industry. The implication or question for the AHS Task F to consider in the evaluation of RSCs with mixed and separate commercial vehicles is if this vehicle type should be the design standard for deployment and control. More information on the size and weight characteristics of these and the other single unit and combination vehicles is presented in the following sections.

3.1.2.2 Truck Size & Weight

In order to appreciate the current climate in which trucks are regulated and operated on the nation's highways, background statistics on Federal and State laws governing the permissible maximum sizes and weights of commercial vehicles were obtained from the American Trucking Association's Motor Carrier Advisory Service [14]. These statistics are summarized in Appendix Table A-5 in terms of the number of States with the size and weight limits indicated.

As indicated, maximum truck sizes a nd weights on most Interstate highways are currently set by law at 80,000 lbs. maximum gross weight, 53 feet long, 102 inches wide, and 13 feet 6 inches high. Twin trailer combination units are set at 28 feet long, and maximum single axle loads are 20,000 lbs. The exceptions to these limits are "grandfathered" states which permitted longer, heavier combination vehicles (LCVs) prior to the 1992 ISTEA legislation.

Recommendations for changing the current national truck weight regulations were prepared and published in the June, 1990 TRB Special Report, "Truck Weight Limits. Issues, & Options",[15]. The study committee recommendations, which are still under discussion by various environmental and rail industry representatives, included changing the existing Federal Bridge Formula for maximum truck weight on Interstate Highways to permit heavier loadings, and providing broader permit processes for heavier vehicles to operate. The intent, as indicated by ATA's Robert E. Farris, Vice President of Policy, at a 1991 Congressional

Seminar on Longer and Heavier Trucks (16), was to bring all the States into uniformity on maximum truck weights.

Another TRB study, "New Trucks for Greater Productivity and Less Road Wear, an Evaluation of the Turner Proposal" (16), named after a former FHWA Administrator, proposed a longer double combination trailer, a twin 34' to replace the twin 28', with more axles to allow 110,000 to 112,000 lbs maximum gross weight. This would conceivably result in a 25 percent reduction in pavement damage. This proposal has not been adopted by AASHTO nor embraced by the trucking industry, which prefers to run their existing twin 48' trailers, or double- twin 28' combinations retrofitted with additional axles to cushion the additional total load.

The TRB 225 Special Report prepared estimates of the benefits to the trucking industry of increasing the gross weight limits on the Interstate system. Trucking costs would decrease by $2.7 billion per year, offset by $0.3 billion in taxes to pay for the additional bridge and pavement infrastructure costs. Additional benefits would include shifts of heavy trucks from non-Interstate to Interstate roads, and shifts from three to four axle trucks, of benefit to pavements.

Changes in truck size and weight limits affect maximum payloads. High-density freight is controlled by weight; low-density is controlled by cubic capacity. Increases in weight limits increase weight per trip, and reduce the number of trips and truck vehicle miles. Diversion from rail to truck and truck to rail is influenced by truck weight limits, primarily by changes in truck transport costs. These include: over the road costs; loading / unloading costs; storage, loss, and damage costs; delivery time unreliability; and the cost of capital on goods in transit and inventory. AHS for commercial vehicles would provide potential reductions in travel time and damage costs, thereby increasing the diversion of certain shipments from rail to truck.

The railroad industry views attempts to increase truc k size and weight limits negatively. Testifying at the same June 7th, 1991 Congressional Seminar noted above, the Association of American Railroads' President and CEO, William H. Dempsey argued for the promotion of intermodal transport of highway trailers for long hauls, with the motor carriers performing the shorter hauls. He cited AAR study findings that permitting general use of LCVs, i.e. twin 48' trailers, on the Interstate Highway System would cost the rail industry 40 to 50 percent of its net operating revenue. He also noted AASHTO's reluctance to change the current policy towards LCVs until further studies are conducted, and quoted a statement of three major U.S. environmental organizations listing the following objections to increased truck sizes and weights: "increased air pollution, increased congestion, subsidized competition with more energy efficient rail transportation, and increased pavement damage which in turn would require spending scarce Federal transportation dollars on highway and bridge repair rather than on investments in more energy efficient alternatives." Similar objections to AHS operations by LCVs can be anticipated from these sources.

Cornell University investigated the New York State heavy truck permit system to determine its benefits to the economy, as compared to what would happen if Federal load limits were maintained. It's Final Report, "Economic and Safety Consequences of Increased Truck Weights" (18) provides a wealth of information on economic and safety impacts of heavy trucks, relevant to their potential operation on Automated Highways.

The Cornell researchers concluded from their studies that the permit system has reduced the number of truck-miles driven by the relevant trucking industry fleet by 79 percent, without a change in accident rates or severities. It has reduced the number of accidents, fatalities, and injuries due to the reduced number of trucks used to move the same loads. They further estimated that the economic benefits to the heavy truck operators of the permit system were as much as $690 Million in reduced operating costs annually. The costs to the infrastructure, i.e. pavements and bridges, of the heavy truck permit program were to be estimated in a parallel study, " Effect of Truck Weights on Deterioration, Operations, and Design of Bridges and Pavements" (19). This study focused on the impacts to roadway pavements and bridges of the program. An attempt was made to determine the differences in pavement costs to New York State with and without the heavy permit vehicles. The results were inconclusive, however, due to the small percentage of these vehicles.

The potential impacts of heavier vehicles on bridges were discussed by focusing on the most common type of bridge in New York State, the simple-span, steel, multi-beam or girder bridge. These were noted as most sensitive to increased truck loading fatigue damage. State data indicated an average of three bridges per mile on urban Interstates and close to one bridge per mile on rural Interstates. This totaled over 1,300 bridges on these existing highways. Of these, it was estimated that nearly 20 percent are subject to fatigue damage due to their structural design characteristics. The costs to upgrade and maintain these bridges to accommodate the heavy permit trucks vs non-permit trucks were found to be minimal on an annual basis.

In the third of a series of studies conducted by the U.S. General Accounting Office as directed by ISTEA, the costs and benefits of expanding LCV operations to other Interstate and primary highways were estimated. As reported in the August 22, 1994 issue of Transport Topics(20), GAO found that allowing triple and longer double trailer combinations to use all Interstate highways and some primary roads could save an estimated $3.4 billion annually in freight transportation costs. The required infrastructure costs for bridge replacement, interchange reconstruction, and staging areas for breakdown and assembly of LCVs would be relatively modest, assuming their confinement to rural Interstates. FHWA estimated this cost at a one-time investment of $2.1 to $3.5 billion.

Based upon these studies it can be inferred that permitting LCVs to use rural sections of AHS lanes or roadways would also be justified to the trucking industry through even greater economic benefits at acceptable infrastructure costs. Further analysis is required to verify this inference.

3.1.2.3 Vehicle Handling and Stability Characteristics

To assess the risks and control requirements associated with permitting trucks, particularly longer, heavier commercial vehicles on AHSs, the diverse handling and other dynamic characteristics of these vehicles have been identified and are discussed in the following section. Vehicle handling and stability properties affected by truck weight or configuration include: Rollover Threshold, Hydroplaning, Rearward Amplification, Braking, Steering Sensitivity, Low-Speed Offtracking, and High-Speed Offtracking.

Rollover Threshold - This is defined as the maximum level of steady lateral acceleration that the vehicle can sustain without rolling over. It is related to the ratio of center-of -gravity height to track width. Other factors include suspension properties and, for combination vehicles, coupling properties. It is not affected by truck configuration. Fully loaded tractor-semitrailers and five-axle doubles have similar rollover threshold values. It is affected by Gross Vehicle Weight (GVW), decreasing with increased weight for both single-unit and combination trucks. Fatal rollover crash rates of combination vehicles increase with increased GVW. Data on single-unit truck fatal rollover crash rates are not sufficiently complete.

Rollover threshold characteristics relating to truck types, axle loadings, gross weight, truck width, and payload center of gravity were defined and explained in a Texas Transportation Institute (TTI) report, "Geometric Design Characteristics for Separate Truck

Lanes"[21]. It was noted that rollover thresholds vary from .25 to .40 g's, where 1 g equals the weight of the truck. Accordingly, to avoid rollover, the maximum lateral force developed by the tires on the pavement must be less than about 25 percent of the truck's weight. If the rollover threshold is greater than the pavement coefficient of friction, the vehicle will skid on a turn. If it is less, it will roll over. The design implications for AHS use by commercial vehicles is that impending rollover conditions need to be sensed by the control system, either within the vehicle (C1), the roadway (C3), or both (C2).

Hydroplaning - TTI conducted tests to investigate the problem of unloaded tractor-trailers losing control during wet weather. At 58 mph, and tire inflation pressure of 75 psi, hydroplaning was observed, while loaded tractor-trailer tires were shown to have much higher minimum hydroplaning speeds, over 75 mph. It was noted that, for unloaded conditions, large differences in hydroplaning speeds exist between the steering and driving axle tires of the tractor. This results in rotational movement about the tractor's center of gravity, which causes jackknifing. TTI found that dynamic hydroplaning speeds of highway vehicle tires vary with both tire pressure and the tire footprint aspect ratio, which is the ratio of the surface contact zone to the length. Accordingly, sensing of hydroplaning threshold speeds of loaded, partially loaded, and unloaded trucks on wet pavements will be a requirement of AHS control systems for commercial vehicles.

Rearward Amplification - This occurs in multiple-trailer combination vehicles, where the rear trailer exhibits an exaggerated, whiplike response to rapid steering maneuvers such as sudden lane-changing or obstacle-avoidance. The rear trailer may overturn at high speeds. Drivers of five-axle doubles often cannot sense this impending instability. This is a safety concern for doubles and triples, but not for tractor-semitrailers or single-unit trucks. It increases with increased GVW. The implication is that significant increases in GVW of these combination vehicles will increase fatal accident probabilities. The resulting issue is whether AHS control systems should include the ability to sense this movement on LCVs or if they should be prohibited from using AHS roadways entirely due to this major safety concern.

Braking - Both truck brake stopping distance and vehicle control or stability during braking affect traffic safety. Stopping distance is influenced by available tire-to-pavement friction, vehicle loads and the distribution of loads on individual axles, wheel-load shifts during braking, and the different truck brake systems with wide variations in performance and brake maintenance practices. Stability during braking depends on the probability that wheels on one or more axle sets will lock up, leading to "jackknifing" on combination vehicles and "spin-out" on single-unit trucks. Truck brake systems are designed for fully-loaded conditions and are oversized for partial or empty loads. Controllable braking of doubles is complicated by the practice of coupling an empty trailer behind a full one. Tractor-trailers and five-axle doubles do not vary significantly in stopping distances, while single-unit trucks require shorter distances. Increased GVW is not likely to affect practical stopping distances or vehicle control for fully loaded trucks, but may affect braking under partial or empty conditions. Accordingly, AHS check-in systems will have to focus on braking systems and individual vehicle loading characteristics for commercial vehicles.

The paper, "Large Truck Braking Capabilities and the Inadequacies of Geometric Design and Traffic Operations Standards" [22], reported on the braking capabilities of large trucks in Canada, and recommended changes to the current Canadian road design standards for stopping distances. They studied loaded, partially loaded, and unloaded straight trucks, tractor semi-trailers, and doubles, and found that the existing standard design minimum safe stopping sight distances were too low for actual conditions. Using an unloaded tractor semi-trailer, 3-S2 configuration with a 4.82 m (15.8') tractor wheelbase and 10.59m (34') trailer wheelbase, and a minimum coefficient of tire-pavement friction of 0.2 to represent worn tires on a wet pavement, suggested changes to the current minimum design standards for safe stopping sight distances were developed, as follows:

Operating Speed kph (mph)	Friction Coeff.	Braking Distance m (ft.)	Minimum Stopping Distance 1.0 sec m (ft.)	Standard m (ft.)	% Incr.
40 (25)	0.40	30 (98)	45 (148)	45 (148)	0.0
60 (37)	0.30	90 (295)	105 (344)	85 (279)	23.5
80 (50)	0.25	191 (626)	215 (705)	140 (460)	53.6
100 (62)	0.22	340 (1115)	370 (1214)	200 (656)	85.0
120 (75)	0.21	512 (1680)	545 (1788)	285 (935)	91.2

(40 km/hr =25 m/hr, 30 m = 98.4 ft, 100 m = 328 ft.)

As driver's eye heights are higher than the 1.05 m used, these increases would not affect vertical curve design, but should be considered for horizontal or vertical sight line obstructions, and, more significantly in AHS design, for minimum headway values for commercial vehicles. The 1.0 second value in the above table refers to driver brake reaction time. The Canadian standard, (as well as AASHTO), uses 2.5 seconds to represent the 90th percentile driver, while the authors note that truck drivers would be at the 1.0 sec. value. An AHS would reduce this value to fractions of a second from detection to brake application, thereby reducing the above minimum stopping distances to the braking distances, which are still, for all but 40km/hr, significantly higher than the current design standards. The authors also included data and a plot of the results of field tests reported in TRR No. 1052, "Sight Distance Problems Related to Large Trucks" (23). The braking field test results for trucks with worn tires on wet pavement conducted in this study were in agreement with the braking model results obtained by the Canadians. It is also noted that existing roadway design standards assume ideal brake efficiency, while in reality 70 percent brake efficiency is obtained for loaded trucks and only 40 percent efficiency is obtained for partially loaded and unloaded trucks, as determined from field data.

By comparison, current AASHTO braking distance criteria are considered to be outdated, as they are based upon ideal equipment, tire and pavement conditions. AASHTO braking distances for passenger vehicles are computed as $V^2 / 30 f$, where V = speed and f = coefficient of friction. Studies quoted in the previously noted report, "Geometric Design Considerations for Separate Truck Lanes" (21), indicated that passenger car braking distances are about two-thirds those of trucks. This was used to support a recommendation to increase the AASHTO truck braking distances as follows:

Design Speed mph (kph)	Friction Coefficient	Braking Distances Current AASHTO ft. (meters)	Proposed ft. (meters)
40 (64)	0.32	167 (50)	250 (76)
55 (89)	0.30	336 (102)	504 (154)
60 (97)	0.29	414 (126)	620 (190)
70 (113)	0.28	584 (178)	875 (267)

These braking distances are 50 percent higher than AASHTO's. Comparison with the Canadian researchers recommendation indicates their use of a lower wet pavement friction coefficient and higher percent increases at speeds greater than 80 km/hr (50mph).

The relevance of this work to AHS for commercial vehicles is the impact that safe stopping distances, or safe braking distances, (since the driver is not in control), have on headways. At 100 km/hr (62mph), the Canadian recommendations call for over 1,100 ft., while the Texas proposal calls for 620 ft. at 60mph. The differences between the two study results need to be resolved, and safe control headways on AHSs with commercial vehicles permitted need to be determined.

Steering Sensitivity - This affects ease of vehicle control. It is a property of the towing unit, defined as the rate of change of steering angle with respect to lateral acceleration. It is sensitive to center-of gravity height of the payload, tire properties, and fore-and-aft distribution of roll stiffness. It is not dependent on truck configuration per se. Steering sensitivity of both tractor-semitrailers and five-axle doubles decreases slightly with increased GVW. Higher sensitivity values were found to be associated with lower single-vehicle fatal crash rates. This major AHS-controlled vehicle handling characteristic will require a sophisticated sensing system given the number of variables noted above.

Low-Speed Offtracking - This refers to wheelpath differences at intersections under low speeds, causing encroachment of turning trucks on adjacent lanes. Current design turning path templates permit new facilities or improvements to be designed to allow for this. Doubles with 28' trailers encroach about 7% less than 45' tractor-semitrailers. GVW does not affect this, nor are accidents associated with it. It is anticipated that low speed turns will be controlled by the driver and that these turns will occur both prior to AHS ramp entry or after AHS ramp exit movements.

High-Speed Offtracking- This refers to wheelpaths at high speeds on curves, and is influenced by wheelbase dimensions, axles, number of articulation points, and tire properties. Five-axle doubles exhibit larger high-speed off-tracking than tractor-semitrailers. Higher GVW results in increased high-speed offtracking. This characteristic partially explains the increased number of truck accidents at freeway exit ramps. More forgiving geometric design standards on AHS interchange ramps will be required to address this concern.

3.1.2.4 Pavements and Bridges

Pavements: The parameter used for pavement design is Equivalent Single Axle Load (ESAL). An 18,000 lb. single axle is 1.00 ESAL. AASHTO design procedures allow a given percentage increase in the number of ESALs to be accompanied by a smaller percentage increase in pavement thickness and cost. ESALs increase sharply with vehicle weight, but decline with the number of axles. A nine axle combination truck carrying 110,000 lbs has less effect on pavements than a five axle combination carrying 80,000lbs. The Turner proposal, studied by TRB, in its previously noted Special Report 227 [17] would allow higher gross weights by adding extra axles to reduce the ESALs. The report authors estimated the average cost per mile of upgrading Interstate highways in rural and urban areas to accommodate a 10 percent increase in ESALs at between $700,000 and $1,100,000.

Pavement life is influenced by the following truck components:

Tire Pressure - Higher tire pressures increase ESALs and hasten pavement wear.

Single vs Dual Tires - Although single tires have more adverse affects on pavements, unbalanced loads on dual tires and random lateral placement of the truck on the highway can have counter affects. Tire "Wander" actually is viewed as beneficial in spreading the load and reducing pavement rutting. AHS lateral control systems will need to consider this

Suspension System - Unconfirmed European findings indicate that improved suspensions that reduce dynamic load impacts might reduce pavement wear by about 5 percent. Commercial vehicle suspension systems will require inspection at AHS check-in ramps.

Axle Spacing - The net affect of changes in axle spacing on pavement wear is complex and dependent on the pavement structure. the impacts vary with pavement type, flexible vs rigid.

Pavement designs on AHS facilities permitting commercial vehicles will have to focus on high strength, infrequent maintenance, and design lives of 50 years±. Current procedures allow for such requirements to be met (24).

Bridges: There are 580,000 bridges in the U.S., of which 250,000 have been rated as deficient. Increased truck weight limits will increase the cost of bridge repairs and replacement. Overstress and fatigue are the two bridge responses that must be considered for heavy vehicles. Overstress may occur when two or more heavy trucks load a bridge simultaneously. As the number of heavy trucks increase, the probability of multiple heavy trucks on a bridge at the same time will also increase. Although bridge design practice accounts for this by means of safety factors, usually design allowable stresses of 55 percent of limiting yield stresses, the AHS scenario of separate truck roadways, with convoys of heavy vehicles, leads to identification of a major bridge design and cost issue. Fatigue Life must be considered in terms of repetitive truck loads on bridges. A doubling of stress for a single truck passage on a steel bridge causes eight times as much fatigue damage. Rehabilitation of existing bridges and construction of new bridges on AHS roadways which permit heavy commercial vehicles will require consideration of both overstress and fatigue in their design. In the section of TRB Special Report 227 (17) on Bridges, the authors estimated differences in construction cost increases on new and existing bridges carrying increased heavy truck traffic, both conventional and "Turner" trucks. The results ranged from no changes in new bridge costs to an average of $400,000 each to replace deficient existing Interstate and primary highway bridges. The numerous variables to be considered in developing bridge construction, replacement, and maintenance cost estimates for AHS lanes on roadways permitting conventional and/or new, heavier LCVs will require further detailed study and quantification.

3.1.2.5 Traffic Operations

Traffic operations characteristics affected by truck weight or configuration include: Speed on Upgrades, Freeway Merging, Weaving, Lane Changing, Downhill Operations, Intersection Operations, Traction Ability, and ability of Longitudinal Barriers to restrain and redirect vehicles upon impact.

Speed on Upgrades - The ability of trucks to maintain desirable speeds on upgrades declines with the percent and length of grade and the gross weight / net horsepower ratio of the vehicle, where net horsepower is the brake horsepower of the truck measured at the clutch. AASHTO states that truck speeds decrease by about 7 percent on upgrades. No differences in performance on grades have been found between tractor semi-trailers and doubles. Excessive speed differences between slow moving trucks on upgrades and faster moving passenger cars are associated with increased rear-end crash rates. AASHTO design guidelines use a weight to hp ratio of 300 to represent trucks on grades. However, this ratio is decreasing with improved truck engines and transmissions, and the average ratios of existing combination vehicles are slightly over 200 lbs per net hp.

Freeway Merging, Weaving, and Lane Changing - These maneuvers will be more difficult with increased truck sizes and GVWs. However, the effects of increased weight / hp ratios on these operations have not been quantified. Nor have relationships between truck accident rates and freeway maneuvers, truck lengths, or weight / hp ratios. The authors of TRB Special

Report 225 noted that AASHTO's guidelines for acceleration lane lengths are based upon the performance of passenger cars, and, consequently are inadequate for existing trucks attempting freeway merging and will be even more so for trucks with higher weight / hp ratios.

Downhill Operations - Both driver practices and truck brake characteristics affect the safety of downhill operations. Driver failure to properly downshift at the top of the hill can cause overheated brakes or brake failure. As the number of brakes and the GVW increase, the probability of improper brake adjustment and increased truck brake temperatures during downhill descents increases. As the GVW increases, the probability of runaway crashes on downhill roadway sections increases.

Intersection Operations - Sight distances are critical at unsignalized intersections, to allow trucks sufficient time to turn into or to cross the other roadway. Increased GVWs and truck lengths will require longer sight distances. AASHTO's design values for unsignalized intersection sight distances are considered to be inadequate for today's trucks and even more so for those with higher weight / hp ratios.

Traction Ability - The truck weight / hp ratio determines maximum truck speed on upgrades. This ability increases as the percent of GVW on the tractor drive axles (Traction Ratio), or the number of powered axles increases. Typical traction ratios range from 0.425 for tractor-semitrailers to 0.225 for five-axle doubles, indicating the superior traction ability of the former, particularly in snow and ice conditions. Relationships between truck accident rates and traction ability have not been established.

Longitudinal Barriers - Except for limited installations (NJ Turnpike), most of these barriers have been designed to restrain and redirect passenger vehicles. Combination vehicles are more likely than single-unit trucks to roll over after hitting a longitudinal barrier. Higher GVWs and centers of gravity will require barrier redesign. The effects of barrier properties on truck accident rates have not been established.

3.1.2.6 Summary and Conclusions

The issues and risks to be considered under Roadway Design and Vehicle Characteristics for Commercial Vehicles are led by the initial and subsequent questions as to whether and how commercial vehicles should be provided their own AHS lane, separate from passenger vehicles.

If so, should all types, sizes, weights, and combinations be permitted, or should the AHS lane or lanes only allow smaller single unit trucks with dynamic characteristics similar to passenger vehicles?

While heavier and longer veh icles are viewed as needed by the trucking industry, what place do they have, if any, on the initial and subsequent AHSs that will be developed and constructed over the next decades?

What, if any should the truck type and size restriction be?

What are the cost implications for pavements and bridges?

Should AHSs be designed only for passenger vehicles, vans, buses, and single unit trucks with a weight limit of 10,000 lbs, allowing the other commercial vehicles to remain on separate but non-instrumented sections of the Interstate System in both urban and rural areas?

Or, should longer and heavier trucks be allowed, as is being lobbied for by the trucking industry?

In theory, AHS will permit the drivers' tasks to be automated except for ingress and egress, and the risk of truck driver and / or passenger vehicle driver error leading to accidents will largely be eliminated.

If heavier vehicles (LCVs) are allowed on rural Interstate highway sections, as indicated to be cost-effective by GAO, should they be provided separate lanes or mixed AHS lanes with AHS equipped passenger vehicles?

The costs of fail safe, automated control of the vehicle handling and stability functions of large commercial vehicles, listed and described in Section 3.1.2.3, will have to be determined and assessed against their safety risks and capacity requirements.

Most rural Interstate highways are two lanes in each direction, for safe passing, for maintenance/operation of one lane during construction, and for provision of slower vehicle lanes. AHS will, for the I2 RSC, require a "buffer" lane for access/egress and separation of AHS from non-AHS operations. Provision of separate AHS commercial vehicle lanes, particularly for LCVs on rural Interstates, may require a full additional lane in each direction.

There has not been a similar lobbying effort to allow LVCs on Interstate highway sections in urban areas, as the risks of operating them on more heavily traveled highways are recognized.

However, if tractor-trailers and large single u nit trucks are either restricted from, provided their own AHS, or allowed to operate with other AHS equipped vehicles on dense urban Interstate sections where trucks constitute a relatively high proportion of total traffic (10 percent±) what will be the requirements and impacts on total travel within the corridor?

Prohibiting them entirely will require them to occupy a greater portion of the remaining non-AHS lanes, which will have to be upgraded in design to provide safe acceleration, deceleration, and braking distances, adequate horizontal curvature, particularly, at interchange exit ramps. The capacity available for passenger vehicles may not be adequate.

Requiring trucks to operate within separate truck-only AHS lanes may result in excess capacity in those lanes, with the other passenger vehicles forced into the remaining non-AHS lanes.

This suggests that two AHS lanes might be required on urban Interstates, one for passenger vehicles and a second for mixed single unit trucks and passenger vehicles. The third, non-AHS lane would be for heavier combination vehicles and non-AHS equipped passenger vehicles. Obviously, the remaining capacity of this lane will be limited. These possible scenarios have been developed and analyzed in Section 3.3.

3.1.3 Truck Safety Characteristics/Issues

The driver is instrumental in the precipitation or prevention of accidents. Trucks with good handling and stability properties may have poor safety records if driven by inexperienced or unsafe drivers. Good drivers can operate less- than- ideal trucks safely. National Transportation Safety Board reports indicate that driver factors such as fatigue, inattention, substance abuse, or driving at speeds inappropriate for prevailing conditions have been primary accident contributing elements.

A 1991 study conducted for the Pennsylvania Department of Transportation (PennDOT)[25], identified those factors contributing to truck involved accidents. The study focused on the driver, the vehicle, and the motor carrier. Its findings, relevant to the overview of issues to be addressed in AHS for Commercial Vehicles, are summarized below.

3.1.3.1 The Driver

For heavy combination vehicles, the margin for driver error is much less than for smaller vehicles. While truck drivers generally have a better safety record than the average motorist, four out of ten accidents involving trucks are attributed to driver-related causes. These causes include : speeding, tailgating, improper turning, and careless lane changing. The skills that a professional truck driver must have include: braking, shifting, absorbing and analyzing information on proper lane position and speed, weather conditions, other road users, signing, record-keeping, routing, etc. The current and projected shortage of trained drivers is a major source of concern. Wages have not kept up with other occupations, qualifications are getting harder to meet, including the Commercial Drivers License, and initial formal training and continuous skills retraining and monitoring is not legally required. Untrained drivers are over- represented in fatal accidents, and errors in judgment have been cited as the cause in over 90 percent of the accidents when the truck was at fault. The above referenced PennDOT study referred to an American Automobile Association (AAA) study [26] indicating fatigue to be one of the primary causes in 41 percent of large truck crashes. Although there is a federal requirement that drivers sleep after driving 10 hours, fatigue and stress can occur before this, especially during high risk times between midnight and 8 AM. The 10 hour limit is often disregarded due to the pressures of delivery deadlines. A dramatic example was the recent fatal truck accident on Interstate 287, the Cross-Westchester Expressway in New York State, attributed to apparent driver fatigue or misjudgment of speed on a main roadway curve.

AHS represents a potential solution to the driver safety problem.

The Penn State report referred to earlier NHTSA, USDOT, and other studies which provided the following information:

1. Only about 10 percent of all heavy trucks involved in accidents had mechanical defects.
2. The three top failures/defects contributing to combination-unit trucks were broken, worn-out, or inoperative brakes; other parts; and worn or smooth tires.
3. Defective brake systems contribute to over one-third of all accidents resulting from mechanical defects.
4. Preventative maintenance and regular vehicle inspection programs are viewed as the means to reduce the truck accidents attributable to the vehicle, particularly for older vehicles which apparently receive less maintenance. Cited in this report was the federally-funded Motor Carrier Safety Assistance Program designed to facilitate roadside truck inspections. However, in Pennsylvania less than one percent of the total trucks on the highways are inspected.
5. The disparity of braking distances between passenger cars and large trucks was also noted, with highway design criteria indicated to be based upon the stopping distances of the former. Use of Anti-locking Braking Systems (ABS) on large trucks, and providing compatible braking systems on both trucks and their trailers were cited as means to reduce this disparity. These improvements are recognized as being needed by the industry.
6. Rollovers are involved in about 60 percent of fatal truck occupant accidents. Improved steering control, proper loading procedures were noted as means to reduce these accident types.

By requiring vehicle inspections at AHS check-in points, AHS wi ll potentially eliminate most vehicle equipment failure accidents on these facilities.

3.1.3.2 The Carrier

The PennDOT study pointed out that the carriers themselves set the tone for the safety of their operations, through safety training programs, maintenance practices, driver hiring and personnel programs, and operating regulations affecting routes, driver hours, delivery schedules, and cargo handling. The intense competition growing out of deregulation of the for- hire trucking industry has resulted in deferred or breakdown maintenance policies and the accompanying higher risks of equipment failure accepted in order to reduce costs. The question to be considered with respect to AHS is how to obtain the compliance of the industry in properly maintaining their fleets to meet the performance standards of these special roadways.

3.1.3.3 National Truck Accident Statistics

Effects of truck configurations and weight on fatal truck accidents were presented in the previously noted TRR 255 Report (15), based upon University of Michigan studies conducted with 1980 to 1985 data. These studies indicated somewhat higher fatal rollover and jackknife crashes involving doubles than tractor-semitrailers. Increased truck weights were also related to higher rollover and ramp-related fatal crashes, but not to jackknife and sideswipe fatal accidents. Accident rates used for the studies of impacts of alternative truck type and weight scenarios on safety were:

NATIONAL ACCIDENT STATISTICS, LIMITED ACCESS HIGHWAYS

Truck Type	**Accident Rate (per 100 MVM)**		
	Fatal	**Injury**	**PDO**
Single-unit	7.7	185	499
Tractor-semi-trailer	10.2	245	595
Doubles	11.2	269	653

These rates indicate nearly one-third greater fatal and injury accident rates for heavy trucks and 45 percent higher rates for the doubles as compared to single unit trucks. The Property Damage rate comparisons show lower increases in rates as the truck size and configuration increases, about 20 and 30 percent, respectively for the tractor semi-trailer and the double.

Accident statistics for trucks and passenger vehicles on all roadway types for 1980 and 1990 were provided in the previously cited USDOT's National Transportation Statistics Annual Report, June 1992 (1). The vehicle accidents, involvement rates, and occupancy fatality rates for these vehicles are summarized below:

PASSENGER CAR AND TRUCK ACCIDENT STATISTICS, 1980, 1990

Vehicle	1980	1990
Passenger Cars		
No. of Vehicles in Accidents (Millions)	22.8	14.3
Vehicle Involvement Rate (/ 100MVM)	3.5	2.2
Occupant Fatality Rate (/ 100MVM)	2.5	1.6
Trucks		
Total No. of Accidents 31,389	35,735	
Vehicle Involvement Rate (/ 100MVM)		
Single-Unit	4.3	3.2
Combination	5.8	3.9
All Trucks	5.4	3.3
Occupant Fatality Rate (/ 100MVM)		
Single-Unit	2.4	1.7
Combination	1.3	0.5
All Trucks	2.2	1.5

These data show that both truck and passenger car accidents and involvement rates have declined between 1980 and 1990. Single - unit trucks have maintained higher total involvement rates than passenger cars, and about the same occupant fatality rates over these years. While combination trucks have had higher vehicle involvement rates than both passenger cars and single - unit trucks, they have maintained lower occupant fatality rates. Overall, because of the greater number of single - unit trucks, the occupant fatality rates for both passenger cars and total trucks have been about the same. Of significance is the 62 percent reduction in the occupant fatality rate of the combination truck between 1980 and 1990, as compared to only a 36 percent reduction for passenger cars and 29 percent for single - unit trucks. The percentage reductions in accident involvement rates for both passenger cars and total trucks were about the same, 37 and 39 percent, respectively.

Accident data for the New Jersey Turnpike from 1986 to 1992 obtained from the Turnpike Authority indicate a declining but still disproportionate number and rate of truck accidents as compared to the total number of vehicles and accidents. The total number of accidents decreased from a peak in 1989 of 5,588 to 4,116 in 1992, corresponding to accident rates of 126.7 and 95.8, respectively. Truck accidents decreased from 2,178 (39.1 percent) to 1,331 (32.3 percent) in those same years, and truck accident rates dropped from 347.1 to 239.6., or from 2.73 times the total rate to 2.5 times the total rate. The truck percentage of total vehicles in those two years dropped from 12.2 to 11.0.

In his 1993 paper, " The Decade of Declining Heavy Truck Fatalities- A Tribute to the Cooperative Process" [27], Farrell L. Krall described the significant reductions in medium and heavy truck accidents and driver fatalities experienced since 1980, citing the increased use of seat belts by drivers as the single largest contributor to the lower fatality rate. He noted that between 1979 and 1992, the frequency of heavy truck occupant fatalities declined by 58 percent while truck vehicle miles increased by 40 percent; that truck occupant fatalities are split 75 percent in combination tractor-trailers and 25 percent in straight trucks; and that rollover crashes account for 15 percent of heavy truck fatal crashes and 57 percent of driver fatalities.

3.1.3.4 Summary and Conclusions

The above review of a sample of the truck safety literature, research findings, and available accident statistics leads to the conclusion that by eliminating the opportunity for driver fatigue and error, by controlling the condition of the vehicles entering an AHS, and by sensing threshold levels for rollover and other truck stability parameters, additional reductions in truck and truck/passenger vehicle accidents and fatalities could be achieved. The control and maintenance requirements needed for longer combination vehicles (LCVs), if they are permitted, need careful evaluation, in view of the greater accident potential of these commercial vehicles. The industry is, judging from the accident rate reductions achieved over the past decade, focusing on safety and proud of its accomplishments. It should, accordingly, be participating in the AHS efforts, to lend its expertise and experience in those vehicle and driver-related areas which will produce the most benefits in the early phases.

3.1.4 Benefits and Costs of Commercial Vehicle Use of AHS

3.1.4.1 Travel Time & Schedule Adherence

AHS has the potential to reduce travel time on the line haul sections of intercity, intra-urban, and interstate truck routes through providing control of speeds at optinum safe levels for roadway conditions, and through reductions of delays caused by accidents and normal peak period congestion. Under current competitive pressures for on-time delivery service, this potential benefit translates into real bottom-line improvements. it is currently estimated that commercial vehicle time is valued at $60/hour. Assuming that AHS can offer at least a one minute per mile savings on an average truck trip of 400 miles, a $400 savings in travel time is possible. The actual savings would be realized through increased driver and truck productivity in terms of number of additional trips or pick up/deliveries that could be made annually by each.

3.1.4.2 Operating Costs, Labor, Fuel, Maintenance

Average annual operating costs for the trucking industry are provided in the August issue of Commercial Carrier Journal (5,6). The 1992 data for the LTL segment of the industry indicate an average cost of $1.16 per vehicle mile, broken down as follows:

LTL	(percent)
Labor	67
Fuel Oil & Lubes	3
Maintenace	5
Insurance	2
Taxes. Fees	3

Accordingly, drivers wages and other salary and benefit costs comprise two-thirds of the industry's operating costs per mile.

To the extent that AHS can reduce these operating cost components, it will be accepted by the industry. As labor is the most significant of these cost items, AHS would have to offer potential labor cost savings. These will include increased driver productivity as noted in the previous section, as well as reduced costs for downtime caused by accidents, drug and alcohol abuse, and fatigue induced stress.

AHS also offer the carriers potential savings in fuel consumption through controlled speed operations and reduced low or stop and go operations through congested sections of main roadways. However, vehicle maintenance requirements will increase, in order for carriers to operate their vehicles on AHS roadways.

Operating costs also include road user taxes and licenses assessed by the states and federal government to finance roadway construction and maintenance. The industry is highly sensitive to these user fees and anticipates that the IVHS and AHS programs may result in increased assessment of these fees, with questionable benefits.

The industry has been lobbying for longer and heavier vehicle use of rural interstate highways to provide real economic benefits estimated to well exceed the additional infrastructure costs it would have to bear. In this case, the benefits and costs estimated released by GAO [20] have been favorably received. The AHS program, in its subsequent phases, must provide similar estimates.

3.1.4.3 Accident Reduction

Review of the commercial vehicle safety literature, described in the previous section, indicates that driver error has been involved in over 40 percent of heavy truck accidents, and that truck accident rates nationwide are at about one-third higher than passenger vehicle accident rates (see previous Section 3.1.3.4). Truck accident rates on the NJ Turnpike in 1992 were 2.5 times the total rate for all vehicles. If AHS has the potential to reduce the driver's contribution to truck accidents, it could be estimated that this potential is up to a 40 percent reduction in truck accident rates. On the New Jersey Turnpike, for example the 1,331 truck accidents could drop to about 800, a reduction of 531 accidents. The economic cost of this reduction using average accident cost data from NJDOT(1988 combined urban & rural data, escalated to 1992 @ 5 percent/year), verified $19,500/accident, would be over $12 million in 1992!

3.1.4.4 Summary & Conclusions

AHS provides the potential to offer the commercial trucking industry a range of benefits, including reduced travel times on each run, increased labor productivity, lower fuel consumption costs, and significant savings in accidents and their costs. The potential costs required to obtain these benefits will include increased equipment maintenance, higher wages to attract AHS qualified drivers, and increased road user fees to pay for the roadway and bridge improvements required to accommodate the AHS infrastructure.

It is premature to provide meaningful estimates of the overall benefits and costs under this precusor analysis. However, as the Representative Systems Configurations become narrowed, the benefit and cost items and unit costs noted above can be applied to quantify these values. A first attempt has been made, in Section 3.3, AHS Scenarios With Commercial and Transit Vehicles, to quantify vehicle miles of travel (VMT) and person hours of travel (PHT) for a variety of AHS Scenarios and options. The estimates of VMT and VHT provided in Appendix Table A12, 18, and 24 for the Long Island Expressway, New York State Thruway, and New Jersey Turnpike when multiplied by commercial vehicle operating costs permile and value of commercial vehicle time, result in the user costs for each scenario as well as the 'No Build' alternative.

Comparison of each of these alternatives to the 'No Build' alternative provides an indication of how the costs of both time and mileage change as more AHS capacity is added. Time and resources have not permitted an estimate of accident cost changes. Current accident rates for both the LIE and NYS Thruway are available, and could be applied, with estimates of average accident costs in New York State, to derive accident costs for each Scenario and Option vs. the 'No Build' alternative.

It is recommended that this or a comparable method be used in the subsequent AHS study program.

3.2 TRANSIT

This section identifies both current and future mar ket and operational characteristics of the transit industry, as they relate to potential usage of and benefits derived from AHS. In light of the current congestion and air pollution concerns nationwide, transit and ridesharing are currently being revisited with strategies and actions including High-Occupancy Vehicle (HOV) lanes being implemented by state and city transportation agencies to increase the person carrying capacities and levels of service of congested roadway corridors. In order to assess the potential for transit use of AHS, a review of the current and anticipated future characteristics of the transit industry was made.

3.2.1 Functional/Market/Operational Characteristics/Issues

3.2.1.1 The Transit Industry

The public transit industry provides local, regional and intercity passenger services for the general public, including the disadvantaged, disabled and the aged. Public transit service includes both public and privately contracted bus, rail and ferry operations. Contracted vanpools, taxis, and other transportation services are also available. Amtrak and Greyhound, which provide intercity services, complete the national and regional picture.

Buses, the dominant form of public transport in the US, carry more than 70 percent of all transit riders, and provide local and express services that both complement and compete with rail transit. As noted in Appendix Figure A-6, prepared from the USDOT's 1992 National Transportation Statistics Annual Report (2), buses are responsible for more than 65 percent of all revenue vehicle miles for local transit, versus 24 percent for commuter/light/heavy rail. Demand responsive or paratransit service, characterized mostly by small buses and vans, provides about 10 percent of all local transit service.

Buses travel approximately 21 million passenger miles annually and offer the potential to significantly increase the person-carrying capacity of existing highway corridors with excessive demand and limited room for physical expansion. Of the more than 271,000 employees that operate, maintain and administer public transit service, approximately 165,000, or 60 percent are employed in motorbus service.

Accordingly, bus transit has a potentially significant role to play in AHS, including markets for line-haul express, semi-express, and local feeder service.

Urban Public Transit Usage Characteristics: The Center of Urban Transportation Research of the University of South Florida prepared a comprehensive report, Factors Related to Transit Use (28), which identifies consumer preferences of both automobile users and transit users in 17 metropolitan areas across the county who had ready access to public transportation. The findings of the study were as follows:

- 22 percent were auto captives
- 30 percent were transit dependent
- Of the transit dependent, only 37 percent indicated they would drive to work if an auto were available.
- The four most significant reasons stated by transit users for not using the auto were 1) cost of parking, 2) availability of parking, 3) travel time, and 4) traffic congestion.

- About half of those driving to work could be considered potential transit riders if flexible and convenient transit service were provided.
- Other factors that would favor increased transit use were non-transfer service, express routes and increased auto parking fees.
- Traffic congestion was viewed as very serious by 36 percent of respondents and somewhat serious by 28 percent.

As reported in the 1992 APTA Transit Fact Book [29] (hereafter referred to as APTA) work trips were the most common reason for transit travel, accounting for 54 percent of all transit trips taken in 1991. Trips to school accounted for approximately 15 percent; shopping and social for approximately 10 percent each; medical for 5 percent; and "other" for approximately 6 percent (APTA, Table 35) However, according to the 1990 U.S. Census Bureau's journey-to-work data [30], the percentage of workers using transit to get to work declined from 6.4 percent in 1980 to 5.3 percent in 1990. Similarly, the number of people using carpools and vanpools declined from 19.7 percent in 1980 to 13.3 percent in 1990. Single-occupant vehicles accounted for over 70 percent of all work trips in 1990.(APTA, Table 36). Clearly, bus transit's potential has not been fully utilized. However the new federal ISTEA and CAAA legislation is designed to counter these trends by providing financial incentives for new transit initiatives as well as penalties for failure to increase vehicle occupancy levels. Improved express and semi-express bus service using preferential or reserved HOV lanes for the line haul portion of the trip represents a major opportunity. AHS lanes for such operations represent the subsequent evolution of this strategy.

Intercity Bus: In 1992 there were 4,603 intercity passenger bus carriers with active ICC authority. The overwhelming majority of these are charter and tour bus companies. According to the USDOT's Office of Highway Information Management [31], over 630,000 buses were registered in intercity service in 1991, of which nearly 518,000 or 82 percent were school buses. Fewer than 1 percent were used in intercity regular route service. The intercity regular route passenger bus market is highly concentrated, and Greyhound is the only company left with a national network. There are approximately 110 regional carriers providing regular route intercity passenger bus service. Twenty of these Class I bus carriers provide mainly regular-route bus service in specific regions. (Class I carriers are bus companies having adjusted annual operating revenues of $5 million or more for three consecutive years.) According to the report produced by the US General Accounting Office(GAO), SURFACE TRANSPORTATION: Availability of Intercity Bus Service Continues to Decline [32], Greyhound dominates the regular-route service by intercity carriers, with 75 percent of revenues and 43 percent of the passengers. The next largest intercity carriers account for only 8 percent of the 1990 revenues.

The steady decline in regular route intercity bus service, including Greyhound, which is downsizing to focus on shorter intercity routes between 100 and 400 miles (NY Times, August 10, 1994), which has taken place over the last 20 years, is due to extensive intermodal competition from the private auto, Amtrak, and the airlines. Because of convenience, speed, and competitive pricing of these other modes, the bus industry only has about a 1.2 percent share of total intercity passenger-miles. Government subsidies to these other modes have also adversely affected the bus industry's ability to compete.

3.2.1.2 The Transit Passenger Market

In order to identify the potential role of transit in AHS, transit's current and future markets must be identified; in particular, the financial impetus to transit provided by ISTEA and the CAAA and the needs of current and potential transit passengers.

Transit serves two markets: the transit 'captives' and the transit 'choice' users. Transit 'captive' passengers include those with low incomes, the elderly, students and those without access to personal transportation. Local public transit users are primarily women, who account for 53 percent of the riders. Forty five percent of the riders are white, 31 percent are black, 18 percent are Hispanic, 6 percent are Asian or Native American, and 1.5 percent are disabled.(*APTA,* Americans in Transit Survey). Approximately 85 percent of the riders are between the ages of 18 and 65, 10 percent are 18 years and younger, and 5 percent are over the age of 65.

The majority of local transit riders, approximately 57 percent, are in the middle income range and earn an average annual income between $15,000 and $50,000. The lower income range, earning less than $15,000 per year, encompasses approximately 25 percent of the riders, and approximately 18 percent are in the upper income range of earnings greater than $50,000.(*APTA*, Table 35).

The transit 'choice' users include commuters and other travelers who do not absolutely have to use transit but do for reasons of speed, comfort, convenience, cost, traffic avoidance, parking unavailability or expense, or environmental principles.

Express Bus Commuter Market: Although the urban bus primarily services the commuter market(according to *APTA)*, the single occupant passenger car dominates this market with approximately 73.4 percent of all commuters. The two-person carpool is the second highest mode of passenger trips to work, with 10.5 percent of the market. Transit (rail, bus, etc.) services only 5.1 percent of all commuter trips.

Intercity Passenger Market: The four modes that comprise the major share of the intercity passenger market are the private automobile, commercial airlines, intercity rail(Amtrak) and intercity buses. Other, smaller modes include rental cars, private airplanes, trucks, and subsidized van services. The general picture of the total intercity travel market share based on passenger-miles for 1991 shows rail with the smallest share, about 0.7 percent; bus slightly larger with 1.2 percent; air, 17 percent; and auto, 81 percent. Greyhound's average trip length is 387 miles, while the average trip length on other bus carriers is estimated at 130 miles. Domestic airline trips average 793 miles. Appendix Figure A-7 illustrates the trends in domestic intercity passenger miles traveled between 1960 and 1990. Domestic airline service in 1990 carried 430 million passengers, compared to 35 million carried by Class I buses.

Intercity Transit Passengers: Information provided in the July 1993 report, The US Intercity Regular Route Passenger Bus Industry [33], depicts a slightly different clientele using intercity services from those using local public transit. Citing the April 1991 study, Greyhound On Board Passenger Survey [34], it was noted that the majority of the Greyhound intercity riders are white (58.2 percent), and 59.7 percent are between the ages of 24 and 65. The majority, 53.2 percent, of the Greyhound trips were made to "visit someone." Of those passenger surveyed, 21.7 percent described their home community as rural. Similar to local bus ridership, the majority of the riders are female(57.8 percent) and generally have low incomes. The study indicated that the majority of the riders of intercity transit have very low incomes; 46 percent have annual household incomes less than $15,000.

In summary, intercity bus passengers are largely lower-income, non-business travelers who are very price sensitive. Intercity bus service has shrunk to a minor transportation alternative in the face of increased auto ownership and availability, and aggressive airline pricing. In the previously noted "Intercity Bus Service Continues to Decline" report, Greyhound noted that, " ...even the very poorest citizens make 92 percent of their intercity travel by means other than bus." Accordingly, while AHS offers the potential for improved travel time and reliability for intercity buses, the market is relatively small.

Airlines: Scheduled air passenger service is offered at over 800 airports throughout the U.S., of which 109 hub airports account for about 97 percent of all airline passengers. Since deregulation of air passenger transportation in 1978, airlines have increasingly attracted the economy-minded intercity passenger transport segment that formed the base of bus passengers. Although AHS on intercity Interstate highways may offer improved speed and/or schedule reliance it does not appear to offer a service competitive to intercity airline service for non-auto passengers.

Amtrak: Amtrak serves about 600 U.S. points and relies on federal operating subsidies. Although Amtrak may only offer daily service on some routes, it competes with unsubsidized intercity bus service, with fares frequently reduced below comparable intercity bus fares. Amtrak is not always a competitor of the bus industry, as it offers intermodal service with the bus industry. A program called "Throughway Bus Connections" expands Amtrak's potential network through train-bus connections with chartered motor coaches. As noted previously, Amtrak's share of the intercity travel market is lower than buses, affected similarly by intercity airline service. AHS would represent a competitive mode, working against the environmental goals of increased rail passenger travel.

3.2.1.3 Potential Impacts of New Transportation Legislation

The downward trend in the transit market is being reversed through federal legislation enacted in 1990 and 1991. The 1990 Clean Air Act Amendments (CAAA) and 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) are the two most important actions taken in recent years to enhance transit as a viable mode choice.

Clean Air Act Amendments of 1990: In order to achieve compliance with the Clean Air Act Amendments(CAAA) by 1996, measures to reduce vehicle trips in air quality non-attainment areas must be implemented. Employers with more than 100 employees are required to participate in the Employer Commute Option (ECO) program, otherwise known as Employee Trip Reduction. These employers must increase the average passenger vehicle occupancy of their employees by 25 percent above the region's average vehicle occupancy. Special programs must be implemented by employers to make transit more attractive such as: guaranteed ride home, employer sponsored vehicle policies, Transit Check, etc. Non complying companies are subject to fines set by each state. Failure of the states to meet CAAA goals will result in loss of federal transportation funds.

Transit use is being encouraged to meet these goals. However, although pollution levels for bus transit vehicles are lower than for passenger vehicles, they are not low enough to meet the CAAA goals. Technologies for alternate fuel use are currently being developed and implemented to achieve lower, and ultimately zero emission levels in bus fleets.

Fuel Efficiency, Energy Consumption: The use of public transit results in reduced energy consumption. Based on U.S. Department of Energy (USDOE) data, *APTA* estimates the fuel efficiency of transit versus commuter auto as follows:

1 bus with 7 passengers = 1 auto

1 full bus = 6 autos

While an automobile consumes 4,063 BTUs/passenger mile, a transit bus consumes 3,711 BTUs/passenger mile (*APTA,* p. 17).

The annual gasoline savings projected for increased transit use are:

- 200 gallons for each person switching from driving alone

- 85 million gallons for a 10 percent increase in transit ridership in the 5 largest U.S. cities
- 135 million gallons for a 10 percent nationwide increase in transit ridership.

If the AHS program can incorporate attra ctive, competitive transit service in selected high travel demand corridors, the potential benefits in reduced energy consumption will be significant based upon the above projections.

Intermodal Surface Transportation Efficiency Act (ISTEA): Under ISTEA, the funds allocated to the Surface Transportation Program (STP) are highly flexible and may be used entirely for transit capital projects. Eligible projects include high-occupancy vehicle lanes(HOV). State and local officials will now be allowed to select the best mix of projects to address air quality, congestion, mobility, or other problems without being influenced by funding requirements for one mode of transportation versus another [(35)].

ISTEA also includes programs to support intercity bus service. Section 18, The Intercity Bus Transportation Program, requires each state to set aside a portion of the appropriated money and authorizes over $122 million to be spent on intercity bus service over the next 5 years. Programs include subsidies for routes serving non-urbanized areas, terminal assistance, bus service and bus program analyses as well as terminals for intercity or commuter bus service. The additional funding will assist in developments within the industry to improve bus service with the goal of increasing ridership. AHS technology on selected intercity Interstate Highway segments may be eligible for inclusion under Section 18.

With the funding of the ISTEA programs and the requirements of the CAAA, the spotlight will be on fuel efficient and user-friendly transit and high occupancy vehicles to move the nation out of congestion. These programs provide the opportunity for transit to receive a greater share of federal funding than ever before. Accordingly, the development of the AHS program should focus on transit, operating within existing and future reserved HOV lanes that can readily evolve into automated operation through intelligent vehicles, intelligent roadway lanes, or combinations thereof.

3.2.1.4 Transit Operations

Transit use of AHS has the potential to improve vehicle operations, increase ridership, and reduce operating costs. Public transit, as a public service, receives governmental financial assistance to cover the shortfall between operating expenses (labor, maintenance, fuel, etc.) and farebox revenues. State and federal government subsidies comprise 25 percent of the nation's transit operating revenues. The other 75 percent is received from passengers, (about 36 percent) and from local government and non-government sources. (39 percent). The CAAA, ADA, and ISTEA legislation of the early 1990's provide additional federal funds for capital and start-up operating expenses of transit service improvements.

Transit Operating Expenses: In 1991, operating expenses for the public transit industry totaled about $16.8 billion, of which bus transit accounted for $9.6 billion, or 57 percent of the total of all modes. Of the total federal funds paid for transit infrastructure(facilities, vehicles and major equipment), 35 percent were for bus facilities, vehicles and equipment.

Salaries and fringe benefits comprised the largest share of transit system operating expenses, about 70 percent of total annual costs, with the other 30 percent for fuel, maintenance, insurance, etc.

Casualty and liability costs account for about 4 percent of the transit industry's annual operating expense. According to APTA, these costs totaled approximately $630 million in 1991. Accident-related costs include:

- Workers Compensation
- Third Party Claims
- Insurance
- Repairs and maintenance costs
- Lost productivity

Productivity: Transit passenger fares have increased 60 percent more than inflation over the past 25 years[36]. Fares increased more than 30 percent in real terms between 1979 and 1987, but still only cover 33 percent of the total costs of the average transit trip in the U.S. One reason attributed to the cost increase is the decline in productivity of the U.S. transit industry, in terms of market served. While this decline may be due to higher fares, it can more directly be related to the rapid growth of automobile ownership and highway construction, contributing to the growth of jobs and residences in low-density suburban areas that are poorly served by transit. In 1960, only about 36 percent of the workers who lived in medium- and large-sized metropolitan areas in the US had jobs in the suburbs. By 1980, nearly 50 percent of workers who lived in these areas had suburban jobs. The 1990 Journey to Work [30] data showed a slowing of this prior 20 year trend, with older cities showing increases in the number of workers employed in central city counties. This indicates the potential for greater transit productivity in denser, older cities where central cores are regaining their older vitality. AHS is a potential application of new technology for selected non-rail transit transportation corridors in these cities, including New York, Philadelphia, and Washington, D.C.

3.2.1.5 The Transit Vehicle

Significant developments have been initiated in transit bus designs over the last few years. Technological advances in engine designs are currently being tested to reduce vehicle emissions; structural designs are being modified to improve accessibility; new materials are being incorporated into bus designs; IVHS technologies are being incorporated to improve communications, safety, reliability and efficiency of operations. Present day bus dimensions, performance characteristics and design parameters are included in Appendix Tables A-4 and A-6.

Advanced Technology Transit Bus (ATTB): The developing technologies in bus transit design are being driven by the Clean Air Act Amendments (CAAA) of 1990 and the Americans with Disabilities Act(ADA) of 1990. The CAAA dictates that future bus designs must have emissions lower than the current diesel engine and meet specific tailpipe standards. In California, where pollution is severe, "Zero Emissions Vehicles (ZEV)" are being produced. The ADA requirements mandate that transit manufacturers develop user friendly designs for handicapped and disabled persons. These government initiated policies are shaping the current designs of buses. Transit agencies that purchase any additional vehicles must order buses with engines using alternate fuels to ensure reduced emissions. The structural design and the composition of the vehicles are also being altered to reduce the weight and improve performance characteristics.

The Federal Transit Administration is supporting the development of the Advanced Technology Transit Bus(ATTB). These vehicles are being designed to incorporate alternate fuels, which reduce emissions and improve fuel efficiency. The vehicles will also be "low floor" to improve accessibility for disabled persons, and improve dwell times.

Advanced Public Transportation Systems (APTS): Technology is currently being developed by the bus transit industry and its suppliers to improve communications as well as the information flow to and from passengers. These advances are being pursued by the

Federal Transit Authority(FTA) in association with IVHS America. The IVHS Advanced Public Transportation System (APTS) Committee has been supporting the development of new technologies including Smart Traveler, Smart Vehicle, and Smart Intermodal Systems.

Smart Traveler technologies are being explored to increase the ease and convenience of using transit. Smart Vehicle technologies represent new methods of increasing reliability, efficiency, and safety, and improving vehicle and fleet planning, scheduling, and operations. Greyhound is currently implementing a VORAD radar-based system which signals the driver when there is a vehicle too close on either side, if he is following too closely to the vehicle in front, and if his speed is in excess of the programmed allowable speed. Sensors indicate when the headway distances are less than 3 seconds and indicate blind spots on the right side. The system monitors vehicle speeds and a tone sounds if the vehicle is operating above 65 or 70 mph. It has been in operation for more than one year, and Greyhound is planning to incorporate it into the entire fleet. Smart Intermodal Systems involve the integration of APTS technologies into traffic management and other non-transit applications of IVHS. Improved transportation services should attract more riders to transit and ridesharing; thereby providing public benefits of reductions in traffic congestion, air pollution and energy consumption. These innovations will be in place before AHS is implemented, but will set the stage for bus transit's evolution as an acceptable user of either exclusive transit or mixed vehicle AHS operations.

IVHS America's APTS Committee's goal is to increase the market share of transit and ridesharing by:

- **Reducing the Number of Transfers** - One of the primary goals is to limit the number of intersystem or intermodal transfers. This would reduce travel time, reduce congestion, and increase convenience by providing a non-stop or passenger loading only stop between trip origin and destination points, e.g., park & ride areas in suburban and urban fringe areas and central bus terminals in downtown and other major employment centers.
- **Improving Safety and Security** - Communications systems between vehicles and a control center would increase the perception as well as reality of passenger safety and security.
- **Reduction of Operating Costs** - Low speed feeder circulation combined with high speed trunk line route segments and efficient turnaround operations in central terminals would contribute to reduced operating costs through higher labor productivity, lower fuel costs, and lower accident rates.

The programs being developed through the APTS Committee's efforts, it successful, will promote increased ridership, demonstrate transit's effectiveness in achieving ISTEA, CAAA, and ADA objectives, and ease the natural progression to transit operation on AHS.

3.2.1.6 Summary and Conclusions

AHS must be seen by the Local/Express Bus and Intercity transit industries as a cost effective, significant means to maintain current patronage and encourage new ridership.

The transit industry will need to demonstrate to the American public reasons for becoming competitive with personal autos. A study noted in "Perceptions of Public Transportation", Public Transportation [37] cited the following factors influencing the choice of auto over transit:

- Reliability
- Able to leave when you desire

- Shortest time door-to-door
- Able to stop when you wish
- Weather protection
- Adequate space to carry items
- Transfer not needed
- Independence
- Clean vehicle
- Able to travel at own speed

If AHS can provide the transit industry with the technology, service, reliability, frequency, direct routing (minimal transfers), at competitive costs with personal auto, there will be a demand for it.

Contrary to the trends experienced over the last few decades, the emphasis in urban and suburban transportation is towards increased transit use, particularly based upon new federal legislation mandating change in travel habits by the public. The success of these new programs in accomplishing their goals depend on transit's ability to provide more reliable, safe, and efficient transportation.

With AHS lanes or roadways available in high density travel corridors, buses, vans and qualifying high-occupancy vehicles will be afforded the opportunity to consistently meet on-time performance standards and schedules. Improved reliability and travel time will enhance customer service and attract 'choice' users from other modes.

3.2.2 Transit Safety Characteristics / Issues

3.2.2.1 Accident Characteristics

One of the primary goals of the AHS program is to improve safety and reduce the potential for accidents. In order to assess the potential benefits to transit of AHS, the safety characteristics of existing systems have been reviewed.

Accident Rates and Types: Transit is one of the safest modes of passenger travel in the U.S[36]. The 1988-1990 average fatality rates in terms of 100 million passenger miles for the various modes are listed below:

	Fatality Rate
Auto	1.12
Intercity & commuter RR	0.03
Airlines	0.02
Intercity buses	**0.01**
School buses	0.03
Transit buses	**0.01**

Many factors contribute to transit system accidents: people, vehicles, facilities, traffic conditions, ergonomics, maintenance support equipment, communications, procedures, training, and management controls. Data cited by the New York State Public Transit Safety Board (PTSB) in its 1992 annual report [38], which presents accident statistics for bus transit, intercity and local/express bus services, and rail, indicated the predominant transit accident causes to be driver error and mechanical failure.

3.2.2.2 The Driver and the Vehicle

According to the above noted PTSB report, "over the six year period (1987 through 1992), 61 percent of all bus accidents were caused by transit systems' bus drivers or factors related to equipment." The report further noted that 86 percent of the accidents caused by bus drivers over the six year period were attributed to failure to drive defensively and operate a bus safely, failure to keep a safe following distance behind other vehicles, and failure to properly utilize bus equipment, such as rear door interlocks and wheelchair lifts.

Often, drivers alter their driving habits to maintain their schedules. This results in sharp stops as the bus drivers speed up and then abruptly stop to pick up passengers. Highway crashes involving buses are estimated to result in about 35,000 injuries in the US each year. According to the 1994 TRB paper, "Recommendations for Reducing Bus Passenger Injuries" [39] many bus-related injuries involve non-collision accidents which occur when passengers are riding buses.

The report noted that "Bus drivers should be screened, properly trained, and continually monitored," because it is the bus driver's inability to control his vehicle that results in many passenger injuries. The non-collision related accidents reported on buses included passenger falls while boarding or alighting as well as injuries while the vehicle is stopping or standing.

As noted in the PTSB Annu al Report, a high percentage of bus accidents occur due to equipment failure. Use of transit on an AHS would require increased maintenance of vehicles, which would reduce the potential for accidents due to electrical fires and faulty brakes and the accompanying bus down-time for repairs.

While AHS could potentially eliminate the driver entirely from the trunk line portion of the transit route, prior to that (if feasible), it can relieve the bus driver of his vehicle control responsibilities on this route segment. Although this could potentially reduce the rate of accidents occurring because of the driver, it would not preclude their proper training. AHS transit vehicle operation will require enforcement of proper driver training as well as increased vehicle inspections and maintenance operations.

3.2.2.3 Perceived Safety

Many potential passengers do not ride transit due to perceptions of compromised safety. The results of the study, "Perception of Crime on Public Transit in Small Systems in the Southeast" [40], were presented at the 1994 Annual TRB Conference. The findings indicate that when crime is experienced on transit systems, it is generally soft crime(begging, panhandling etc.).

It has been noted that people's perception of safety is improved with a noticeable transit force. The driver serves as the guardian of his passengers and acts as a deterrent to crime. On rail, for example, although there are a number of railroad personnel on board the trains, the cars are segregated and few train cars have personnel in them. On the average, riders are not usually concerned that the train has only a limited number of personnel on board, and do not expect one person in each vehicle. Passengers using a multiple platoon transit AHS could become accustomed to a similar arrangement.

There are other concerns that would arise if the driver were removed from a transit vehicle on an AHS. Disabled persons in need of assistance would be at a disadvantage. Under system malfunction conditions, how would control of the vehicle be maintained without jeopardizing passenger safety? Therefore, although anticipated AHS technology will not require the driver's skills at all times, his presence on board provides redundancy and well as reassurance to his passengers.

3.2.2.4 Summary and Conclusions

AHS offers improved service and safety by reducing the potential for driver-related accidents. Removing the driver from the continuous operation of the vehicle and providing guidance and warning systems will enhance the performance of bus transit service on AHS facilities in high travel demand corridors. Continuous, predictable reliable service and well-maintained vehicles will eliminated excessive acceleration and deceleration rates which also cause numerous passenger injuries. Increased maintenance practices would enhance vehicle operations and improve service reliability and safety.

3.2.3 Potential Transit AHS Applications

3.2.3.1 Existing HOV Lanes

As congestion has increased along with poor air quality, moving more people in fewer vehicles has become a major goal of urban and regional transportation planning and operating agencies. Giving preferential treatment to high-occupancy vehicles (HOVs) is not a new concept. During the energy crisis of the 1970's, in an effort to conserve fuel, many cities initiated HOV programs to move more people in fewer vehicles. When the crisis ended, the idea was further developed in an effort to reduce congestion on highways, especially during commuter hours. Throughout the U.S., busways and HOV lanes are being provided in dense commuter highway corridors to increase the total person carrying capacity, thereby reducing congestion while addressing environmental concerns. In support of these measures, the Federal government issued a mandate, Title 23 USCS Section 109(h), stating that further roadway expansion must not degrade the environment beyond certain safe standards. Roadway expansion is now a concern in all metropolitan areas.

The primary goal of these preferential treatment lanes is to carry more people than the same lane when used by single-occupant vehicles during peak travel periods. The number of people moving in this lane should be equal to or greater than the number of auto occupants in the adjoining lane. This goal has been met successfully in existing HOV lane operations throughout the country. In considering AHS as a natural next stage in the evolution of the HOV lane concept, objectives established for the latter operation can be re-stated as:

1. Maximize total person fl ow and reduce net person delay.
2. Provide adequate scheduled bus transit service to meet existing and potential demands.
3. Improve vehicle speeds and schedule dependability of bus transit.
4. Coordinate/combine express and feeder local bus services.

HOV and preferential bus lanes ideally should serve high-density residential areas, link them to high-density employment centers, and provide convenient distribution within these major activity centers.

According to *APTA,* there are more than 59 high-occupancy vehicle lane operations nationwide with lengths greater than one mile. They carry more than 85 percent of all A.M. peak-hour person-trips through the Lincoln Tunnel to New York City, and over 50 percent of all peak-hour travelers on the San Francisco-Oakland Bay Bridge in California, the Shirley Highway in Northern Virginia, the Ben Franklin Bridge in Philadelphia, and the Long Island Expressway in Queens, New York.

HOV/transit facilities have been operating for over 20 years and have demonstrated that increased transit usage can be achieved through bus priority measures. The delay reductions and time savings experienced have varied from 5 to 30 minutes, and compare favorably with time savings resulting from rail transit improvements. AHS on these facilities has the potential to provide even greater travel time savings, delay reductions and schedule reliability through higher average maintained speeds and virtual elimination of non-recurring congestion.

The present bus priority measures have been effective when provided in concert with over-all transportation management strategies dealing with traffic operations, parking control and financial support of public transit. Consequently, these measures would be required in transitioning to AHS on priority transit lane facilities. These include support of equitable transit fares; congestion pricing of downtown parking and single occupant vehicle tolls, strict enforcement of bus and HOV priority usage of the AHS lane during peak periods, and provision of adequate downtown terminal and distribution facilities for the greater volume of transit vehicles processed.

3.2.3.2 Station Stops, Terminal Concepts

Station stops along the trunk line portion of express/semi-express bus routes include facilities for buses to leave the preferential lane for passenger pick-up and delivery. These stops could be within the right-of-way of the highway, above grade, or on new adjacent right-of-way. In both cases, passengers would be served by transfers from feeder bus routes, park and ride lots, or "kiss & ride" areas. Illustrations of existing station stops on express bus/HOV lanes are shown in Appendix Figure A-8. They are directly applicable to transit AHS lane station-stop concepts.

Effective central passenger terminal and distribution facilities are essential complements to regional bus transit services. Distribution may take place in on-street bus lanes, bus tunnels, and bus terminals. Downtown express bus transit terminals are located at points of "optimum efficiency" within short walking distances of major employment concentrations, or connected with secondary public transport distribution systems including subways and local buses.

High capacity bus transit terminals will be required at the ends of AHS transit lanes to efficiently process high volumes of buses and other permitted HOVs. Distribution from these lanes into the local street network could create substantial queues, unless multiple platform intercepting terminals or multiple exit ramps to the street system are provided.

It can be argued that rail or "people-mover" systems are more feasible alternatives to AHS transit lanes in high density travel corridors. In defense of transit AHS, "dual service" type transit vehicles offer the potential of lower equipment and operating costs than rail cars, as well as lower physical infrastructure costs, while providing much greater flexibility. Buses can be driven onto and off of AHS lanes, and have the flexibility to serve many origins and destinations as compared to the inflexibility of fixed rail rapid transit. The old "dual mode" bus concept provided retractable rail wheels for operation on tracks along the trunkline segment of its route. Under AHS, this feature would be unnecessary.

The significant person carrying capability of existing bus and HOV lanes is best demonstrated by the Route 495 Lincoln Tunnel Express Bus Lane in northern New Jersey. The bus lane serves approximately 725 buses per hour, which represents about 35,000 passengers per hour under peak conditions [41]. Similarly, the reversible HOV lanes on the Shirley Highway in northern Virginia are highly productive, serving 16,500 passengers within the peak hour [42]. Of these, over 4,800 passengers are carried in 134 buses/hour and 8,500 persons are carried in 2,100, 3 or more person carpools and vanpools/hour. These actual performance data indicate that properly planned and utilized bus and HOV lanes provide an alternative to rail transit at these demand levels, ranging between 10,000 and 35,000 persons per hour.

Although bus infrastructure is less costly than initial investments in rail systems, this tends to be counterbalanced by the higher labor productivity(lower operating costs) of rail operations. If AHS platoon operations are feasible, in which the lead bus has a driver and the following buses are driverless, labor costs would be reduced or drivers could be deployed from trunkline segments to local circulation and feeder service.

3.2.3.3 Summary & Conclusions

Similar to the advantages o f busways, buses and HOVs on AHS would include the following cost and service advantages:

1. Relatively low initial construction is required; i.e. convert existing HOV lanes to AHS, use existing central bus terminals, and expand as bus demand increases.
2. AHS transit lanes can be utilized by trucks during non-rush hour periods of the day.
3. Dual service buses provide manually driven feeder service, non-transfer trunk line AHS service, and downtown manually driven distribution service.

Expected time sa vings for HOVs can range from 0.5 to 2.0 minutes/mile. Carpooling has increased on HOV lanes in some cases up to 100 percent, and transit ridership has increased between 10 and 20 percent. The technology inherent to AHS would allow greater travel time savings and, potentially, higher ridership. In general, HOV lanes have shown good ridership growth and proven congestion mitigation. As travel demand grows and peak period capacity requirements outstrip available HOV lane capacity, AHS offers the next solution, with at least a doubling of vehicle carrying capability, and much greater multiples of person carrying capacity.

3.2.4 BENEFITS & COSTS OF TRANSIT USE OF AHS

Automated Highway Systems have the opportunity to benefit the transit industry in a number of significant ways. AHS has the potential for making public transportation more attractive to 'choice' riders by improving service, reliability, and safety and reducing out of pocket fare costs by controlling operating expenses.

These practical benefits can be realized through the increase in lane capacity, average travel speeds, and increased productivity of individual vehicles. However, this additional through-put of persons and vehicles will require larger central terminals to provide the unloading and loading capacities required to match the greater trunkline capacities provided. Alternatively, increased numbers of local street bus lanes would be needed to accommodate these terminating transit vehicles.

The transit industry, as well as the environm ent, would benefit from improvements in fuel efficiency. Travel at a maintained, controlled constant speed results in a lower fuel consumption than travel with frequent acceleration and deceleration. Lower vehicle emissions will also result from controlled constant speeds, assisting in CAAA goals.

3.2.4.1 Travel Time & Schedule Adherence

AHS has the potential to reduce travel time for local/express bus services as well as for intercity buses. however, as discussed in Section 3.2.1, the intercity bus market has lost a significant share of riders to the airline industry, whose low travel times and competitive fares would be difficult to match by intercity buses on AHSs. The major competitive advantage that AHS offers for transit is an alternative to the private auto in express/local distribution between residential and employment center trip ends. By guaranteeing travel times and schedules under nearly all weather conditions, AHS can provide the alternative to driving for commuters in corridors not served by rail transit systems. As a dual service type of operation, it offers a no-transfer ride that cuts travel time by eliminating the need for park and ride facilities and mode changes.

3.2.4.2 Operating Costs, Labor, Fuel, Maintenance

While AHS has the potential to reduce operating costs in terms of fuel savings, more frequent maintenance would be required to comply with AHS check-in requirements. Additional vehicle trips would result in more wear and tear on the vehicles and require more parts purchases. It is anticipated that these additional costs would be offset by increased revenue from growth in ridership due to better service.

If the driver is removed from the vehicle, substantial cost savinsg could be achieved. APTA reports that nearly half of the operating expenses are attributed to salaries and wages.

3.2.4.3 Accident Reduction

In view of the high percentage of driver related incidents, AHS operations together with improved maintenance procedures would reduce the number of accidents related to driver and equipment failure. Accident-related operating expenses would be reduced. Reduced personal injuries to drivers and passengers, third party claims, and down-time for vehicles damaged or destroyed in accidents. This will lead to the lowering of insurance premiums.

The transit agencies are currently experimenting with Intelligent Vehicle Highway Systems(IVHS) and Advanced Public Transportation Systems(APTS) to improve vehicle and fleet planning, scheduling and operations, as well as reliability, efficiency and safety. These experiments, if successful, will provide a natural progression to incorporation of "smarter" and safer transit technology, including collision avoidance controls, and evolution to AHS operations in the appropriate travel corridors.

3.2.4.4 Summary and Conclusions

Improvements in the design of transit vehicles, and introduction of user-friendly transit information systems through IVHS programs, as well as additional government support through the mandates of the Clean Air Act Amendments and incentives introduced in ISTEA legislation, will lead to transit's evolution to a much more attractive alternative than it has been in the past. AHS offers the potential to make transit even more reliable, safer, and less time consuming. In light of the current legislation and support of transit by government policy to move people more efficiently, transit can be an integral, if not leading, component of initial AHS systems. Incorporation of transit into an AHS would allow transit agencies and their passengers to reap significant benefits, provided that the implementation and operating cost changes over existing conditions are viewed as worthwhile in terms of the benefits achieved. These potential benefits to the transit industry and its passengers include:

- Increased ridership due to better customer service
- Reduced travel time: ability to compete with other, faster, modes of transportation
- Improved safety, reduced insurance costs, fewer third party claims from injuries sustained on-board buses, reduced fuel, energy consumption reduced bus down-time

- Reduced labor costs due to vehicle productivity increases
- Contribution to environmental goals of the CAAA, ISTEA.

Incorporation of AHS technologies into an existing High Occupancy Vehicle (HOV) lane or roadway would provide a cost effective transition from existing infrastructure. Transit vehicles and high occupancy vehicles would be among the first to benefit from AHS.

3.3 AHS SCENARIOS WITH COMMERCIAL & TRANSIT VEHICLES

3.3.1 Introduction

Three existing Interstate highway facilities: the Long Island Expressway, New Jersey Turnpike, and the New York State Thruway, have been analyzed as case studies to determine the potential impacts of AHS implementation on peak period traffic operations under alternative passenger, commercial and transit vehicle lane use. The presence of commercial vehicles including heavy trucks and buses could significantly alter the expected performance of an AHS lane, while exclusion of these vehicles could have major impacts on adjacent general use lanes (GULs). It is therefore important in the evaluation of AHS on actual roadways to understand the implications of inclusion or exclusion of single unit trucks, tractor trailers, and buses.

High volumes of trucks and buses in AHS as well as GULs limit the space available for passenger vehicles. In order to serve the same number of passengers, increased carpooling and transit use is the alternative to additional lane construction. The mandates of the Clean Air Act Amendments/Employee Commute Options(CAAA/ECO), require that average passenger vehicle occupancies be increased by 25 percent in the next five (5) years by companies with over 100 employees that are located in air quality non-attainment areas. The results of the analyses described in this section indicate several configurations and lane restrictions which support compliance with these regulations, as well as other configurations which detract from these goals.

3.3.1.1 Assumptions

Base Condition: The "No Build" Scenario for the three case study highways in the year 2024 will be considered as the base condition, with no automation or significant capacity increasing technologies other than expanded traffic management systems in operation.

The first facility, the Long Island Expressway (Interstate 495), is currently comprised of three lanes in each direction in Nassau and Suffolk Counties on Long Island, New York. A 2.5 mile long eastbound roadway section between New Hyde Park Road and Mineola Boulevard/Willis Avenue in Nassau County provides a good representation of a mixed urban/suburban high traffic roadway section (over 180,000 vehicles daily) and was used for this analysis. The traffic operations occurring within this segment are indicative of operations within the 15 mile corridor of the LIE, under evaluation in other Tasks. It is noted that the New York State Department of Transportation (NYSDOT) is currently studying the addition of a fourth lane in each direction for HOVs only in this section. The "No Build" Scenario assumes that the fourth lane has been built and is operating with HOVs of two or more occupants in this lane, at level of service`C` or 80 percent of capacity(1,760 passenger car equivalents/hour)

The New York State Thruway, (I-87) is comprised of two, two lane directional roadways between Exits 16 and 18 in the Newburgh area, a distance of 31 miles. This rural section of the northbound roadway of the Thruway was used for the second case study.

The third case study, the New Jersey Turnpi ke, (I-95) consists of three lanes in each direction on both its eastern and western "Spurs" in northern New Jersey and two, six-lane roadways in the combined section to the south. Only the northbound roadways were considered in this analysis. It has high volumes of commercial vehicles including commuter buses from suburban areas headed into New York City's Port Authority Bus Terminal.

For study purposes, it has been assumed that traffic volumes will be evenly distributed among the lanes and all vehicle types would be allowed free access between lanes for the base "No Build" Scenario. Analyses of subsequent future base year and alternative AHS scenarios comprised estimating traffic volume capacity ratios, roadway lane capacity, and vehicle occupancy requirements to achieve non-congested (Level of Service E) conditions. For each alternative, passenger vehicle, commercial vehicle, and bus vehicle miles and passenger hours of travel were computed. Subsequent calculations of vehicle operating and travel time costs were made for comparison of each alternative with the base "No Build" Scenario.

Future Year 2024 Traffic Volumes: Forecast peak hour traffic volumes for the Long Island Expressway for the year 2015, and 1993 volumes for the New York State Thruway were used as base year data. These volumes were factored up to a future design year of 2024 at a 2 percent compounded annual growth rate, or 1.85 times 1993 and 1.2 times 2015 peak hour volumes. The New Jersey Turnpike Authority provided 1993 peak hour traffic volumes that were similarly factored up to the year 2024 using the same 2 percent annual growth rate.

Vehicle classifications for the Long Island Expressway and the New York State Thruway were derived from the *1990-1991 Truck Weight and Continuous Count and Special Station* computer printout furnished by NYSDOT. As the highway locations provided are not the specific sections under analysis, only relative percentages of heavy vehicles and single unit trucks/buses were obtained. Bus percentages were not included in the NYSDOT report and were obtained from other sources. An estimate of the percentage of buses utilizing the Thruway in the Newburgh area was provided by the Thruway Authority. Actual hourly vehicle classification breakdowns by volume were provided by the New Jersey Turnpike Authority. These percentages and actual counts were used to develop the future projections of peak hour passenger vehicles, single unit and tractor trailer trucks and buses used in the alternative scenario analyses.

Commercial and transit vehicles have different operational characteristics than passenger cars and can significantly affect traffic operations. To determine the impact of heavy vehicles and buses on the traffic stream, an adjustment must be made to the traffic volumes. Under current highway capacity analysis procedures [(43)] passenger car equivalents (PCEs) are applied to actual vehicle counts for trucks and buses to determine the number of passenger cars that would consume the same percentage of the roadway's capacity as one truck or bus, under prevailing roadway and traffic conditions. PCEs were utilized to determine the relative effects of the heavy vehicles on the traffic stream, both in the AHS lane and in the GULs. The critical assumption for the AHS lane is that the same passenger vehicle/truck equivalence factors as are now used for conventional lanes would apply. This is based upon the assumption that relative vehicle geometry and braking distances will remain the same as they are today and that the physical and dynamic vehicle characteristics (acceleration, deceleration, braking) will be the same for vehicles on AHSs as on conventional lanes.

An average PCE of 3.0 was applied to single unit trucks, tractor trailers and buses for both the AHS lanes and GULs on the New Jersey Turnpike and the New York State Thruway. On the Long Island Expressway, where as-built information was available, the actual grade along the roadway between New Hyde Park Road and Mineola Blvd./Willis Avenue, and the relative distribution of the percentage of trucks in the traffic stream, was considered in the determination of the PCEs. For capacity analysis purposes, the "typical" truck population is assumed to have a characteristic ratio of 200 lb/hp. A PCE of 4.0 was determined from Table

3-4, *Passenger Car Equivalents for Typical Trucks(200 lb./hp),* of the 1985 Highway Capacity Manual[43] and applied to the heavy vehicle volumes. Although buses typically operate at a performance level better than trucks, and intercity buses tend to be more uniform in their characteristics, to be conservative, a PCE of 4.0 was also applied to the bus volumes. These values represent a conservative estimate of the anticipated traffic stream along these roadways.

It has been assumed that AHS lane capacity in passenger vehicles/hour will be 4500 pvphpl or over twice the capacity of the GULs, 2200 pvphpl.

Vehicle Occupancies: Average vehicle occupancies were used to determine the number of people transported on each of the highway facilities. An average vehicle occupancy (AVO) of 1.20 was used for both the Long Island Expressway(Fourth Lane Study) and the New York State Thruway. The passenger vehicles travelling in the HOV lane under No Build conditions on the LIE carry an AVO 2.0. An AVO of 1.25 was used on the New Jersey Turnpike.

It was assumed that only one driver is present in each truck and an average of 48 passengers are on buses on the New Jersey Turnpike and the New York State Thruway. An AVO of 30 was used for the mixed distribution of buses and vanpools using the Long Island Expressway.

These vehicle occupancies were used for the projected forecast year 'No Build' conditions.

3.3.1.2 Scenario Descriptions

The goal of this analysis has been to determine the effect of restricted use of the AHS by various vehicle types, and to identify impacts on the AHS and GULs. If the established highway configuration cannot be altered by adding lanes, it is important to understand how people will be transported along the existing remaining roadway lanes. All indications suggest that increased carpooling/transit will become the only viable means of future travel on these facilities if widening is not possible. Accordingly, four scenarios for AHS and manual lane use have been investigated, each with three lane use options based on vehicle class. These include:

Scenario #1: An exclusive AHS lane for passenger vehicles only;

Scenario #2: Mixed use in all lanes, including the AHS lane(s);

Scenario #3: An exclusive AHS lane for passenger vehicles and light trucks; with semi trailers prohibited;

Scenario #4: An exclusive AHS lane for all commercial and transit vehicles.

Each scenario has three different options or combinations of lane type, AHS or non AHS (GUL):

Option A, composed of one(1) AHS lane and two(2) GULs;

Option B, two(2) AHS lanes and one(1) GUL;

Option C, a fully automated highway with three(3) AHS lanes.

Distribution of Traffic among Lanes: Throughout the scenarios it was assumed that there will be a range of market shares for the AHS, from 33 percent to 100 percent eligible vehicles. Projected peak hour passenger and commercial vehicle traffic volumes have been divided accordingly.

Scenario #1 - Exclusive AHS Lane for Passenger Vehicles Only

Option A - under this configuration, the AHS lane carries 50 percent of the passenger vehicle demand of the roadway, and the remaining 50 percent is divided between the two GULs. The single unit truck, tractor trailer, and bus volumes are distributed evenly between the two GULs.

Option B - one AHS lane is used exclusively by 50 percent of the passenger vehicle demand. The second AHS lane carries all single unit, tractor trailer, and bus volumes; there are no passenger vehicles in this lane. The GUL carries the second 50 percent of the passenger vehicles.

Option C - the three AHS lanes carry the same vehicle distribution as Option B.

Scenario #2 - Mixed Use in AHS Lane(s)

There are no lane restrictions within Scenario #2; all vehicle types are distributed evenly among the three lanes, regardless of lane capacity, for each of the same three AHS lane options as in Scenario #1. This represents a low of 33 percent AHS use by passenger and commercial vehicles under Option A to a high of 100 percent by both under Option C.

Scenario #3 - Exclusive Lane for Passenger Vehicles, Light Trucks and Transit Vehicles

Option A - 50 percent of the passenger vehicles, 50 percent of the single unit trucks (SU), and 50 percent of the buses are included in the AHS lane. No tractor trailers are permitted in this lane. The remaining 50 percent of the PVs, SUs and buses are distributed evenly among the two (2) GULs. Tractor trailer volumes are likewise divided evenly between the two (2) GULs.

Option B - tractor trailers are restricted from the two(2) AHS lanes. PVs, SUs and bus volumes are evenly distributed among the three lanes. All tractor trailers must use the remaining one (1) GUL.

Option C - the same vehicle restrictions and distribution is used as in Option B, above, with the third former GUL for tractor-trailers now an AHS lane.

Scenario #4 - Exclusive AHS Lane for all Commercial and Transit Vehicles

Option A - all trucks and buses are in the One (1) automated lane, and passenger cars are distributed evenly between the two (2) GULs.

Option B - trucks and buses remain segregated in one (1) AHS lane, however, 50% of the passenger vehicle demand is serviced by the second AHS lane. The remainder of the passenger vehicles are carried by the single (1) GUL.

Option C - one (1) AHS carries only trucks and buses, and the passenger vehicle volume is distributed evenly between the remaining two (2) AHS lanes.

3.3.2 Long Island Expressway(Urban, Suburban)

3.3.2.1 General

A 2.5 mile section of the eastbound Long Island Expressway(LIE) in Nassau County, New York was evaluated to determine the potential traffic conditions within an AHS and General Use Lanes (GULs) in the year 2024. This segment between New Hyde Park Road and Mineola Boulevard/Willis Avenue, was used to evaluate the operation of the lanes, the resultant vehicle distribution and average passenger vehicle occupancies for each scenario based on lane capacity, either AHS or GUL for the entire 15 mile roadway length. Within this section of the roadway an I-2 scenario (where the AHS lane is accessed from the GULs) was analyzed. Given the physical constraints of the Long Island Expressway corridor and the overall AHS Program goals, the I-2 RSC appears to be a more probable candidate for early deployment than an I-3 Scenario where separate ramp entrances and exits would be provided. Peak hour traffic volumes for both the AHS lane and the GULs were projected to the planning year 2024 at a 2 percent compounded annual growth rate.

The approximate percentage of heavy vehicles utilizing the LIE was derived from the *1990-1991 Truck Weight and Continuous Count and Special Station* computer printout furnished by New York State Department of Transportation(NYSDOT). The only location along the LIE that was recorded in this data was a segment between Kissena Boulevard and Utopia Parkway, in Queens. At this location, approximately 6.9 percent of the total vehicles are heavy vehicles, ranging from Class F4 through F13, which includes buses and large tractor trailers, and 93.1 percent passenger vehicles. Approximately 0.1 percent of the total vehicles are large trucks ranging from Class F8 through F13, which includes tractor trailers and double bottom vehicles; thus 6.8 percent of the vehicles are classified as single unit vehicles, F4 through F7. Review of data from the Long Island Expressway Fourth Lane Study [(44)], indicates that 0.5 percent of the traffic is buses/vanpools, which are grouped within the single unit vehicle class. The resulting heavy truck(Class F4 through F7) distribution is 6.3 percent. Based on these data, for the AHS analyses of the LIE, the overall vehicle distribution was assumed to be comprised of 93.1 percent passenger vehicles, 6.3 percent single unit trucks (SU), 0.5 percent buses/vanpools and 0.1 percent tractor trailer combination units.

3.3.2.2 Analysis Results

Base Condition: In the year 2024, peak hour traffic demand for the three GULs on the LIE between New Hyde Park Road and Mineola Blvd./Willis Avenue will be more than double the existing roadway's capacity, as shown in Appendix Table A-7, Base Conditions, HOV No Build. To maintain operations at a Level of Service(LOS) of E in the general use lanes, while serving the same number of people, the projected number of passenger vehicles in the lanes would have to be reduced by forcing average passenger vehicle occupancies in the lanes to increase.The HOV lane would operate at a LOS of C.This would maintain an AVO of 2.0 in the HOV lane, and cause an increase in AVO in the GULs from 1.2 to 3.2 in each of the three lanes. Although, it has been assumed that this fourth lane will have been constructed prior to the possible implementation of any of the alternative AHS scenarios evaluated, under the AHS I-2 RSC configuration, only three of the four lanes will be available for through-travel as the fourth lane will be the transition lane.

<u>Scenario #1 - Passenger Vehicles in Separate AHS Lane</u>

Under the traffic distribution allocated for Scenario #1, Option A, all three lanes exceed capacity, as shown in Appendix Table A-8. In order to operate at capacity, the average vehicle occupancy(AVO)for the AHS lane would have to increase from 1.2 to 1.5 persons/vehicle and the GULs to 6.0. This indicates that the LIE would only remain operational under this configuration with a 25 percent increase in passenger vehicle occupancy on the AHS lane, but a significant increase in vanpooling within the GULs. The AHS lane would have an excess demand of over 1,000 passenger vehicles, unless it were restricted to higher occupant vehicles.

Under Option B, with a second AHS lane for commercial vehicles and buses, the passenger vehicle AHS lane would exceed capacity by 25 percent, while the truck/bus AHS lane would operate at a volume to capacity ratio(v/c) of 0.7, below capacity. The GUL would have a demand of 2.5 times capacity, unless average occupancy increased to 3.0. Vehicle occupancies within the passenger vehicle AHS lane would have to increase to 1.5. This would require designation of both passenger vehicle AHS and non-AHS lanes for HOV operations, although less restrictive in the AHS lane due to its higher vehicle capacity.

Under Option C, the two passenger vehicle AHS lanes would operate at 25 percent above capacity unless vehicle occupancies were higher, averaging 1.5. The truck/bus AHS lane would operate again below capacity, at a v/c ratio of 0.7.

Scenario #2 - Mixed Vehicles in AHS Lane(s)

Under Option A, the demand for the single AHS lane would be about 300 vehicles over capacity, while demand for the two non-AHS lanes would be more than double their capacity, as shown in Appendix Table A-9. This would require increasing average vehicle occupancy to 1.3 in the AHS lane and to 4.0 in the GULs. Vanpooling and increased transit would be required to maintain vehicle operations at capacity in the two GULs.

Under Option B, all lanes would operate above capacity. Vehicle occupancies would have to increase to 1.3 in the two AHS lanes and to 4.0 in the GUL to achieve capacity operations. Vanpooling and transit increases would be required in the non-AHS lane.

Under Option C, all three AHS lanes would operate at about 300 vehicles over capacity, and average vehicle occupancies would have to increase to 1.3, or only 8 percent above current levels. This does not support CAAA goals, unless alternate fuel or electric vehicles are assumed, by the end of the 30 year planning period.

Scenario #3 - Exclusive AHS Lane for Passenger Vehicles Light Trucks and Transit Vehicles

Under Option A, demand in all lanes would be about 60 percent over capacity and vehicle occupancies would have to increase to 2.3 in the single AHS lane and 2.4 in the two GULs, as shown in Appendix Table A-10. Carpooling with 2+ to 3+ occupancies would be required in all of these lanes.

Under Option B, with two AHS lanes and a third, non-AHS lan e in which the tractor trailers would be allowed, passenger vehicle occupancies would have to increase to 1.3 in the two AHS lanes and to 4.2 within the GUL, in order to achieve capacity operations. AHS users in both lanes would have to increase their vehicle occupancies only slightly, while vanpooling and increased transit would be required on the GUL in order to reduce the number of passenger vehicles.

Under Option C, with three AHS lanes, of which only one carries tractor trailers, traffic demand is less than 10 percent above capacity. Passenger vehicle occupancies averaging 1.3 would be required in all three lanes to achieve capacity operations, requiring increased carpooling, but not to the degree being promoted by the CAAA.

Scenario #4 - Exclusive AHS Lane for all Commercial and Transit Vehicles

Under Option A, the truck/bus AHS lane would operate at a v/c ratio of 0.7, while the two GULs would have a demand of more than double their capacity, as shown in Appendix Table A-11. Average passenger vehicle occupancy would have to increase to 3.0 in the two

GULs to achieve capacity operations. This would require carpools of 2+, 3+, vanpooling and increased transit use.

Under Option B, the single truck/bus AHS lane would operate as in Option A, at a v/c ratio of 0.7, while the passenger vehicle AHS lane would be 20 percent over capacity. The remaining GUL would have a demand over double its capacity. The passenger vehicle AHS lane would have to increase its average vehicle occupancy from 1.2 to 1.5, or by over 20 percent, and the GUL would require an AVO of 3.0. An increase in carpooling would be required in the AHS lane and carpools of 3+, vanpooling, and more transit service would be required in the GUL.

Under Option C, with three AHS lanes, the third passenger vehicle AHS lane would operate similarly to the second AHS lane in Option B. A 20 $^{+}$ percent increase in carpooling would be required in the two passenger vehicle AHS lanes in order to achieve capacity flow.

3.3.2.3 Summary and Conclusions

Most of the forecast year AHS Scenarios and Options discussed above provide operating improvements in comparison to the base 'No Build' condition in which the HOV lane and three general use lanes have demands above capacity. Vehicle occupancies in the general use lanes would have to average 3.2 in order to achieve capacity traffic flows of 2200 equivalent passenger vehicles per lane per hour. The HOV lane would operate better than the GULs, at a v/c ratio of 0.8.

Under Scenario #1, Option A presents poor ope rations with all lanes at capacity and AVOs reaching 6.0 in the GULs. Option B presents only the truck/bus AHS lane operating below capacity and an AVO of 3.0 in the GUL. Option C exhibits similar lane capacities with lower vehicle occupancies of nearly 1.5 in all three AHS lanes.

Under Scenario #2, all lanes under Option A are at capacity and the GULs have AVOs of 4.0. All lanes under both Options B and C also operate at capacity. The GUL in Option B has an AVO of 4.0 and the AHS lanes of Options B and C all have AVOs of 1.3, about 8 percent higher than the current experience.

Under Scenario #3, all lanes under Option A are at capacity and the GULs have AVOs of 2.4. All lanes under both Options B and C also operate at capacity. The GUL in Option B has an AVO of 4.2 and the AHS lanes of Options B and C have AVOs of about 1.3.

Under Scenario #4, the truck/bus AHS lane operates below capacity for all three Options, while all other lanes operate at capacity. Under Options A and B, all GULs have AVOs of 3.0 and the passenger vehicle AHS lanes of Options B and C have AVOs of about 1.5.

It is evident from this analysis that the influence of trucks and buses within the AHS is significant and has the potential to alter the passenger and passenger car distributions of the facility. The results indicate that the volumes exceed the capacity of up to three AHS lanes. The average vehicle occupancies fluctuate based on the vehicle mix and lane restrictions. In some instances the lanes of the AHS-equipped roadway operate the same as or worse than the "No Build" condition in terms of capacity and vehicle occupancy. The managed capacity would require carpooling and vanpooling in order to accommodate the high passenger demand. Vehicle occupancies between 1.3 and 1.5 fall short of meeting the objectives of the ECO program. Options that encourage AVOs of 2.0 or greater should be pursued.

Table A-12 presents a summary of vehicle-miles and person-hours traveled by vehicle classification for each scenario and option of this analysis. This information was used to generate Appendix Figure A-9 "Optimum AHS RSC Configurations." This graph illustrates the most efficient combination of AHS and non-AHS lanes based on vehicle-miles(VMT) and person-hours(PHT) traveled. From this it appears that the "optimum" conditions at which both VMT and PHT are lowest,would occur at a total hourly roadway capacity of 8,900 pcph. This best corresponds to a one AHS lane, two GUL configuration. Scenario #4 Option A (4A) represents the alternative with the least vehicle-miles traveled and the least person-hours of travel.

3.3.3 New York State Thruway (Rural)

3.3.3.1 General

A 31 mile segment of the New York State Thruway between Exits 16 and 18 was analyzed in the northbound direction. Existing traffic volumes (assumed to be 1993) were provided by other Calspan Team Members for their Scenario T, in a fax transmission dated June 22, 1994. These peak hour volumes, for both the AHS lane and the GULs, were projected 31 years to the planning year 2024 at a 2 percent compounded annual growth rate.

The distribution of traffic between the AHS and GULs was determined by DEA. The vehicle classification breakdown was extracted from the *1990-1991 Truck Weight and Continuous Count and Special Station* computer printout for a segment between Exit 35 and Exit 36, as information between Exits 16 and 18 was not available. At this location, approximately 10.8 percent of the total vehicles are heavy trucks, ranging from Class F4 through F13 which includes buses and Large Commercial Vehicles (LCVs), and 89.2 percent passenger vehicles. Approximately 0.8 percent of the total vehicles are large trucks ranging from Class F8 through F13, which includes tractor trailers and double bottom vehicles; thus 10.0 percent of the vehicles are classified as single unit vehicles, F4 through F7. According to the Thruway Authority [45], of the single unit class approximately 3.0 percent are buses. For the AHS analyses of the NYS Thruway between Exits 16 and 18, these same percentages will be used. The overall vehicle stream was therefore assumed to be comprised of 89.2 percent passenger vehicles, 7 percent single unit trucks (SU), 0.8 percent tractor trailer combination units, and 3 percent buses.

The same three scenarios and four options as used in the Long Island Expressway analysis were considered in the evaluation of the influence of single unit trucks, bus and tractor trailers on the Thruway. The current configuration represents an I-2 RSC, with AHS access from the GULs. The existing two-lane directional roadway section would be widened to three lanes to accommodate the AHS lane, and two lanes would be available for manual operation.

3.3.3.2 Analysis Results

Base Condition: In the year 2024, the two GULs on the New York State Thruway will operate at 80 percent of their capacity, as shown in Appendox Table A-13. It appears that AHS technology would be instituted as a means to improve safety and travel time efficiency along this route, as it would not be needed to increase capacity. From the physical characteristics of the roadway, it appears that an I-2 RSC would be an appropriate configuration.

<u>Scenario #1 - Passenger Vehicles in Separate AHS Lane</u>

Under Option A, all lanes operate well below their respective capacities. The passenger vehicle AHS lane would operate at one-third of its capacity, and the two GULs would each operate at half of their capacity, as shown in Appendix Table A-14. Consequently, no vehicle occupancy restrictions would apply and the AVO will remain at 1.2.

Under Option B, with a second AHS lane for commercial vehicles and buses, the passenger vehicle AHS lane v/c ratio would be 0.3, and the truck/bus AHS lane would operate more freely at a v/c ratio of 0.2. The GUL would operate at 60 percent of its capacity. No vehicle occupancy restrictions would be required and the AVOs would remain at 1.2.

Under Option C, all AHS lanes would operate well below capacity with v/c ratios ranging from 0.2 to 0.3. Again, no vehicle occupancy restrictions would be required, and the AVOs would remain at 1.2.

Scenario #2 - Mixed Vehicles in AHS Lane(s)

Under Option A, the AHS lane would operate at 30 percent of its capacity, and the two GULs would each operate at one half of their capacity, as shown in Appendix Table A-15 Vehicle occupancy restrictions would not be required, and the AVO would remain at 1.2.

Under Option B, again, all lanes would operate well below capacity. The two AHS lanes would have v/c ratios of 0.3, and the GUL would operate at one half of its capacity.

Under Option C, all three AHS lanes would operate at 30 percent of their capacity. AVOs would remain at 1.2.

Scenario #3 - Exclusive AHS Lane for Passenger Vehicles, Light Trucks and Transit Vehicles

Under Option A, the demand in all three lanes would be about 40 percent of capacity, as shown in Appendix Table A-16.

Under Option B, with two AHS lanes and a third, non-AHS lane in which tractor trailers would be allowed, vehicle occupancies would not increase, as additional capacity is not required. The two AHS lanes would operate at 30 percent of capacity, and the GUL would operate at half of its capacity.

Under Option C, all three AHS lanes would operate at 30 percent of capacity. As with Options A and B, vehicle occupancy restrictions would not be required.

Scenario #4 - Exclusive AHS Lane for all Commercial and Transit Vehicles

As shown in Appendix Table A-17, under Option A, the AHS lane reserved for commercial and transit vehicles would operate well below capacity at a v/c ratio of 0.2. The two GULs would also operate below capacity, at 60 percent of capacity.

Under Option B, the truck/bus AHS lane would operate as in Option A, at a v/c ratio of 0.2, and the passenger vehicle AHS lane would operate at a v/c ratio of 0.3. The GUL would operate at 60 percent of its capacity.

Under Option C, the truck/bus AHS would operate at a v/c ratio of 0.2. The two passenger vehicle AHS lanes would operate at 30 percent of their capacity.

As in all previous scenarios there would not be any vehi cle occupancy restrictions for Options A, B or C.

3.3.3.3 Summary and Conclusions

This analysis of three Scenarios for AHS operation of a three lane directional roadway section of the NYS Thruway confirms that the primary reason to implement the technology in this segment would be to improve the safety and travel speed characteristics of the freeway. The forecast 2024 volumes do not warrant an increase in capacity.

Appendix Table A-18 summarizes the vehicle-miles and person-hours traveled for each Scenario and Option, as well as the no-build base condition. Appendix Figure A-10, "Optimum AHS RSC Configuration," illustrates that there is no one configuration that is truly efficient in vehicle-miles and person-hours of travel. If AHS is implemented to improve safety and efficiency then Option A, with one AHS and two GULs, provides the most cost-effective use of the New York State Thruway under an AHS. In all other options, the infrastructure is excessive for the low volumes. None of the twelve options promote carpooling or require any kind of vehicle occupancy restrictions.

3.3.4 New Jersey Turnpike

3.3.4.1 General

Segments of the New Jersey Turnpike north of Exit 14 through Exits 16E and 18W in Hudson and Bergen Counties were analyzed. Both the east and west "Spurs", as well as the combined section that feeds them from the south, were analyzed. The western segment, is 6 miles long; the eastern segment, is 5 miles long; and the combined roadway section is 2 miles long. Traffic volume classification counts were provided by the New Jersey Turnpike Authority. These volumes were factored at a rate of 2 percent per year to reflect future growth projections for 2024 peak hour conditions. A.M. peak hour traffic conditions were analyzed to determine truck and bus distributions by type and the effects of these commercial and transit vehicles within the AHS lanes and GULs.

The distribution of passenger vehicles, single unit vehicles, tractor trailers and buses was obtained from the existing classification counts. Of the distributions for both roadway "Spurs", the higher truck volume percentages were applied to all three segments: east, west, and combined sections. The resulting base conditions for all segments was: 66.8 percent passenger vehicles; 7.5 percent single unit trucks; 15.7 percent tractor trailers; and 10 percent buses.

It was assumed that the future AHS would be an I-2 RSC, with access to the AHS lanes from the GULs, given the physical constraints and the cost of infrastructure construction. A fourth AHS lane has been assumed to be added to the existing three-lane directional roadways, however only two non AHS, GULs would be available as one lane would function as a transition area.

3.3.4.2 Analysis Results

Base Condition: In the year 2024, the three GULs on both the west and east Spur and the six GULs on the combined section of the New Jersey Turnpike will exceed capacity. To maintain operations at a LOS of E, the peak hour passenger vehicle demand in the lanes would have to be reduced. This would require vehicle occupancies to rise from the present AVO of 1.25 (1.3) to 2.1 on the west; 3.7 on the east; and 2.7 on the combined section. These results are summarized in Appendix Table A-19.

As these three segments must operate as one cohesive system (i.e. if carpooling is required on the west Spur it would be introduced in the combined section and the east Spur as well), the Scenario/Option with the most restrictive conditions will govern the operations of the facility.

<u>Scenario #1 - Passenger Vehicles in Separate AHS Lane</u>

Under Option A, the single passenger vehicle AHS lane would operate below capacity with a v/c ratios ranging from 0.7 to 0.9. The two GULs would exceed capacity in all segments by 40 to 80 percent. In order to operate at LOS E, AVOs would have to increase to 2.6 along the west, to 10.1 along the east, and to 4.5 along the combined section. These conditions would require increased mass transit in the form of passenger vans and buses in place of passenger cars to maintain traffic operations at a LOS of E along this facility.

Under Option B for all Turnpike segments, both the passenger vehicle and the truck/bus AHS lanes would operate at conditions less than capacity with the passenger vehicle

AHS v/c ratio ranging from 0.7 to 0.9 and the truck/bus AHS with v/c ratios ranging from 0.7 to 0.9. The GUL would exceed capacity by 40 to 80 percent along all three segments. For capacity operations vehicle occupancies for the GUL would range from 1.7 on the west, to 2.2 on the east and to 2.0 on the combined section. This would require 2+ person carpools along the roadway to meet the conditions imposed by the east Spur.

Under Option C, all three AHS lanes along the three segments would operate at volumes ranging from 70 to 90 percent of their capacity. The AVOs would remain at 1.3 and the CAAA/ECO objectives would not be achieved.

The above results are summarized in Appendix Table A-20.

Scenario #2 - Mixed Vehicles in AHS Lane(s)

Under Option A for each Turnpike segment, vehicular d emand for the AHS lane and the two GULs would meet or exceed capacity by up to 30 percent. Passenger vehicle occupancies would have to be increased to meet this demand. The resulting AVOs for the AHS lane would range from 1.3 on the west to 1.9 on the east; and the combined section would have an AVO of 1.6. The AVOs of the GULs of the west would remain at 1.3; the AVO for the GULs on the east would increase to 2.0; and the AVO of the combined section GULs would be 1.6. Carpools of 2+ persons would be required to sustain vehicle operations within this vehicle mix.

Under Option B the two AHS lanes along the west and the combined section would operate at volumes from 70 to 90 percent of capacity. Consequently, the AVO would remain at 1.3. The east would operate at capacity, with AVOs remaining at their current level (1.25). All GUL segments would operate at v/c ratios of 1.4 to 1.8. AVOs of 2.1 on the west, 3.7 on the east and 2.7 along the combined section would be required to meet the demands posed by this configuration and vehicle mix. Vanpools and transit buses would be required to maintain capacity operations.

Under Option C along the west and combined section all three AHS lanes would operate at volumes from 70 to 90 percent of capacity. Consequently, the AVO would remain at 1.3. Along the east Spur, all AHS lanes would operate at capacity and the AVO would remain at 1.3. Carpooling restrictions would not be required and CAAA/ECO objectives would not be achieved.

These results are summarized in Appendix Table A-21.

Scenario #3 - Exclusive Lane for Passenger Vehicles, Light Trucks and Transit Vehicles

Under Option A only the AHS lane of the west Spur would operate at conditions better than LOS E. The AVO would remain at 1.3. The east and combined sections would operate at or exceed capacity. To reduce this vehicular demand would require AVOs of 1.4 and 1.3, respectively. The two GULs along all three segments would exceed capacity by 20 to 60 percent. AVOs of 1.7 for the west, 3.2 for the east, and 2.3 along the combined section would be required for LOS E operations. Vanpooling would have to be instituted to maintain capacity operations along the facility.

Under Option B the displacement of all the tractor trailers to the GUL would bring this lane to a stand-still along the east and combined sections. As this distribution of commercial vehicles would exceed lane capacity, this option for the east spur and combined section is unacceptable. The west Spur, however, would operate at 60 percent of capacity in the two AHS lanes, while exceeding capacity in the GUL. Average passenger vehicle occupancies in the GUL would increase to 9.0, and vanpools/transit would be required.

Under Option C for all three segments, the two AHS lanes without tractor trailers would operate at volumes 60 to 70 percent of capacity. The AHS lane with the tractor trailers would exceed capacity within the east and combined sections. AVOs of 1.3 for the west, 1.7 for the east and 1.3 along the combined section would be required for LOS E operations.

Refer to Appendix Table A-22 for these results.

Scenario #4 - Exclusive AHS Lane for all Commercial and Transit Vehicles

Under Option A for all three segments, only the AHS lane would operate below capacity, with v/c ratios ranging from 0.7 to 0.9. Along all segments, the two GULs would have v/c ratios of 1.4 to 1.8. The GULs would have AVOs of 1.7 for the west Spur, 2.2 for the east Spur, and 2.0 along the combined section. Carpooling of 2+ persons would be required.

Under Option B for all three segments, the two AHS lanes would operate below capacity at v/c ratios ranging from 0.7 to 0.9. The GUL would exceed capacity along all segments, by 40 to 80 percent. As in Option A, in order to operate at LOS E, the GULs would have AVOs of 1.7 in the west 2.2 in the east and 2.0 in the combined section. Carpooling of 2+ persons would be required.

Under Option C for all three segments, all three AHS lanes would operate below capacity with v/c ratios ranging from 0.7 to 0.9. All AVOs would remain at 1.3. No driver/carpool restrictions would be required.

These results are shown in Appendix Table A-23.

3.3.4.3 Summary and Conclusions

The introduction of AHS technology improves operations along the New Jersey Turnpike, as compared to the "No Build" condition for 2024, in most of the scenarios under consideration.

The passenger and vehicle demand created by each of the various scenarios and options works towards the goals of the ECO Program in eight of the twelve cases. Only three cases, Option C for Scenarios #1, #2 and #3 exhibit no change in AVO from the current ratio (1.25). Scenario #3, Option B is unacceptable for the east and combined sections. Scenario #1, Option B (1B); Scenario #2, Option A (2A); Scenario #4, Options A (4A) and B (4B) require carpools of 2+ persons in one or more of the lanes. Scenario #2, Option B (2B); Scenario #3, Options A (3A) and C (3C) require vanpooling in one or more of the lanes, and Scenario #1, Option A (1A) and Scenario #3, Option B (3B) - west Spur, require increased bus transit service in one or more of the lanes.

Based on these findings, it appears that, under certain applications, AHS would be viable along this northern section of the Turnpike, and would support the objectives of the CAAA/ECO Program.

Appendix Table A-24 presents a summary of vehicle-miles and person-hours traveled, by vehicle classification, for each Scenario and Option for both the east Spur and the Combined section of this analysis. The information is depicted in Appendix Figures A-11 and A-12, "Optimum AHS RSC Configurations," which illustrate the most efficient combination of AHS and manual lanes based on vehicle-miles and person-hours traveled for each of the two roadway segments. From this, it appears that optimum conditions occur at a total roadway capacity of 8900 pcph along the east Spur. This best corresponds to Scenario #4, Option A and Scenario #1, Option A. Accordingly, this”worstcase” east Spur would govern the scenario selected for the combined section.

3.3.5 Summary and Conclusions, AHS Scenarios

From the analysis conducted above for the Long Island Expressway, the New York State Thruway, and the New Jersey Turnpike, it is evident that each type of freeway, urban or rural, exhibits varying capabilities for incorporating AHS technology.

'No Build' conditions for both the Long Island Expressway(LIE) and New Jersey Turnpike will require additional vehicle capacity in the year 2024. AHS technology would be theoretically viable to alleviate congestion. The findings in the analyses for the LIE indicate that Option A for Scenario #4,with an ultimate capacity of 8,900 pcph, would be the “optimum” alternative. These Options also exhibit favorable average vehicle occupancies for compliance with the CAAA/ECO Program goals. Along the east Spur of the New Jersey Turnpike Options A for Scenarios #1 and #4, with an ultimate capacity of 8,900 pcph, appear to be the most efficient. Option A for Scenarios #1 and #4 for the combined section of the Turnpike would also represent “optimum” conditions of VMT and PHT. These Options would require carpools of 2+ persons and aid in the effort to achieve the CAAA/ECO Program goals.

Under 'No Build' conditions in 2024, the rural section of the New York State Thruway was studied and indicates that it would not require additional capacity. An AHS could be implemented in this corridor for reasons of safety and efficiency. Option A, with one (1) AHS lane and two (2) GULs, would be the most cost effective Option.

4.0 CONCLUSIONS AND SUMMARY OF ISSUES

The issues, concerns, conclusions, findings and risks which have emerged from the Task F studies of commercial vehicle/transit use of AHS are summarized in Table 4.1.

Table 4.1
Summary of Issues, Concerns, Risks and Conclusions, Commercial and Transit AHS

Number	Item Type	Description	Conclusions/Findings/Risks	RSC Impact	Task Impact	Section Reference
1.	Issue, Concern	Acceptance by trucking, transit industries. Will the industries accept the costs of upgrading their equipment and maintenance practices required to use AHS ?	Benefits, costs, derived from specific demonstrations will need to be provided to skeptical trucking industry. Transit may be more receptive.	2, 4, 6, 7, 10, 11	O, P	3.1.1, 3.2.1
2.	Issue, Concern	Competition with Intermodal Rail, AMTRAK. Is federally funded AHS program in direct competition with private sector rail for long-haul freight market?, with AMTRAK for intercity passenger market?	Commercial vehicle operations on AHS may be most appropriate for trip lengths and weights less than those served by Intermodal Rail. Diversion from AMTRAK is a risk.	2, 4, 6, 7, 10, 11	O	3.1.1, 3.2.1
3.	Issue	Acceptance by organized labor, drivers. Will labor view AHS as a job reduction act by the government and industry?	The potentially safer environment for the driver, reduced travel time per run, elimination of fatigue, upgraded responsibilities as "autopilot", potentially higher pay as AHS-certified, improved quality of life, need to be shown.	2, 4, 6, 7, 10, 11	N, O	3.1.3, 3.2.1
4.	Issue	Vehicle Handling & Stability. Will AHS controls for commercial vehicles be capable, at acceptable costs, to cover the multiple truck weight and configuration properties for loaded and unloaded conditions, wet and dry pavements?	Electronic sensors can be designed to perform complex detection and control tasks. Costs must be determined, demonstrations performed, decisions made as to maximum truck size and type.	2, 4, 6, 7, 10, 11	B, C ,D, E, J, N	3.1.2
5.	Issue	Infrastructure Costs, Pavements & Bridges. Will the incremental costs be significant to upgrade pavements and bridges to accomodate commercial vehicles on AHSs as compared to passenger vehicles only?	Heavy truck studies on rural Interstates have indicated industry benefits to exceed the infrastructure costs. These include fewer truck trips, lighter axle loads. Extra costs should be borne by users.	2, 4, 6, 7, 10, 11	A, H, P	3.1.2

Table 4.1
Summary of Issues, Concerns, Risks and Conclusions, Commercial and Transit AHS

Number	Item Type	Description	Conclusions/Findings/Risks	RSC Impact	Task Impact	Section Reference
6.	Issue, Concern	Traffic Operations. What are the AHS passenger vehicle equivalencies to commercial and transit vehicles?	It has been assumed that the same equivalencies can be used in AHS lanes as in non-AHS lanes. This must be verified.	2, 4, 6, 7, 10, 11	A, D, H, K	3.1.2, 3.3.1
7.	Issue	Safety. For safe operations,should trucks and full-size transit vehicles be separated from passenger vehicles on AHS roadways?	Passenger vehicle geometric design requirements and dynamic characteristics differ from heavy trucks and buses. Each vehicle type has its own requirements, with the tractor trailer and LCVs the most demanding and presenting higher risks, more severe accident potential.	2, 4, 6, 7, 10, 11	B, C, D, E, H, J, K, L, N, P	3.1.2, 3.1.3, 3.2.2
8.	Issue, Concern	Traffic Operations. What happens at the terminus of the AHS lane? How will transit vehicles be distributed within the center city? New/improved bus terminals?	This issue has not been researched under this task however the impact on transit operations and scheduling, as well as on other vehicles, is critical to the viability of AHS. This must be researched and analyzed.	2, 4, 6, 7, 10, 11	A, C, E, H, I, J, K, N, O	3.2.3

APPENDIX A: TABLES AND FIGURES FOR SECTIONS 1.0 THROUGH 4.0

Table A-1
National Transportation Statistics for 1990

Inventory:	Air Carrier	General Aviation	Highway	Automobile*	Intercity Bus	Truck	Local Transit	Rail: Freight Class I	Rail: Passenger Amtrak
Mileage by Functional System:									24,000
Rural Mileage:									
Interstate			33,547						
Urban Mileage									
Interstate			11,527						
Other Freeways			7,670						
Number of Vehicles:	4,727	212,229		143,549,627		44,478,848			
Intercity Bus, total					19,491				
Public Transportation:							93,752		
Motor Bus							59,753		
Heavy Rail							10,419		
Light Rail							913		
Trolley Bus							832		
Demand Response							16,222		
Ferryboat							119		
Commuter Rail							4,415		
Other							1,079		
Railroads									
Freight Cars								658,902	
Locomotive								18,835	318
Passenger Train-Cars									1,983
Intercity Bus, Total									
Number of Operating Companies					3,925				
Miles of Highway Served					213,000				
Intercity Bus, Class I									
No. of Operating Companies					21				
No. of Vehicles					6,502				
Miles Served					146,000				

*Passenger Cars Taxis
Source for Tables and Figures: National Transportation Statistics for 1990, Annual Report, June 1992, Volpe National Transportation Center, US DOT

Table A-1
National Transportation Statistics for 1990

Inventory Continued:	Air	Highway Transportation				Public Transportation	Rail Transportation	
	Air Carrier	Highway	Automobile	Intercity Bus	Truck	Local Transit	Freight	Passenger Amtrak
Number of Employees	588,926	808,600	4,433,100	26,000	3,723,000	265,410	336,516	24,000
Trucking and Truck Terminals					1,534,000			
Truck Drivers and Deliverymen					2,189,000			
Class I Railroads							216,424	
Line-Haul Railroads							119,758	
Public Transportation:								
Motor Bus						164,499		
Heavy Rail						46,102		
Light Rail						4,089		
Trolley Bus						1,924		
Demand Response						23,260		
Ferryboat						2,871		
Commuter Rail						21,452		
Other						1,213		

Table A-1
National Transportation Statistics for 1990

Performance:							Rail	
	Air Carrier	Highway	Automobile*	Intercity Bus	Truck	Local Transit	Freight	Amtrak Passenger
Vehicle-Miles of Travel by Highway (millions)		852,923	1,515,370	5,728	616,831			
Rural Highway								
Interstate		200,573	130,220**	568	69,785			
Other		669,836	436,134	2,885	230,817			
Urban Highway								
Interstate		278,404	209,056	452	68,896			
Other Freeways and Expressways		127,431	749,532	1,823	247,333			
Vehicle-Miles of Travel, Freight (millions)	3,963				616,831			
Single Unit Truck					466,827			
Other Single Unit Truck					53,522			
Combination Vehicles					96,482			
Class I Railroad							26,159	
Ton-Miles	9,064				735,000		1,034	
Single Unit Truck								
Other Single Unit Truck								
Combination Truck								
Passenger-Miles(millions)	345,873		2,455,000					6,129
Intercity Bus, Total				23,000				
Intercity Bus, Class I				13,820				
Train-Car Miles								300.86
Public Transportation Passenger Miles(millions)						41,411		
Motor Bus						21,127		
Heavy Rail						11,475		
Light Rail						571		
Trolley Bus						193		
Demand Response						468		
Ferry boat						331		
Commuter Rail						7,082		
Other						164		

* Passenger Cars & Taxis

Table A-1
National Transportation Statistics for 1990

Performance (cont'd):

							Rail	
	Air Carrier	Highway	Automobile	Intercity Bus	Truck	Local Transit	Class I	Amtrak
Num. of Revenue Passengers (millions)				334		8,873	328	22.40
Intercity, Totals								
Local Transit Passenger Trips:								
Motor Bus						5,754		
Heavy Rail						2,346		
Light Rail						176		
Trolley Bus						126		
Demand Response						62		
Ferryboat						50		
Commuter Rail						329		
Other						30		
Revenue Passenger-Miles (millions)						41,411		6,040.77
Intercity, Totals				23,000				
Commutation							7,330	
Domestic								
Certificated, all services	345,872.95							
Major, all services	327,112.62							
Nationals, all services	16,756.82							
Large Regional, all services	1,752.62							
Revenue Vehicle Miles (millions)						3,274		
Motor Bus						2,153		
Heavy Rail						537		
Light Rail						24		
Trolley Bus						14		
Demand Response						317		
Ferry boat						2		
Commuter Rail						213		
Other						14		

* Passenger Cars & Taxis

Table A-1
National Transportation Statistics for 1990

Performance:	Air Carrier	Highway	Automobile*	Intercity Bus	Truck	Local Transit	Rail Freight	Rail Amtrak Passenger
Vehicle-Miles of Travel by Highway (millions)		852,923	1,515,370	5,728	616,831			
Rural Highway								
Interstate		200,573	130,220**	568	69,785			
Other		669,836	436,134	2,885	230,817			
Urban Highway								
Interstate		278,404	209,056	452	68,896			
Other Freeways and Expressways		127,431	749,532	1,823	247,333			
Vehicle-Miles of Travel, Freight (millions)	3,963				616,831			
Single Unit Truck					466,827			
Other Single Unit Truck					53,522			
Combination Vehicles					96,482			
Class I Railroad							26,159	
Ton-Miles	9,064				735,000		1,034	
Single Unit Truck								
Other Single Unit Truck								
Combination Truck								
Passenger-Miles(millions)	345,873		2,455,000					6,129
Intercity Bus, Total				23,000				
Intercity Bus, Class I				13,820				
Train-Car Miles								300.86
Public Transportation Passenger Miles(millions)						41,411		
Motor Bus						21,127		
Heavy Rail						11,475		
Light Rail						571		
Trolley Bus						193		
Demand Response						468		
Ferry boat						331		
Commuter Rail						7,082		
Other						164		

Table A-2

Carrier Utilization By Mode
Fiscal Years 1984 and 1993

Method	Shipments		Weight (lbs.,Millions)		Charges ($, Millions)	
	1984	1993	1984	1993	1984	1993
Rail	20,813	10,606	3896	3,883	89	103,375
Motor	1,226,088	1,199,643	11,796	13,345	377	435,581
Frt Forwarder	6,789	11,509	40	40	2	3,095
Water	1,377	1,299	6,559	5,676	15	15,386
Pipeline	3,369	2,965	15,549	15,877	35	43,730
Air Freight	83,332	113,595	14	14	13	10,872
Air Forwarder	161,183	78,938	20	46	18	19,662
Bus	6,014	122	0.2	0.8	0.1	0.1
Unidentified	0	0	0	0	0	0
TOTAL	1,508,965	1,418,677	37,875	38,881	549	631
Truck %	81%	85%	31.1%	34%	68%	69%

Table A-3

Military vs. Total U.S. Goods Movement by Truck
1984 - 1993

Revenue ($ Millions)

Fiscal Year	Military	Non-Military	Total U.S.	% Military
1984	$377	$199,400	$199,777	0.19
1985	$397	$205,400	$205,797	0.19
1986	$440	$213,000	$213,440	0.21
1987	$463	$224,400	$224,863	0.21
1988	$424	$238,900	$239,324	0.18
1989	$399	$253,750	$254,149	0.16
1990	$413	$270,650	$271,063	0.15
1991	$474	$274,250	$274,724	0.17
1992	$418	$292,800	$293,218	0.14

Tonnage (Millions)

Fiscal Year	Military	Non-Military	Total U.S.	% Military
1984	5.898	2,125	2,131	0.28
1985	5.895	2,131	2,137	0.28
1986	6.599	2,236	2,243	0.29
1987	6.881	2,364	2,371	0.29
1988	6.579	2,422	2,429	0.27
1989	6.805	2,543	2,550	0.27
1990	6.499	2,589	2,595	0.25
1991	7.617	2,684	2,692	0.28
1992	7.352	2,838	2,845	0.26

Sources: 1. Military Traffic Management Command, Department of the Army, May 1994
2. "Transportation in America", ENO Transportation Foundation, Inc., Dec. 1993

Table A-4
Commercial and Transit Vehicle Design Characteristics

	Affects:	Design Vehicle: Trucks: Sngl.-Unit (SU)	Intermediate Semi-Trlr. (WB-40)	Larger Semi-Trlr. (WB-50)	Dbl.Bottom Semi/Full Trlr. (WB-60)	Buses: Single- Unit	Articulated
Height	Vertical Clearances, Rollover	162in.	162in.	162in.	162in.	162in.	117.6-126in.
Width	Lane, Shoulder Widths	102 in.	102 in.	102 in.	102 in.	102 in.	102 in.
Length	Offtracking, Pavement Width	30 ft.	50(55) ft.	55ft.	65 ft.	40 ft.	60 ft.
Driver Eye Height	Sight Distance, Crest Vertical Curves	3.5 ft.	7.58-8.92 ft.	7.58-8.92 ft.	7.58-8.92 ft.		
Headlight Height	Sight Distance, Sag Vertical Curves	2 ft.	2 ft.	2 ft.	2 ft.		
Weight/HP Ratio	Performance on Grades	300 to 1	300 to 1	300 to 1	300 to 1		
Braking Distance (@55mph)	D=V^2/30f, f=Coef. Frict. Crest Vertical Curve Lengths, Lateral Sight Distances	256-336 ft. (TTI recommends increasing by 50%)	256-336 ft.	256-336 ft.	256-336 ft.		
Brake Reaction Time	Total Safe Stopping Distances	2.5 sec.	2.5 sec.	2.5 sec.	2.5 sec.	2.5 sec.	2.5 sec.
Decision Sight Distance (@55mph)	Complex Maneuvers Distance to detect,initiate, complete hazard avoidance maneuver	1,150 ft. (Urban)	1,150 ft. (Urban)	1,150 ft. (Urban)	1,150 ft. (Urban)		
Passing Sight Distance (@ 55mph)	Total Length Required For Passing : psd= V(Lf+Ls +P+R)/dV V=Passing Veh. Speed, Lf, Ls= Vehicle Lengths, P &R = Pullout & Return Lgths, 150 ft.+/- dV=Speed Differential, 10mph	1,155	1,430	1,430	1,540	1,265	1,485
Horizontal Alignment (@55mph)	Minimum Radius of Curvature : R=V^2/15(e+f) V= Vehicle Speed, e= Superelevation, .06 f= Limiting Side Friction Factor, .13	1,060	1,060	1,060	1,060	1,060	1,060
Widening On Curves (@25mph, 150 ft. min. R, Case II, prov. for passing)	Offtracking w = Wc-Wn, where: Wc = N(U+C) + (N-1)Fa +Z, and: N=no. lanes; w = widening req'd., Wc = width of pave. on curve; U= track width, out-out, tires; C = lateral clearance of vehicle, 2-3 ft.; Fa = width of front overhang, ft.; Z = extra width allowance for driving difficulty on curves, 2 ft.	6 ft.	9 ft.	11 ft.	16 ft.	7 ft.	10 ft.
Horizontal Sight Distance	Clearance to Obstructions along inside of curves M=(5730/D)*(1-Cos S*D/200)	Function of Degree of curvature, D, and Stopping Sight Distance, S					
Vertical Alignment: Control Grades	Speed Decreases 7% + on Upgrades, Increases 5% on Downgrades	See AASHTO, Figures III-27A-C, pages 229-231					
Critical Length	Distance Required for no more than 10 mph speed reduction on Upgrade	See AASHTO, Figure III-31, pg.238					
Curves	Function of Driver's Eye Height, Object on Pavement Height	See AASHTO, pages 281-295					
Cross Section: Lane Width	Wv + 4.5 ft., More for Double & Triple Combinations	13 ft. for 102" Trucks					
Shoulder Width	Safe Clearance for Stopped Vehicles	12 ft. for heavy truck traffic					

TABLE A-5

Truck Sizes and Weights

MAXIMUM SIZE LIMITS: / NUMBER OF STATES (INCL. D.C.)

HEIGHT	13'-0"/ 1	**13'-6"/ 34**	14'-0"/15	14'-6"/1
WIDTH	**102"/ 49**	108"/ 1(HAWAII)		

LENGTH, Single Unit Truck:

40'/ 35	42'-45'/ 11	50'/ 1	60'/ 4	
Straight Truck + Trailer:				
50'-59'/ 4	**60'-65'/29**	80'-85'/ 2	Nr/Ns 7	
Semitrailer On Interstate & Nat'l Network:				
48'-50'/ 11	**53'-54'/ 31**	57'-58'/ 3	59'-60'/ 4	Nr/ 2
Semitrailer Off National Network:				
45'-49'/ 16	**50'-54'/ 18**	57'-65'/ 7	Nr/Ns/ 10	
Tractor- Semitrailer Combination, Other Roads				
53'/ 1	55'/ 2	**60', 65'/ 21**	70', 75'/ 4	**NR/ 23**

LENGTH, TWIN COMBINATIONS:

Semitrailer Or Trailer On Interstate & National Net:				
28'-30'/ 39	50'-70'/ 7	80'-95'/ 3	NR/ 3	
Semitrailer Or Trailer On Other Roads:				
28'-29'/ 3	**58'-65'/ 11**	70'-75'/ 5	81'-82'/ 2	**NP/ 21**
			NR/NS/ 9	

MAXIMUM AXLE LIMITS: LBS / NUMBER OF STATES

SINGLE AXLE		TANDEM AXLE		TRIDEM AXLE	
20,000/	**41**	**34,000/**	**42**	34,000-39,000/	2
20,340/	1	34,320/	1	**41,500-42,500/**	**39**
21,600/	1	36,000/	4	48,000-66,000/	6
22,000/	2	38,000/	1		
22,400/	5 (N.E.)	44,000/	1		
22,500/	1				

TABLE 5

MAXIMUM GROSS VEHICLE WEIGHTS:
INTERSTATE HIGHWAYS: 80,000 LBS, EXCEPT 86,400 LBS IN NEW MEXICO

	LBS/ NO. STATES
NON-INTERSTATE ROADS:	73,280/2
	80,000 - 88,000/2
	90,000 - 95,000/2
	105,000 - 117,000/3

NOTES:

1. Federal weight provisions apply to Interstate System only, With 80,000 lb maximum GVW.

2. States free to set limits off the Interstate System & have varied regulations, as shown above.

3. The 1982 STAA authorized 48 ft semitrailers, & twin 28ft doubles on a designated network beyond the Interstate System- 180,000 miles +/-.

4. Some states have "Grandfather" provisions allowing trucks heavier than 80,000 lbs on the Interstates

5. NP - Not Permitted; NR - Not Restricted; NS - Not Specified; NE - New England

Table A-6
Transit Design Parameters

Design Parameter	Mainline		Ramp	
	Desirable	Reduced	Desirable	Reduced
Design Speed (mph)	50-60	40	40	30
Alignment				
Stopping Distance (ft)	450-650	400	300	200
Horizontal Curvature (ft/radius)	1,200	600	800	350
Superelevation (ft/ft)	0.06	0.08	0.04	0.06
Vertical Curvature (ft)	200 (k=150 crest) (k=100 sag)	1,125 (k=60 crest) (k=40 sag)	125 (k=60 crest) (k=45 sag)	100 (k=30 crest) (k=15 sag)
Gradients				
Maximum (%)	3.0	6.0	6.0	8.0
Minimum (%)	0.3	0.3	0.3	0.3
Maximum Length (ft)	–	750	750[1]	500[1]
Clearance				
Vertical (ft)	16.5	14.5	15.0	14.5
Lateral (ft)	5	2	5	2
Lane Width				
Travel Lanes (ft)	12	11	13	12
Transition Lanes				
Acceleration (ft)	900-1,200[2]	400[2]	900[2]	400[2]
Deceleration (ft)	50-720[2]	320[2]	900[2]	320[2]
Tapers (ratio)	30:1 (exit) 50:1 (ent)	20:1 (exit) 20:1 (ent)	– –	– –
Cross Slope (ft/ft)				
Maximum	0.020	0.020	0.020	0.020
Minimum	0.015	0.015	0.015	0.015
Turning Radius Minimum (ft)	[1]	[1]	50	45
Superelevation - Depends on curve radii and design speed (0.1 ft/ft maximum)				
Design Load on Structures - State DOT or AASHTO Design Load, whichever governs				

Source: References (2, 39, 46)

[1] Not applicable for mainline connector ramps.
[2] Adjusted for grade.

Source: High Occupancy Vehicles Facilities. Charles A. Fuhs.

Long Island Expressway

Base Conditions, HOV NO BUILD

Section	From/To		Total PCE@4.0	PVs	SU	Trk.Trlr.	Buses
NewHydePk Rd. to	Exit 34 to 37	vph		11,113	752	12	60
Willis Avenue		pcph	14,408	11,113	3,008	48	239

* Capacity is based on 4500 pcphpl
** Capacity is based on 2200 pcphpl
*** Based on actual number of vehicles(not PCEs),
(PVs and buses only)

1 HOV/3 GULs	HOV Lane 1 PVs and Buses(PCEs)						For each; Lanes 2 through 4 Mixed(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	86.4%	0.0%	0.0%	13.6%	No. PCEs	v/c**	75.8%	23.8%	0.4%	0.0%	No. PCEs	v/c**
Demand -pcph	1521	0	0	239	1760	0.8	3197	1003	16	0	4216	1.9
Demand - No. Occpts @ 1.2PV;2.0HOV; 1.0Tks;30Bus/Var	3042			1793			3836	251	4			
Vehicle Mix Per Lane @ Capacity	1521			239	1760		1181	1003	16		2200	1.0
Avg. Vehicle Occupancy	**2.0**			**30.0**			**3.2**	**1.0**	**1.0**			
Total No. of Passengers(PVs and buses only)	4,835						3,836					
% Vehicle Distribution by Lane-Capacity	86.4%	0.0%	0.0%	10.9%			53.7%	45.6%	0.7%	0.0%		

Table A-8
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
Long Island Expressway
Scenario #1, Passenger Vehicles in Separate AHS Lane

OPTION A. **1AHS Lane, 2 GULs**	AHS Lane 1 PVs Only						GUL Lane 2 Mixed(PCEs)						GUL Lane 3 Mixed(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*	62.8%	34.0%	0.5%	2.7%	No. PCEs	v/c**	62.8%	34.0%	0.5%	2.7%	No. PCEs	v/c**
Demand -pcph	5557	0	0	0	5557	1.2	2778	1504	24	119	4426	2.0	2778	1504	24	119	4426	2.0
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;30 Bus/Van	6668						3334	376	6	895			3334	376	6	895		
Vehicle Mix Per Lane @ Capacity	4500				4500	1.0	553	1504	24	119	2200	1.0	553	1504	24	119	2200	1.0
Avg. Vehicle Occupancy	**1.5**						**6.0**	**1.0**	**1.0**	**30.0**			**6.0**	**1.0**	**1.0**	**30.0**		
Total No. of Passengers(PVs and buses only)	6,668						4,229						4,229					
% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			25.1%	68.4%	1.1%	5.4%			25.1%	68.4%	1.1%	5.4%		

OPTION B. **2 AHS Lanes; 1 GUL**	AHS Lane 1 PVs Only						AHS Lane 2 SU +TrkTlr+Buses(PCEs)						GUL Lane 3 Remaining(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*	0.0%	91.3%	1.4%	7.2%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c**
Demand -pcph	5557	0	0	0	5557	1.2	0	3008	48	239	3295		5557	0	0	0	5557	2.5
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;30 Bus/Van	6668							752	12	1791			6668					
Vehicle Mix Per Lane @ Capacity	4500				4500	1.0					4500	0.7	2200				2200	1.0
Avg. Vehicle Occupancy	**1.5**							**1.0**	**1.0**	**30.0**			**3.0**					
Total No. of Passengers(PVs and buses only)	6,668						1,791						6,668					
% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			0.0%	54.1%	0.9%	4.3%			100.0%	0.0%	0.0%	0.0%		

OPTION C. **3 AHS Lanes**	AHS Lane 1 PVs Only						AHS Lane 2 SU +TrkTlr+Buses(PCEs)						AHS Lane 3 Remaining(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*	0.0%	91.3%	1.4%	7.2%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*
Demand -pcph	5557	0	0	0	5557	1.2	0	3008	48	239	3295		5557	0	0	0	5557	1.2
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;30 Bus/Van	6668							752	12	1791			6668					
Vehicle Mix Per Lane @ Capacity	4500				4500	1.0					4500	0.7	4500				4500	1.0
Avg. Vehicle Occupancy	**1.5**							**1.0**	**1.0**	**30.0**			**1.5**					
Total No. of Passengers(PVs and buses only)	6,668						1,791						6,668					
% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			0.0%	54.1%	0.9%	4.3%			100.0%	0.0%	0.0%	0.0%		

Table A-9
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS

Long Island Expressway

Scenario #2, Mixed Vehicles in AHS Lane(s)

OPTION A. **1AHS Lane, 2 GULs**	AHS Lane 1 Mixed(PCEs)						GUL Lane 2 Mixed(PCEs)						GUL Lane 3 Mixed(PCEs)**					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	77.1%	20.9%	0.3%	1.7%	No. PCEs	v/c*	77.1%	20.9%	0.3%	1.7%	No. PCEs	v/c**	77.1%	20.9%	0.3%	1.7%	No. PCEs	v/c**
Demand -pcph	3704	1003	16	80	4803	1.1	3704	1003	16	80	4803	2.2	3704	1003	16	80	4803	2.2
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;30 Bus/Van	4445	251	4	597			4445	251	4	597			4445	251	4	597		
Vehicle Mix Per Lane @ Capacity	3402	1003	16	80	4500	1.0	1102	1003	16	80	2200	1.0	1102	1003	16	80	2200	1.0
Avg. Vehicle Occupancy	**1.3**	**1.0**	**1.0**	**30.0**			**4.0**	**1.0**	**1.0**	**30.0**			**4.0**	**1.0**	**1.0**	**30.0**		
Total No. of Passengers(PVs and buses only)	5,042						5,042						5,042					
% Vehicle Distribution by Lane-Capacity	75.6%	22.3%	0.4%	1.8%			50.1%	45.6%	0.7%	3.6%			50.1%	45.6%	0.7%	3.6%		

OPTION B. **2 AHS Lanes; 1 GUL**	AHS Lane 1 Mixed(PCEs)						AHS Lane 2 Mixed(PCEs)						GUL Lane 3 Mixed(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	77.1%	20.9%	0.3%	1.7%	No. PCEs	v/c*	77.1%	20.9%	0.3%	1.7%	No. PCEs	v/c*	77.1%	20.9%	0.3%	1.7%	No. PCEs	v/c**
Demand -pcph	3704	1003	16	80	4803	1.1	3704	1003	16	80	4803	1.1	3704	1003	16	80	4803	2.2
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;30 Bus/Van	4445	251	4	597			4445	251	4	597			4445	251	4	597		
Vehicle Mix Per Lane @ Capacity	3402	1003	16	80	4500	1.0	3402	1003	16	80	4500	1.0	1102	1003	16	80	2200	1.0
Avg. Vehicle Occupancy	**1.3**	**1.0**	**1.0**	**30.0**			**1.3**	**1.0**	**1.0**	**30.0**			**4.0**	**1.0**	**1.0**	**30.0**		
Total No. of Passengers(PVs and buses only)	5,042						5,042						5,042					
% Vehicle Distribution by Lane-Capacity	75.6%	22.3%	0.4%	1.8%			75.6%	22.3%	0.4%	1.8%			50.1%	45.6%	0.7%	3.6%		

OPTION C. **3 AHS Lanes**	AHS Lane 1 Mixed(PCEs)						AHS Lane 2 Mixed(PCEs)						AHS Lane 3 Mixed(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	77.1%	20.9%	0.3%	1.7%	No. PCEs	v/c*	77.1%	20.9%	0.3%	1.7%	No. PCEs	v/c*	77.1%	20.9%	0.3%	1.7%	No. PCEs	v/c*
Demand -pcph	3704	1003	16	80	4803	1.1	3704	1003	16	80	4803	1.1	3704	1003	16	80	4803	1.1
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;30 Bus/Van	4445	251	4	597			4445	251	4	597			4445	251	4	597		
Vehicle Mix Per Lane @ Capacity	3402	1003	16	80	4500	1.0	3402	1003	16	80	4500	1.0	3402	1003	16	80	4500	1.0
Avg. Vehicle Occupancy	**1.3**	**1.0**	**1.0**	**30.0**			**1.3**	**1.0**	**1.0**	**30.0**			**1.3**	**1.0**	**1.0**	**30.0**		
Total No. of Passengers(PVs and buses only)	5,042						5,042						5,042					
% Vehicle Distribution by Lane-Capacity	75.6%	22.3%	0.4%	1.8%			75.6%	22.3%	0.4%	1.8%			75.6%	22.3%	0.4%	1.8%		

Table A-10
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS

Long Island Expressway

Scenario #3, Exclusive AHS Lane for Passenger Vehicles, Light Trucks and Transit Vehicles

OPTION A. **1AHS Lane, 2 GULs**	AHS Lane 1 PVs +SU+Buses(PCEs)						GUL Lane 2 Mixed(PCEs)						GUL Lane 3 Mixed(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	77.4%	20.9%	0.0%	1.7%	No. PCEs	v/c*	76.9%	20.8%	0.7%	1.7%	No. PCEs	v/c**	76.9%	20.8%	0.7%	1.7%	No. PCEs	v/c**
Demand -pcph	5557	1504	0	119	7180	1.6	2778	752	24	60	3614	1.6	2778	752	24	60	3614	1.6
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;30 Bus/Van	6668	376		895			3334	188	6	448			3334	188	6	448		
Vehicle Mix Per Lane @ Capacity	2877	1504		119	4500	1.0	1364	752	24	60	2200	1.0	1364	752	24	60	2200	1.0
Avg. Vehicle Occupancy	**2.3**	**1.0**		**30.0**			**2.4**	**1.0**	**1.0**	**30.0**			**2.4**	**1.0**	**1.0**	**30.0**		
Total No. of Passengers(PVs and buses only)	7,563						3,782						3,782					
% Vehicle Distribution by Lane-Capacity	63.9%	33.4%	0.0%	2.7%			62.0%	34.2%	1.1%	2.7%			62.0%	34.2%	1.1%	2.7%		

OPTION B. **2 AHS Lanes; 1 GUL**	AHS Lane 1 PVs +SU+Buses(PCEs)						AHS Lane 2 PVs +SU+Buses(PCEs)						GUL Lane 3 Mixed(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	77.4%	20.9%	0.0%	1.7%	No. PCEs	v/c*	77.4%	20.9%	0.0%	1.7%	No. PCEs	v/c*	76.6%	20.7%	1.0%	1.6%	No. PCEs	v/c**
Demand -pcph	3704	1003	0	80	4787	1.1	3704	1003	0	80	4787	1.1	3704	1003	48	80	4834	2.2
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;30 Bus/Van	4445	251		597			4445	251		597			4445	251	12	597		
Vehicle Mix Per Lane @ Capacity	3418	1003		80	4500	1.0	3418	1003		80	4500	1.0	1070	1003	48	80	2200	1.0
Avg. Vehicle Occupancy	**1.3**	**1.0**		**30.0**			**1.3**	**1.0**		**30.0**			**4.2**	**1.0**	**1.0**	**30.0**		
Total No. of Passengers(PVs and buses only)	5,042						5,042						5,042					
% Vehicle Distribution by Lane-Capacity	75.9%	22.3%	0.0%	1.8%			75.9%	22.3%	0.0%	1.8%			48.6%	45.6%	2.2%	3.6%		

OPTION C. **3 AHS Lanes**	AHS Lane 1 PVs +SU+Buses(PCEs)						AHS Lane 2 PVs +SU+Buses(PCEs)						AHS Lane 3 Mixed(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	77.4%	20.9%	0.0%	1.7%	No. PCEs	v/c*	77.4%	20.9%	0.0%	1.7%	No. PCEs	v/c*	76.6%	20.7%	1.0%	1.6%	No. PCEs	v/c*
Demand -pcph	3704	1003	0	80	4787	1.1	3704	1003	0	80	4787	1.1	3704	1003	48	80	4834	1.1
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;30 Bus/Van	4445	251		597			4445	251		597			4445	251	12	597		
Vehicle Mix Per Lane @ Capacity	3418	1003		80	4500	1.0	3418	1003		80	4500	1.0	3370	1003	48	80	4500	1.0
Avg. Vehicle Occupancy	**1.3**	**1.0**		**30.0**			**1.3**	**1.0**		**30.0**			**1.3**	**1.0**	**1.0**	**30.0**		
Total No. of Passengers(PVs and buses only)	5,042						5,042						5,042					
% Vehicle Distribution by Lane-Capacity	75.9%	22.3%	0.0%	1.8%			75.9%	22.3%	0.0%	1.8%			74.9%	22.3%	1.1%	1.8%		

Table A-11
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS

Long Island Expressway

Scenario #4, Exclusive AHS Lane for all Commercial and Transit Vehicles

OPTION A. **1AHS Lane, 2 GULs**	AHS Lane 1 SU+ Trk Tlr+Buses(PCEs)						GUL Lane 2 PVs Only						GUL Lane 3 PVs Only					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	0.0%	91.3%	1.4%	7.2%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c**	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c**
Demand -pcph	0	3008	48	239	3295		5557	0	0	0	5557	2.5	5557	0	0	0	5557	2.5
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;30 Bus/Van		752	12	1791			6668						6668					
Vehicle Mix Per Lane @ Capacity					4500	0.7	2200				2200	1.0	2200				2200	1.0
Avg. Vehicle Occupancy		**1.0**	**1.0**	**30.0**			**3.0**						**3.0**					
Total No. of Passengers(PVs and buses only)	1,791						6,668						6,668					
% Vehicle Distribution by Lane-Capacity	0.0%	91.3%	1.4%	7.2%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		

OPTION B. **2 AHS Lanes; 1 GUL**	AHS Lane 1 SU+ Trk Tlr+Buses(PCEs)						AHS Lane 2 PVs Only						GUL Lane 3 PVs Only					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	0.0%	91.3%	1.4%	7.2%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c**
Demand -pcph	0	3008	48	239	3295		5557	0	0	0	5557	1.2	5557	0	0	0	5557	2.5
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;30 Bus/Van		752	12	1791			6668						6668					
Vehicle Mix Per Lane @ Capacity					4500	0.7	4500				4500	1.0	2200				2200	1.0
Avg. Vehicle Occupancy		**1.0**	**1.0**	**30.0**			**1.5**						**3.0**					
Total No. of Passengers(PVs and buses only)	1,791						6,668						6,668					
% Vehicle Distribution by Lane-Capacity	0.0%	91.3%	1.4%	7.2%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		

OPTION C. **3 AHS Lanes**	AHS Lane 1 SU+ Trk Tlr+Buses(PCEs)						AHS Lane 2 PVs Only						AHS Lane 3 PVs Only					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	0.0%	91.3%	1.4%	7.2%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*
Demand -pcph	0	3008	48	239	3295		5557	0	0	0	5557	1.2	5557	0	0	0	5557	1.2
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;30 Bus/Van		752	12	1791			6668						6668	0	0	0		
Vehicle Mix Per Lane @ Capacity					4500	0.7	4500				4500	1.0	4500	0	0		4500	1.0
Avg. Vehicle Occupancy		**1.0**	**1.0**	**30.0**			**1.5**						**1.5**					
Total No. of Passengers(PVs and buses only)	1,791						6,668						6,668					
% Vehicle Distribution by Lane-Capacity	0.0%	91.3%	1.4%	7.2%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		

Table A-12
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
VEHICLE-MILES & PERSON-HOURS SUMMARY
Long Island Expressway

	No Build	**Scenario # 1**			**Scenario #2**			**Scenario # 3**			**Scenario #4**		
		Options			Options			Options			Options		
	(1HOV/3GUL)	A	B	C	A	B	C	A	B	C	A	B	C
No. of AHS Lanes	0	1	2	3	1	2	3	1	2	3	1	2	3
No. GULs	4	2	1	0	2	1	0	2	1	0	2	1	0
Hrly Roadway Capacity	8,800	8,900	11,200	13,500	8,900	11,200	13,500	8,900	11,200	13,500	8,900	11,200	13,500
Vehicle Classification		**VEHICLE-MILES**											
AHS													
Passenger Vehicles	0	67,500	67,500	135,000	51,030	102,060	153,090	43,155	102,540	153,090	0	67,500	135,000
Single Unit Trucks	0	0	0	45,120	15,045	30,090	45,135	22,560	30,090	45,135	45,120	45,120	45,120
Tractor Trailers	0	0	0	720	240	480	720	0	0	720	720	720	720
Buses	0	0	0	3,585	1,200	2,400	3,600	1,785	2,400	3,600	3,585	3,585	3,585
AHS VMT Total	**0**	**67,500**	**67,500**	**184,425**	**67,515**	**135,030**	**202,545**	**67,500**	**135,030**	**202,545**	**49,425**	**116,925**	**184,425**
GULs													
Passenger Vehicles	75,960	16,590	33,000	0	33,060	16,530	0	40,920	16,050	0	66,000	33,000	0
Single Unit Trucks	45,120	45,120	45,120	0	30,090	15,045	0	22,560	15,045	0	0	0	0
Tractor Trailers	720	720	720	0	480	240	0	720	720	0	0	0	0
Buses	3,585	3,570	3,570	0	2,400	1,200	0	1,800	1,200	0	0	0	0
GUL VMT Total	**125,385**	**66,000**	**82,410**	**0**	**66,030**	**33,015**	**0**	**66,000**	**33,015**	**0**	**66,000**	**33,000**	**0**
Roadway Total VMT	**125,385**	**133,500**	**149,910**	**184,425**	**133,545**	**168,045**	**202,545**	**133,500**	**168,045**	**202,545**	**115,425**	**149,925**	**184,425**
Vehicle Classification		**PERSON-HOURS**											
AHS													
Passenger Vehicles	0	3,334	3,334	6,668	2,223	4,445	6,668	3,334	4,445	6,668	0	3,334	6,668
Single Unit Trucks	0	0	245	245	126	251	377	188	251	377	245	245	245
Tractor Trailers	0	0	4	4	2	4	6	0	0	6	4	4	4
Buses	0	0	584	584	299	597	896	448	597	896	584	584	584
AHS PHT Total	**0**	**3,334**	**4,167**	**7,501**	**2,649**	**5,297**	**7,946**	**3,970**	**5,293**	**7,946**	**833**	**4,167**	**7,501**
GULs													
Passenger Vehicles	7,275	3,334	3,334	0	4,445	2,223	0	3,334	2,223	0	6,668	3,334	0
Single Unit Trucks	377	376	0	0	251	126	0	188	126	0	0	0	0
Tractor Trailers	6	6	0	0	4	2	0	6	6	0	0	0	0
Buses	897	895	0	0	597	299	0	448	299	0	0	0	0
GUL PHT Total	**8,554**	**4,611**	**3,334**	**0**	**5,297**	**2,649**	**0**	**3,976**	**2,653**	**0**	**6,668**	**3,334**	**0**
Roadway Total PHT	**8,554**	**7,945**	**7,501**	**7,501**	**7,946**	**7,946**	**7,946**	**7,946**	**7,946**	**7,946**	**7,501**	**7,501**	**7,501**

Using a 15 mile long section

Table A-13
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New York State Thruway
Base Conditions, NO BUILD

From	To		Total PCEs@3.0	PV's 89.2%	SU 7.0%	Trk.Trlr 0.8%	Buses 3.0%	No. of*** Passengers
Exit 16	18	vph		2552	201	23	86	7,190
Newburgh, NY		pcph	3482	2552	603	69	258	

* Capacity is based on 4500 pcphpl
** Capacity is based on 2200 pcphpl
*** Based on actual number of vehicles(not PCEs), (PVs and buses only)

2 GULs	Lane 1 Mixed (PCEs)						Lane 2 Mixed (PCEs)					
	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c**
% Vehicle Distribution by Lane- Demand	73.3%	17.3%	2.0%	7.4%			73.3%	17.3%	2.0%	7.4%		
Demand - pcph	1276	302	35	129	1741		1276	302	35	129	1741	
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;48 Bus	1531	101	12	2064			1531	101	12	2064		
Vehicle Mix Per Lane @ Capacity					2200	0.8					2200	0.8
Avg. Vehicle Occupancy	**1.2**	**1.0**	**1.0**	**48.0**			**1.2**	**1.0**	**1.0**	**48.0**		
Total No. of Passengers(PVs and buses only)	3,595						3,595					
% Vehicle Distribution by Lane-Capacity	73.3%	17.3%	2.0%	7.4%			73.3%	17.3%	2.0%	7.4%		

Table A-14
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New York State Thruway
Scenario #1, Passenger Vehicles in Separate AHS Lane

OPTION A. **1 AHS Lane, 2 GULs**	AHS Lane 1 PVs Only						GUL Lane 2 Mixed(PCEs)						GUL Lane 3 Mixed(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*	57.8%	27.3%	3.1%	11.7%	No. PCEs	v/c*	57.8%	27.3%	3.1%	11.7%	No. PCEs	v/c**
Demand - pcph	1276	0	0	0	1276		638	302	35	129	1103		638	302	35	129	1103	
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;48 Bus	1531						766	101	12	2064			766	101	12	2064		
Vehicle Mix Per Lane @ Capacity					4500	0.3					2200	0.5					2200	0.5
Avg. Vehicle Occupancy	**1.2**						**1.2**	**1.0**	**1.0**	**48.0**			**1.2**	**1.0**	**1.0**	**48.0**		
Total No. of Passengers(PVs and buses only)	1,531						2,830						2,830					
% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			57.8%	27.3%	3.1%	11.7%			57.8%	27.3%	3.1%	11.7%		

OPTION B. **2 AHS Lanes, 1 GUL**	AHS Lane 1 PVs Only						AHS Lane 2 SU +TrkTlr+Buses(PCEs)						GUL Lane 3 Remaining(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*	0.0%	64.8%	7.4%	27.7%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c**
Demand - pcph	1276	0	0	0	1276		0	603	69	258	930		1276	0	0	0	1276	
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;48 Bus	1531							201	23	4128			1531					
Vehicle Mix Per Lane @ Capacity					4500	0.3					4500	0.2					2200	0.6
Avg. Vehicle Occupancy	**1.2**							**1.0**	**1.0**	**48.0**			**1.2**					
Total No. of Passengers(PVs and buses only)	1,531						4,128						1,531					
% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			0.0%	64.8%	7.4%	27.7%			100.0%	0.0%	0.0%	0.0%		

OPTION C. **3 AHS Lanes**	AHS Lane 1 PVs Only						AHS Lane 2 SU +TrkTlr+Buses(PCEs)						AHS Lane 3 Remaining(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*	0.0%	64.8%	7.4%	27.7%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*
Demand - pcph	1276	0	0	0	1276		0	603	69	258	930		1276	0	0	0	1276	
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;48 Bus	1531							201	23	4128			1531					
Vehicle Mix Per Lane @ Capacity					4500	0.3					4500	0.2					4500	0.3
Avg. Vehicle Occupancy	**1.2**							**1.0**	**1.0**	**48.0**			**1.2**					
Total No. of Passengers(PVs and buses only)	1,531						4,128						1,531					
% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			0.0%	64.8%	7.4%	27.7%			100.0%	0.0%	0.0%	0.0%		

Table A-15
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New York State Thruway
Scenario #2, Mixed Vehicles in AHS Lane(s)

OPTION A. **1 AHS Lane, 2 GULs**	AHS Lane 1 Mixed(PCEs)						GUL Lane 2 Mixed(PCEs)						GUL Lane 3 Mixed(PCEs)**					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	73.3%	17.3%	2.0%	7.4%	No. PCEs	v/c*	73.3%	17.3%	2.0%	7.4%	No. PCEs	v/c**	73.3%	17.3%	2.0%	7.4%	No. PCEs	v/c**
Demand - pcph	851	201	23	86	1161		851	201	23	86	1161		851	201	23	86	1161	
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;48 Bus	1021	67	8	1376			1021	67	8	1376			1021	67	8	1376		
Vehicle Mix Per Lane @ Capacity					4500	0.3					2200	0.5					2200	0.5
Avg. Vehicle Occupancy	**1.2**	**1.0**	**1.0**	**48.0**			**1.2**	**1.0**	**1.0**	**48.0**			**1.2**	**1.0**	**1.0**	**48.0**		
Total No. of Passengers(PVs and buses only)	2,397						2,397						2,397					
% Vehicle Distribution by Lane-Capacity	73.3%	17.3%	2.0%	7.4%			73.3%	17.3%	2.0%	7.4%			73.3%	17.3%	2.0%	7.4%		

OPTION B. **2 AHS Lanes, 1 GUL**	AHS Lane 1 Mixed(PCEs)						AHS Lane 2 Mixed(PCEs)						GUL Lane 3 Mixed(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	73.3%	17.3%	2.0%	7.4%	No. PCEs	v/c*	73.3%	17.3%	2.0%	7.4%	No. PCEs	v/c*	73.3%	17.3%	2.0%	7.4%	No. PCEs	v/c**
Demand - pcph	851	201	23	86	1161		851	201	23	86	1161		851	201	23	86	1161	
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;48 Bus	1021	67	8	1376			1021	67	8	1376			1021	67	8	1376		
Vehicle Mix Per Lane @ Capacity					4500	0.3					4500	0.3					2200	0.5
Avg. Vehicle Occupancy	**1.2**	**1.0**	**1.0**	**48.0**			**1.2**	**1.0**	**1.0**	**48.0**			**1.2**	**1.0**	**1.0**	**48.0**		
Total No. of Passengers(PVs and buses only)	2,397						2,397						2,397					
% Vehicle Distribution by Lane-Capacity	73.3%	17.3%	2.0%	7.4%			73.3%	17.3%	2.0%	7.4%			73.3%	17.3%	2.0%	7.4%		

OPTION C. **3 AHS Lanes**	AHS Lane 1 Mixed(PCEs)						AHS Lane 2 Mixed(PCEs)						AHS Lane 3 Mixed(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	73.3%	17.3%	2.0%	7.4%	No. PCEs	v/c*	73.3%	17.3%	2.0%	7.4%	No. PCEs	v/c*	73.3%	17.3%	2.0%	7.4%	No. PCEs	v/c*
Demand - pcph	851	201	23	86	1161		851	201	23	86	1161		851	201	23	86	1161	
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;48 Bus	1021	67	8	1376			1021	67	8	1376			1021	67	8	1376		
Vehicle Mix Per Lane @ Capacity					4500	0.3					4500	0.3					4500	0.3
Avg. Vehicle Occupancy	**1.2**	**1.0**	**1.0**	**48.0**			**1.2**	**1.0**	**1.0**	**48.0**			**1.2**	**1.0**	**1.0**	**48.0**		
Total No. of Passengers(PVs and buses only)	2,397						2,397						2,397					
% Vehicle Distribution by Lane-Capacity	73.3%	17.3%	2.0%	7.4%			73.3%	17.3%	2.0%	7.4%			73.3%	17.3%	2.0%	7.4%		

Table A-16
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New York State Thruway
Scenario #3, Exclusive AHS Lane for Passenger Vehicles, Light Trucks and Transit Vehicles

OPTION A. **1 AHS Lane, 2 GULs**	AHS Lane 1 PVs +SU+Buses(PCEs)						GUL Lane 2 Mixed(PCEs)						GUL Lane 3 Mixed(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	74.8%	17.7%	0.0%	7.6%	No. PCEs	v/c*	71.9%	17.0%	3.9%	7.3%	No. PCEs	v/c**	71.9%	17.0%	3.9%	7.3%	No. PCEs	v/c**
Demand - pcph	1276	302	0	129	1707		638	151	35	65	888		638	151	35	65	888	
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;48 Bus	1531	101		2064			766	50	12	1032			766	50	12	1032		
Vehicle Mix Per Lane @ Capacity					4500	0.4					2200	0.4					2200	0.4
Avg. Vehicle Occupancy	**1.2**	**1.0**		**48.0**			**1.2**	**1.0**	**1.0**	**48.0**			**1.2**	**1.0**	**1.0**	**48.0**		
Total No. of Passengers(PVs and buses only)	3,595						1,798						1,798					
% Vehicle Distribution by Lane-Capacity	74.8%	34.0%	0.0%	14.5%			71.9%	17.0%	3.9%	7.3%			71.9%	17.0%	3.9%	7.3%		

OPTION B. **2 AHS Lanes, 1 GUL**	AHS Lane 1 PVs +SU+Buses(PCEs)						AHS Lane 2 PVs +SU+Buses(PCEs)						GUL Lane 3 Mixed(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	74.8%	17.7%	0.0%	7.6%	No. PCEs	v/c*	74.8%	17.7%	0.0%	7.6%	No. PCEs	v/c*	70.5%	16.7%	5.7%	7.1%	No. PCEs	v/c**
Demand - pcph	851	201	0	86	1138		851	201	0	86	1138		851	201	69	86	1207	
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;48 Bus	1021	67		1376			1021	67		1376			1021	67	23	1376		
Vehicle Mix Per Lane @ Capacity					4500	0.3					4500	0.3					2200	0.5
Avg. Vehicle Occupancy	**1.2**	**1.0**		**48.0**			**1.2**	**1.0**		**48.0**			**1.2**	**1.0**	**1.0**	**48.0**		
Total No. of Passengers(PVs and buses only)	2,397						2,397						2,397					
% Vehicle Distribution by Lane-Capacity	74.8%	17.7%	0.0%	7.6%			74.8%	17.7%	0.0%	7.6%			70.5%	16.7%	5.7%	7.1%		

OPTION C. **3 AHS Lanes**	AHS Lane 1 PVs +SU+Buses(PCEs)						AHS Lane 2 PVs +SU+Buses(PCEs)						AHS Lane 3 Mixed(PCEs)					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	74.8%	17.7%	0.0%	7.6%	No. PCEs	v/c*	74.8%	17.7%	0.0%	7.6%	No. PCEs	v/c*	70.5%	16.7%	5.7%	7.1%	No. PCEs	v/c*
Demand - pcph	851	201	0	86	1138		851	201	0	86	1138		851	201	69	86	1207	
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;48 Bus	1021	67		1376			1021	67		1376			1021	67	23	1376		
Vehicle Mix Per Lane @ Capacity					4500	0.3					4500	0.3					4500	0.3
Avg. Vehicle Occupancy	**1.2**	**1.0**		**48.0**			**1.2**	**1.0**		**48.0**			**1.2**	**1.0**	**1.0**	**48.0**		
Total No. of Passengers(PVs and buses only)	2,397						2,397						2,397					
% Vehicle Distribution by Lane-Capacity	74.8%	17.7%	0.0%	7.6%			74.8%	17.7%	0.0%	7.6%			70.5%	16.7%	5.7%	7.1%		

Table A-17
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New York State Thruway
Scenario #4, Exclusive AHS Lane for all Commercial and Transit Vehicles

OPTION A. **1 AHS Lane, 2 GULs**	AHS Lane 1 SU+ Trk Tlr+Buses(PCEs)						GUL Lane 2 PVs Only						GUL Lane 3 PVs Only					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	0.0%	64.8%	7.4%	27.7%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c**	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c**
Demand - pcph	0	603	69	258	930		1276	0	0	0	1276		1276	0	0	0	1276	
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;48 Bus		201	23	4128			1531						1531					
Vehicle Mix Per Lane @ Capacity					4500	0.2					2200	0.6					2200	0.6
Avg. Vehicle Occupancy		**1.0**	**1.0**	**48.0**			**1.2**						**1.2**					
Total No. of Passengers(PVs and buses only)	4,128						1,531						1,531					
% Vehicle Distribution by Lane-Capacity	0.0%	47.3%	5.4%	20.2%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		

OPTION B. **2 AHS Lanes, 1 GUL**	AHS Lane 1 SU+ Trk Tlr+Buses(PCEs)						AHS Lane 2 PVs Only						GUL Lane 3 PVs Only					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	0.0%	64.8%	7.4%	27.7%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c**
Demand - pcph	0	603	69	258	930		1276	0	0	0	1276		1276	0	0	0	1276	
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;48 Bus		201	23	4128			1531						1531					
Vehicle Mix Per Lane @ Capacity					4500	0.2					4500	0.3					2200	0.6
Avg. Vehicle Occupancy		**1.0**	**1.0**	**48.0**			**1.2**						**1.2**					
Total No. of Passengers(PVs and buses only)	4,128						1,531						1,531					
% Vehicle Distribution by Lane-Capacity	0.0%	47.3%	5.4%	20.2%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		

OPTION C. **3 AHS Lanes**	AHS Lane 1 SU+ Trk Tlr+Buses(PCEs)						AHS Lane 2 PVs Only						AHS Lane 3 PVs Only					
	PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
% Vehicle Distribution by Lane- Demand	0.0%	64.8%	7.4%	27.7%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*
Demand - pcph	0	603	69	258	930		1276	0	0	0	1276		1276	0	0	0	1276	
Demand - No. Occpts @ 1.20 PV; 1.0 Tks;48 Bus		201	23	4128			1531						1531					
Vehicle Mix Per Lane @ Capacity					4500	0.2					4500	0.3					4500	0.3
Avg. Vehicle Occupancy		**1.0**	**1.0**	**48.0**			**1.2**						**1.2**					
Total No. of Passengers(PVs and buses only)	4,128						1,531						1,531					
% Vehicle Distribution by Lane-Capacity	0.0%	47.3%	5.4%	20.2%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		

Table A-18
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
VEHICLE-MILES & PERSON-HOURS SUMMARY
New York State Thruway

	No Build	Scenario # 1			Scenario #2			Scenario # 3			Scenario #4		
		Options			Options			Options			Options		
		A	B	C	A	B	C	A	B	C	A	B	C
No. of AHS Lanes	0	1	2	3	1	2	3	1	2	3	1	2	3
No. GULs	2	2	1	0	2	1	0	2	1	0	2	1	0
Hrly Roadway Capacity	4400	8900	11200	13500	8900	11200	13500	8900	11200	13500	8900	11200	13500
Vehicle Classification		**VEHICLE-MILES**											
AHS													
Passenger Vehicles	0	39,556	39,556	79,112	26,381	52,762	79,143	39,556	52,762	79,143	0	39,556	79,112
Single Unit Trucks	0	0	18,693	18,693	6,231	12,462	18,693	9,362	12,462	18,693	18,693	18,693	18,693
Tractor Trailers	0	0	2,139	2,139	713	1,426	2,139	0	0	2,139	2,139	2,139	2,139
Buses	0	0	7,998	7,998	2,666	5,332	7,998	3,999	5,332	7,998	7,998	7,998	7,998
VMT Total	**0**	**39,556**	**68,386**	**107,942**	**35,991**	**71,982**	**107,973**	**52,917**	**70,556**	**107,973**	**28,830**	**68,386**	**107,942**
GULs													
Passenger Vehicles	79,112	39,556	39,556	0	52,762	26,381	0	39,556	26,381	0	79,112	39,556	0
Single Unit Trucks	18,724	18,724	0	0	12,462	6,231	0	9,362	6,231	0	0	0	0
Tractor Trailers	2,170	2,170	0	0	1,426	713	0	2,170	2,139	0	0	0	0
Buses	7,998	7,998	0	0	5,332	2,666	0	4,030	2,666	0	0	0	0
VMT Total	**108,004**	**68,448**	**39,556**	**0**	**71,982**	**35,991**	**0**	**55,118**	**37,417**	**0**	**79,112**	**39,556**	**0**
Roadway Total VMT	**108,004**	**108,004**	**107,942**	**107,942**	**107,973**	**107,973**	**107,973**	**108,035**	**107,973**	**107,973**	**107,942**	**107,942**	**107,942**
Vehicle Classification		**PERSON-HOURS**											
AHS													
Passenger Vehicles	0	804	804	1,609	536	1,073	1,609	818	1,073	1,609	0	804	1,609
Single Unit Trucks	0	0	104	104	35	70	106	54	70	106	104	104	104
Tractor Trailers	0	0	12	12	4	8	13	0	0	12	12	12	12
Buses	0	0	2,133	2,133	723	1,446	2,169	1,103	1,446	2,169	2,133	2,133	2,133
PHT Total	**0**	**804**	**3,053**	**3,857**	**1,299**	**2,598**	**3,897**	**1,975**	**2,589**	**3,896**	**2,249**	**3,053**	**3,857**
GULs													
Passenger Vehicles	1,825	833	848	0	1,111	555	0	819	555	0	1,695	848	0
Single Unit Trucks	120	110	0	0	73	36	0	53	36	0	0	0	0
Tractor Trailers	14	13	0	0	9	4	0	13	13	0	0	0	0
Buses	2,461	2,245	0	0	1,497	748	0	1,103	748	0	0	0	0
PHT Total	**4,421**	**3,201**	**848**	**0**	**2,689**	**1,344**	**0**	**1,988**	**1,353**	**0**	**1,695**	**848**	**0**
Roadway Total PHT	**4,421**	**4,006**	**3,900**	**3,857**	**3,988**	**3,942**	**3,897**	**3,964**	**3,942**	**3,896**	**3,944**	**3,900**	**3,857**

Table A-19
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New Jersey Turnpike
Base Conditions, NO BUILD

Section		Total PCE@3.0	PVs 66.8%	SU 7.5%	Trk.Trlr. 15.7%	Buses 10.0%	No. of *** Passengers
West Spur 16W+18W	pcph	8,951	5,981	669	1,401	899	21,865
East Spur 16E+18E	pcph	11,797	7,883	882	1,847	1,185	28,818
Combined	pcph	20,748	13,864	1,551	3,248	2,085	50,683

* Capacity is based on 4500 pcphpl
** Capacity is based on 2200 pcphpl
*** Based on actual number of vehicles(not PCEs), (PVs and buses only)

3 GULs for East and West Spurs 6 GULs for Combined Section		GUL Lane 1						GUL Lane 2						GUL Lane 3					
				Mixed(PCEs)						Mixed(PCEs)						Mixed(PCEs)			
Section		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
	% Vehicle Distribution by Lane- Demand	66.8%	7.5%	15.7%	10.0%	No. PCEs	v/c*	66.8%	7.5%	15.7%	10.0%	No. PCEs	v/c**	66.8%	7.5%	15.7%	10.0%	No. PCEs	v/c**
West Spur 16W + 18W	Demand -pcph	1,994	223	467	300	2,984	1.4	1,994	223	467	300	2,984	1.4	1,994	223	467	300	2,984	1.4
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	2,492	74	156	4,796			2,492	74	156	4,796			2,492	74	156	4,796		
	Vehicle Mix Per Lane @ Capacity	1,210	223	467	300	2,200	1.0	1,210	223	467	300	2,200	1.0	1,210	223	467	300	2,200	1.0
	Avg. Vehicle Occupancy	**2.1**	**1.0**	**1.0**	**48.0**			**2.1**	**1.0**	**1.0**	**48.0**			**2.1**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	7,288						7,288						7,288					
	% Vehicle Distribution by Lane-Capacity	55.0%	10.1%	21.2%	13.6%			55.0%	10.1%	21.2%	13.6%			55.0%	10.1%	21.2%	13.6%		
East Spur 16E + 18E	Demand -pcph	2,628	294	616	395	3,932	1.8	2,628	294	616	395	3,932	1.8	2,628	294	616	395	3,932	1.8
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	3,285	98	205	6,321			3,285	98	205	6,321			3,285	98	205	6,321		
	Vehicle Mix Per Lane @ Capacity	895	294	616	395	2,200	1.0	895	294	616	395	2,200	1.0	895	294	616	395	2,200	1.0
	Avg. Vehicle Occupancy	**3.7**	**1.0**	**1.0**	**48.0**			**3.7**	**1.0**	**1.0**	**48.0**			**3.7**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	9,606						9,606						9,606					
	% Vehicle Distribution by Lane-Capacity	40.7%	13.4%	28.0%	18.0%			40.7%	13.4%	28.0%	18.0%			40.7%	13.4%	28.0%	18.0%		
				Lanes 1 & 2						**Lanes 3&4**						**Lanes 5 & 6**			
Combined	Demand -pcph	4,621	517	1,083	695	6,916	1.6	4,621	517	1,083	695	6,916	1.6	4,621	517	1,083	695	6,916	1.6
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	5,777	172	361	11,117			5,777	172	361	11,117			5,777	172	361	11,117		
	Vehicle Mix Per Lane @ Capacity	2,105	517	1,083	695	4,400	1.0	2,105	517	1,083	695	4,400	1.0	2,105	517	1,083	695	4,400	1.0
	Avg. Vehicle Occupancy	**2.7**	**1.0**	**1.0**	**48.0**			**2.7**	**1.0**	**1.0**	**48.0**			**2.7**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	16,894						16,894						16,894					
	% Vehicle Distribution by Lane-Capacity	47.9%	11.8%	24.6%	15.8%			47.9%	11.8%	24.6%	15.8%			47.9%	11.8%	24.6%	15.8%		

Table A-20
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New Jersey Turnpike
Scenario #1, Passenger Vehicles in Separate AHS Lane, Option A

OPTION A. **1 AHS Lane, 2 GULs**		AHS Lane 1 PVs Only						GUL Lane 2 Mixed(PCEs)						GUL Lane 3 Mixed(PCEs)					
Section		PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c**	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c**
	% Vehicle Distribution by Lane- Demand	100.0%	0.0%	0.0%	0.0%			50.2%	11.2%	23.5%	15.1%			50.2%	11.2%	23.5%	15.1%		
West Spur 16W + 18W	Demand -pcph	2,991	0	0	0	2,991		1,496	335	701	450	2,980	1.4	1,496	335	701	450	2,981	1.4
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	3,739						1,869	112	234	7,192			1,869	112	234	7,192		
	Vehicle Mix Per Lane @ Capacity					4,500	0.7	716	335	701	450	2,200	1.0	715	335	701	450	2,200	1.0
	Avg. Vehicle Occupancy	**1.3**						**2.6**	**1.0**	**1.0**	**48.0**			**2.6**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	3,739						9,061						9,061					
	% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			32.5%	15.2%	31.8%	20.4%			32.5%	15.2%	31.8%	20.4%		
East Spur 16E + 18E	Demand -pcph	3,942	0	0	0	3,942		1,971	441	924	593	3,928	1.8	1,971	441	924	593	3,928	1.8
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	4,928						2,464	147	308	9,480			2,464	147	308	9,480		
	Vehicle Mix Per Lane @ Capacity					4,500	0.9	243	441	924	593	2,200	1.0	243	441	924	593	2,200	1.0
	Avg. Vehicle Occupancy	**1.3**						**10.1**	**1.0**	**1.0**	**48.0**			**10.1**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	4,928						11,944						11,944					
	% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			11.0%	20.0%	42.0%	26.9%			11.0%	20.0%	42.0%	26.9%		
		Lanes 1 & 2						**Lanes 3&4**						**Lanes 5 & 6**					
Combined	Demand -pcph	6,932	0	0	0	6,932		3,466	776	1,624	1,043	6,908	1.6	3,466	776	1,624	1,043	6,909	1.6
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	8,665						4,333	259	541	16,680			4,333	259	541	16,680		
	Vehicle Mix Per Lane @ Capacity					9,000	0.8	958	776	1,624	1,043	4,400	1.0	958	776	1,624	1,043	4,400	1.0
	Avg. Vehicle Occupancy	**1.3**						**4.5**	**1.0**	**1.0**	**48.0**			**4.5**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	8,665						21,013						21,013					
	% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			21.8%	17.6%	36.9%	23.7%			21.8%	17.6%	36.9%	23.7%		

Table A-20
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New Jersey Turnpike
Scenario #1, Passenger Vehicles in Separate AHS Lane, Option B

OPTION B. **2 AHS Lanes, 1 GUL**		AHS Lane 1 PVs Only						AHS Lane 2 SU +TrkTlr+Buses(PCEs)						GUL Lane 3 Remaining(PCEs)					
Section		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
	% Vehicle Distribution by Lane- Demand	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*	0.0%	22.5%	47.2%	30.3%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c**
West Spur 16W + 18W	Demand -pcph	2,991	0	0	0	2,991		0	669	1,401	899	2,969		2,991	0	0	0	2,991	1.4
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	3,739							223	467	14,388			3,739					
	Vehicle Mix Per Lane @ Capacity					4,500	0.7					4,500	0.7	2,200				2,200	1.0
	Avg. Vehicle Occupancy	**1.3**							**1.0**	**1.0**	**48.0**			**1.7**					
	Total No. of Passengers(PVs and buses only)	3,739						14,388						3,739					
	% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%		
East Spur 16E + 18E	Demand -pcph	3,942	0	0	0	3,942		0	882	1,847	1,185	3,914		3,942	0	0	0	3,942	1.8
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	4,928							294	616	18,964			4,928					
	Vehicle Mix Per Lane @ Capacity					4,500	0.9					4,500	0.9	2,200				2,200	1.0
	Avg. Vehicle Occupancy	**1.3**							**1.0**	**1.0**	**48.0**			**2.2**					
	Total No. of Passengers(PVs and buses only)	4,928						18,964						4,928					
	% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%		
		Lanes 1 & 2						**Lanes 3&4**						**Lanes 5 & 6**					
Combined	Demand -pcph	6,932	0	0	0	6,932		0	1,551	3,248	2,085	6,884		6,932	0	0	0	6,932	1.6
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	8,665							517	1,083	33,352			8,665					
	Vehicle Mix Per Lane @ Capacity					9,000	0.8					9,000	0.8	4,400				4,400	1.0
	Avg. Vehicle Occupancy	**1.3**							**1.0**	**1.0**	**48.0**			**2.0**					
	Total No. of Passengers(PVs and buses only)	8,665						33,352						8,665					
	% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%		

Table A-20
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New Jersey Turnpike
Scenario #1, Passenger Vehicles in Separate AHS Lane, Option C

OPTION C. 3 AHS Lanes		AHS Lane 1 PVs Only						AHS Lane 2 SU +TrkTlr+Buses(PCEs)						AHS Lane 3 Remaining(PCEs)					
Section		PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*
	% Vehicle Distribution by Lane- Demand	100.0%	0.0%	0.0%	0.0%			0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%		
West Spur 16W + 18W	Demand -pcph	2,991	0	0	0	2,991		0	669	1,401	899	2,969		2,991	0	0	0	2,991	
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	3,739							223	467	14,388			3,739					
	Vehicle Mix Per Lane @ Capacity					4,500	0.7					4,500	0.7					4,500	0.7
	Avg. Vehicle Occupancy	**1.3**							**1.0**	**1.0**	**48.0**			**1.3**					
	Total No. of Passengers(PVs and buses only)	3,739						14,388						3,739					
	% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%		
East Spur 16E + 18E	Demand -pcph	3,942	0	0	0	3,942		0	882	1,847	1,185	3,914		3,942	0	0	0	3,942	
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	4,928							294	616	18,964			4,928					
	Vehicle Mix Per Lane @ Capacity					4,500	0.9					4,500	0.9					4,500	0.9
	Avg. Vehicle Occupancy	**1.3**							**1.0**	**1.0**	**48.0**			**1.3**					
	Total No. of Passengers(PVs and buses only)	4,928						18,964						4,928					
	% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%		
		Lanes 1 & 2						**Lanes 3&4**						**Lanes 5 & 6**					
Combined	Demand -pcph	6,932	0	0	0	6,932		0	1,551	3,248	2,085	6,884		6,932	0	0	0	6,932	
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	8,665							517	1,083	33,352			8,665					
	Vehicle Mix Per Lane @ Capacity					9,000	0.8					9,000	0.8					9,000	0.8
	Avg. Vehicle Occupancy	**1.3**							**1.0**	**1.0**	**48.0**			**1.3**					
	Total No. of Passengers(PVs and buses only)	8,665						33,352						8,665					
	% Vehicle Distribution by Lane-Capacity	100.0%	0.0%	0.0%	0.0%			0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%		

Table A-21
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New Jersey Turnpike
Scenario #2, Mixed Vehicles in AHS Lane(s), Option A

OPTION A. 1 AHS Lane, 2 GULs			AHS Lane 1 Mixed(PCEs)						GUL Lane 2 Mixed(PCEs)						GUL Lane 3 Mixed(PCEs)**					
Section			PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c**	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c**
		% Vehicle Distribution by Lane- Demand	66.8%	7.5%	15.7%	10.0%			66.8%	7.5%	15.7%	10.0%			66.8%	7.5%	15.7%	10.0%		
West Spur	16W + 18W	Demand -pcph	2,991	335	701	450	4,476		1,496	167	350	225	2,238	1.0	1,496	167	350	225	2,238	1.0
		Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	3,739	112	234	7,194			1,869	56	117	3,597			1,869	56	117	3,597		
		Vehicle Mix Per Lane @ Capacity					4,500	1.0					2,200	1.0					2,200	1.0
		Avg. Vehicle Occupancy	**1.3**	**1.0**	**1.0**	**48.0**			**1.3**	**1.0**	**1.0**	**48.0**			**1.3**	**1.0**	**1.0**	**48.0**		
		Total No. of Passengers(PVs and buses only)	10,933						5,466						5,466					
		% Vehicle Distribution by Lane-Capacity	66.8%	7.5%	15.7%	10.0%			66.8%	7.5%	15.7%	10.0%			66.8%	7.5%	15.7%	10.0%		
East Spur	16E + 18E	Demand -pcph	3,942	441	923	593	5,899	1.3	1,971	221	462	296	2,950	1.3	1,971	221	462	296	2,950	1.3
		Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	4,928	147	308	9,482			2,464	74	154	4,741			2,464	74	154	4,741		
		Vehicle Mix Per Lane @ Capacity	2,543	441	923	593	4,500	1.0	1,221	221	462	296	2,200	1.0	1,221	221	462	296	2,200	1.0
		Avg. Vehicle Occupancy	**1.9**	**1.0**	**1.0**	**48.0**			**2.0**	**1.0**	**1.0**	**48.0**			**2.0**	**1.0**	**1.0**	**48.0**		
		Total No. of Passengers(PVs and buses only)	14,410						7,205						7,205					
		% Vehicle Distribution by Lane-Capacity	56.5%	9.8%	20.5%	13.2%			55.5%	10.0%	21.0%	13.5%			55.5%	10.0%	21.0%	13.5%		
			Lanes 1 & 2						**Lanes 3&4**						**Lanes 5 & 6**					
Combined		Demand -pcph	6,932	776	1,624	1,042	10,374	1.2	3,466	388	812	521	5,187	1.2	3,466	388	812	521	5,187	1.2
		Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	8,665	259	541	16,676			4,333	129	271	8,338			4,333	129	271	8,338		
		Vehicle Mix Per Lane @ Capacity	5,558	776	1,624	1,042	9,000	1.0	2,679	388	812	521	4,400	1.0	2,679	388	812	521	4,400	1.0
		Avg. Vehicle Occupancy	**1.6**	**1.0**	**1.0**	**48.0**			**1.6**	**1.0**	**1.0**	**48.0**			**1.6**	**1.0**	**1.0**	**48.0**		
		Total No. of Passengers(PVs and buses only)	25,341						12,671						12,671					
		% Vehicle Distribution by Lane-Capacity	61.8%	8.6%	18.0%	11.6%			60.9%	8.8%	18.5%	11.8%			60.9%	8.8%	18.5%	11.8%		

Table A-21
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New Jersey Turnpike
Scenario #2, Mixed Vehicles in AHS Lane(s), Option B

OPTION B. 2 AHS Lanes, 1 GUL		AHS Lane 1 Mixed(PCEs)						AHS Lane 2 Mixed(PCEs)						GUL Lane 3 Mixed(PCEs)					
Section		PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c**
	% Vehicle Distribution by Lane- Demand	66.8%	7.5%	15.7%	10.1%			66.8%	7.5%	15.7%	10.1%			66.8%	7.5%	15.7%	10.1%		
West Spur 16W + 18W	Demand -pcph	1,994	223	467	300	2,984		1,994	223	467	300	2,984		1,994	223	467	300	2,984	1.4
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	2,493	74	156	4,800			2,493	74	156	4,800			2,493	74	156	4,800		
	Vehicle Mix Per Lane @ Capacity					4,500	0.7					4,500	0.7	1,210	223	467	300	2,200	1.0
	Avg. Vehicle Occupancy	**1.3**	**1.0**	**1.0**	**48.0**			**1.3**	**1.0**	**1.0**	**48.0**			**2.1**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	7,293						7,293						7,293					
	% Vehicle Distribution by Lane-Capacity	66.8%	7.5%	15.7%	10.1%			66.8%	7.5%	15.7%	10.1%			55.0%	10.1%	21.2%	13.6%		
East Spur 16E + 18E	Demand -pcph	2,628	294	616	395	3,933		2,628	294	616	395	3,933		2,628	294	616	395	3,933	1.8
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	3,285	98	205	6,320			3,285	98	205	6,320			3,285	98	205	6,320		
	Vehicle Mix Per Lane @ Capacity					4,500	0.9					4,500	0.9	895	294	616	395	2,200	1.0
	Avg. Vehicle Occupancy	**1.3**	**1.0**	**1.0**	**48.0**			**1.3**	**1.0**	**1.0**	**48.0**			**3.7**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	9,605						9,605						9,605					
	% Vehicle Distribution by Lane-Capacity	66.8%	7.5%	15.7%	10.0%			66.8%	7.5%	15.7%	10.0%			40.7%	13.4%	28.0%	18.0%		
		Lanes 1 & 2						**Lanes 3&4**						**Lanes 5 & 6**					
Combined	Demand -pcph	4,621	517	1,083	695	6,916		4,621	517	1,083	695	6,916		4,621	517	1,083	695	6,916	1.6
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	5,777	172	361	11,120			5,777	172	361	11,120			5,777	172	361	11,120		
	Vehicle Mix Per Lane @ Capacity					9,000	0.8					9,000	0.8	2,105	517	1,083	695	4,400	1.0
	Avg. Vehicle Occupancy	**1.3**	**1.0**	**1.0**	**48.0**			**1.3**	**1.0**	**1.0**	**48.0**			**2.7**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	16,897						16,897						16,897					
	% Vehicle Distribution by Lane-Capacity	66.8%	7.5%	15.7%	10.0%			66.8%	7.5%	15.7%	10.0%			47.8%	11.8%	24.6%	15.8%		

Table A-21
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New Jersey Turnpike
Scenario #2, Mixed Vehicles in AHS Lane(s), Option C

OPTION C. 3 AHS Lanes		AHS Lane 1 Mixed(PCEs)						AHS Lane 2 Mixed(PCEs)						AHS Lane 3 Mixed(PCEs)					
Section		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
	% Vehicle Distribution by Lane- Demand	66.8%	7.5%	15.7%	10.1%	No. PCEs	v/c*	66.8%	7.5%	15.7%	10.1%	No. PCEs	v/c*	66.8%	7.5%	15.7%	10.1%	No. PCEs	v/c*
West Spur 16W + 18W	Demand -pcph	1,994	223	467	300	2,984		1,994	223	467	300	2,984		1,994	223	467	300	2,984	
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	2,493	74	156	4,800			2,493	74	156	4,800			2,493	74	156	4,800		
	Vehicle Mix Per Lane @ Capacity					4,500	0.7					4,500	0.7					4,500	0.7
	Avg. Vehicle Occupancy	**1.3**	**1.0**	**1.0**	**48.0**			**1.3**	**1.0**	**1.0**	**48.0**			**1.3**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	7,293						7,293						7,293					
	% Vehicle Distribution by Lane-Capacity	66.8%	7.5%	15.7%	10.1%			66.8%	7.5%	15.7%	10.1%			66.8%	7.5%	15.7%	10.1%		
East Spur 16E + 18E	Demand -pcph	2,628	294	616	395	3,933		2,628	294	616	395	3,933		2,628	294	616	395	3,933	
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	3,285	98	205	6,320			3,285	98	205	6,320			3,285	98	205	6,320		
	Vehicle Mix Per Lane @ Capacity					4,500	0.9					4,500	0.9					4,500	0.9
	Avg. Vehicle Occupancy	**1.3**	**1.0**	**1.0**	**48.0**			**1.3**	**1.0**	**1.0**	**48.0**			**1.3**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	9,605						9,605						9,605					
	% Vehicle Distribution by Lane-Capacity	66.8%	7.5%	15.7%	10.0%			66.8%	7.5%	15.7%	10.0%			66.8%	7.5%	15.7%	10.0%		
				Lanes 1 & 2						**Lanes 3&4**						**Lanes 5 & 6**			
Combined	Demand -pcph	4,621	517	1,083	695	6,916		4,621	517	1,083	695	6,916		4,621	517	1,083	695	6,916	
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	5,777	172	361	11,120			5,777	172	361	11,120			5,777	172	361	11,120		
	Vehicle Mix Per Lane @ Capacity					9,000	0.8					9,000	0.8					9,000	0.8
	Avg. Vehicle Occupancy	**1.3**	**1.0**	**1.0**	**48.0**			**1.3**	**1.0**	**1.0**	**48.0**			**1.3**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	16,897						16,897						16,897					
	% Vehicle Distribution by Lane-Capacity	66.8%	7.5%	15.7%	10.0%			66.8%	7.5%	15.7%	10.0%			66.8%	7.5%	15.7%	10.0%		

Table A-22
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New Jersey Turnpike
Scenario #3, Exclusive Lane for Passenger Vehicles, Light Trucks and Transit Vehicles, Option A

OPTION A. 1 AHS Lane, 2 GULs		AHS Lane 1 PVs +SU+Buses(PCEs)						GUL Lane 2 Mixed(PCEs)						GUL Lane 3 Mixed(PCEs)					
Section		PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c**	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c**
	% Vehicle Distribution by Lane- Demand	79.2%	8.9%	0.0%	11.9%			57.8%	6.5%	27.1%	8.7%			57.8%	6.5%	27.1%	8.7%		
West Spur 16W + 18W	Demand -pcph	2,991	335	0	450	3,776		1,496	167	701	225	2,588	1.2	1,496	168	701	225	2,589	1.2
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	3,739	112		7,200			1,869	56	234	3,600			1,869	56	234	3,600		
	Vehicle Mix Per Lane @ Capacity					4,500	0.8	1,107	167	701	225	2,200	1.0	1,107	168	701	225	2,200	1.0
	Avg. Vehicle Occupancy	**1.3**	**1.0**		**48.0**			**1.7**	**1.0**	**1.0**	**48.0**			**1.7**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	10,939						5,469						5,469					
	% Vehicle Distribution by Lane-Capacity	79.2%	8.9%	0.0%	11.9%			50.3%	7.6%	31.8%	10.2%			50.3%	7.6%	31.8%	10.2%		
East Spur 16E + 18E	Demand -pcph	3,942	441	0	593	4,976	1.1	1,971	221	924	296	3,411	1.6	1,971	221	924	296	3,411	1.6
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	4,928	147		9,482			2,464	74	308	4,741			2,464	221	924	4,741		
	Vehicle Mix Per Lane @ Capacity	3,466	441		593	4,500	1.0	760	221	924	296	2,200	1.0	760	221	924	296	2,200	1.0
	Avg. Vehicle Occupancy	**1.4**	**1.0**		**48.0**			**3.2**	**1.0**	**1.0**	**48.0**			**3.2**	**1.0**	**1.0**	**16.0**		
	Total No. of Passengers(PVs and buses only)	14,410						7,205						7,205					
	% Vehicle Distribution by Lane-Capacity	77.0%	9.8%	0.0%	13.2%			34.5%	10.0%	42.0%	13.5%			34.5%	10.0%	42.0%	13.5%		
		Lanes 1 & 2						**Lanes 3&4**						**Lanes 5 & 6**					
Combined	Demand -pcph	6,932	776	0	1,042	8,750		3,466	388	1,624	521	5,999	1.4	3,466	388	1,624	521	5,999	1.4
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	8,665	259		16,676			4,333	129	541	8,336			4,333	129	541	8,336		
	Vehicle Mix Per Lane @ Capacity					9,000	1.0	1,867	388	1,624	521	4,400	1.0	1,867	388	1,624	521	4,400	1.0
	Avg. Vehicle Occupancy	**1.3**	**1.0**		**48.0**			**2.3**	**1.0**	**1.0**	**48.0**			**2.3**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	25,341						12,669						12,669					
	% Vehicle Distribution by Lane-Capacity	79.2%	8.9%	0.0%	11.9%			42.4%	8.8%	36.9%	11.8%			42.4%	8.8%	36.9%	11.8%		

Table A-22
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New Jersey Turnpike
Scenario #3, Exclusive Lane for Passenger Vehicles, Light Trucks and Transit Vehicles, Option B

OPTION B. 2 AHS Lanes, 1 GUL		AHS Lane 1 PVs +SU+Buses(PCEs)						AHS Lane 2 PVs +SU+Buses(PCEs)						GUL Lane 3 Mixed(PCEs)					
Section		PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c**
	% Vehicle Distribution by Lane- Demand	79.2%	8.9%	0.0%	11.9%			79.2%	8.9%	0.0%	11.9%			50.9%	5.7%	35.8%	7.7%		
West Spur 16W + 18W	Demand -pcph	1,994	223	0	300	2,517		1,994	223	0	300	2,517		1,994	223	1,401	300	3,918	1.8
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	2,493	74		4,800			2,493	74		4,800			2,493	74	467	4,800		
	Vehicle Mix Per Lane @ Capacity					4,500	0.6					4,500	0.6	276	223	1,401	300	2,200	1.0
	Avg. Vehicle Occupancy	**1.3**	**1.0**		**48.0**			**1.3**	**1.0**		**48.0**			**9.0**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	7,293						7,293						7,293					
	% Vehicle Distribution by Lane-Capacity	79.2%	8.9%	0.0%	11.9%			79.2%	8.9%	0.0%	11.9%			12.5%	10.1%	63.7%	13.6%		
East Spur 16E + 18E	Demand -pcph	2,628	294	0	395	3,317		2,628	294	0	395	3,317		2,628	294	1,847	395	5,164	2.3
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	3,285	98		6,325			3,285	98		6,320			3,285	98	616	6,320		
	Vehicle Mix Per Lane @ Capacity					4,500	0.7					4,500	0.7					**SU,TT,Bus**	
	Avg. Vehicle Occupancy	**1.3**	**1.0**		**48.0**			**1.3**	**1.0**		**48.0**							**Volumes**	
	Total No. of Passengers(PVs and buses only)	9,610						9,605										**Exceeds**	
	% Vehicle Distribution by Lane-Capacity	79.2%	8.9%	0.0%	11.9%			79.2%	8.9%	0.0%	11.9%							**Capacity**	
		Lanes 1 & 2						**Lanes 3&4**						**Lanes 5 & 6**					
Combined	Demand -pcph	4,621	517	0	695	5,833		4,621	517	0	695	5,833		4,621	517	3,248	695	9,081	2.1
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	5,777	172		11,115			5,777	172		11,120			5,777	172	1,083	11,120		
	Vehicle Mix Per Lane @ Capacity					9,000	0.6					9,000	0.6					**SU,TT,Bus**	
	Avg. Vehicle Occupancy	**1.3**	**1.0**		**48.0**			**1.3**	**1.0**		**48.0**							**Volumes**	
	Total No. of Passengers(PVs and buses only)	16,891						16,897										**Exceeds**	
	% Vehicle Distribution by Lane-Capacity	79.2%	8.9%	0.0%	11.9%			79.2%	8.9%	0.0%	11.9%							**Capacity**	

Table A-22
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New Jersey Turnpike
Scenario #3, Exclusive Lane for Passenger Vehicles, Light Trucks and Transit Vehicles, Option C

OPTION C. 3 AHS Lanes		AHS Lane 1 PVs +SU+Buses(PCEs)						AHS Lane 2 PVs +SU+Buses(PCEs)						AHS Lane 3 Mixed(PCEs)					
Section		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
	% Vehicle Distribution by Lane- Demand	79.2%	8.9%	0.0%	11.9%	No. PCEs	v/c*	79.2%	8.9%	0.0%	11.9%	No. PCEs	v/c*	50.9%	5.7%	35.8%	7.7%	No. PCEs	v/c*
West Spur 16W + 18W	Demand -pcph	1,994	223	0	300	2,517		1,994	223	0	300	2,517		1,994	223	1,401	300	3,918	
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	2,493	74		4,800			2,493	74		4,800			2,493	74	467	4,800		
	Vehicle Mix Per Lane @ Capacity					4,500	0.6					4,500	0.6	1,994	223	1,401	300	4,500	0.9
	Avg. Vehicle Occupancy	**1.3**	**1.0**		**48.0**			**1.3**	**1.0**		**48.0**			**1.3**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	7,293						7,293						7,293					
	% Vehicle Distribution by Lane-Capacity	79.2%	8.9%	0.0%	11.9%			79.2%	8.9%	0.0%	11.9%			50.9%	5.7%	35.8%	7.7%		
East Spur 16E + 18E	Demand -pcph	2,628	294	0	395	3,317		2,628	294	0	395	3,317		2,628	294	1,847	395	5,164	1.1
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	3,285	98		6,320			3,285	98		6,320			3,285	98	616	6,320		
	Vehicle Mix Per Lane @ Capacity					4,500	0.7					4,500	0.7	1,964	294	1,847	395	4,500	1.0
	Avg. Vehicle Occupancy	**1.3**	**1.0**		**48.0**			**1.3**	**1.0**		**48.0**			**1.7**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	9,605						9,605						9,605					
	% Vehicle Distribution by Lane-Capacity	79.2%	8.9%	0.0%	11.9%			79.2%	8.9%	0.0%	11.9%			43.6%	6.5%	41.0%	8.8%		
		Lanes 1 & 2						**Lanes 3&4**						**Lanes 5 & 6**					
Combined	Demand -pcph	4,621	517	0	695	5,833		4,621	517	0	695	5,833		4,621	517	3,248	695	9,081	1.0
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus	5,777	172		11,120			5,777	172		11,120			5,777	172	1,083	11,120		
	Vehicle Mix Per Lane @ Capacity					9,000	0.6					9,000	0.6	4,540	517	3,248	695	9,000	1.0
	Avg. Vehicle Occupancy	**1.3**	**1.0**		**48.0**			**1.3**	**1.0**		**48.0**			**1.3**	**1.0**	**1.0**	**48.0**		
	Total No. of Passengers(PVs and buses only)	16,897						16,897						16,897					
	% Vehicle Distribution by Lane-Capacity	79.2%	8.9%	0.0%	11.9%			79.2%	8.9%	0.0%	11.9%			50.4%	5.7%	36.1%	7.7%		

Table A-23
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New Jersey Turnpike
Scenario #4, Exclusive AHS Lane for all Commercial and Transit Vehicles, Option A

OPTION A. **1 AHS Lane, 2 GULs**		AHS Lane 1 SU+ Trk Tlr+Buses(PCEs)						GUL Lane 2 PVs Only						GUL Lane 3 PVs Only					
Section		PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c**	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c**
	% Vehicle Distribution by Lane- Demand	0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		
West Spur 16W + 18W	Demand -pcph	0	669	1,401	899	2,969		2,991	0	0	0	2,991	1.4	2,991	0	0	0	2,991	1.4
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus		223	467	14,388			3,739						3,739					
	Vehicle Mix Per Lane @ Capacity					4,500	0.7	2,200				2,200	1.0	2,200				2,200	1.0
	Avg. Vehicle Occupancy		**1.0**	**1.0**	**48.0**			**1.7**						**1.7**					
	Total No. of Passengers(PVs and buses only)							3,739						3,739					
	% Vehicle Distribution by Lane-Capacity	0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		
East Spur 16E + 18E	Demand -pcph	0	882	1,847	1,185	3,914		3,942	0	0	0	3,942	1.8	3,942	0	0	0	3,942	1.8
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus		294	616	18,964			4,927						4,928					
	Vehicle Mix Per Lane @ Capacity					4,500	0.9	2,200				2,200	1.0	2,200				2,200	1.0
	Avg. Vehicle Occupancy		**1.0**	**1.0**	**48.0**			**2.2**						**2.2**					
	Total No. of Passengers(PVs and buses only)							4,927						4,928					
	% Vehicle Distribution by Lane-Capacity	0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		
		Lanes 1 & 2						**Lanes 3&4**						**Lanes 5 & 6**					
Combined	Demand -pcph	0	1,551	3,248	2,085	6,883		6,932	0	0	0	6,932	1.6	6,932	0	0	0	6,932	1.6
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus		517	1,083	33,352			8,665						8,665					
	Vehicle Mix Per Lane @ Capacity					9,000	0.8	4,400				4,400	1.0	4,400				4,400	1.0
	Avg. Vehicle Occupancy		**1.0**	**1.0**	**48.0**			**2.0**						**2.0**					
	Total No. of Passengers(PVs and buses only)							8,665						8,665					
	% Vehicle Distribution by Lane-Capacity	0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		

Table A-23
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New Jersey Turnpike
Scenario #4, Exclusive AHS Lane for all Commercial and Transit Vehicles, Option B

OPTION B. 2 AHS Lanes, 1 GUL		AHS Lane 1 SU+ Trk Tlr+Buses(PCEs)						AHS Lane 2 PVs Only						GUL Lane 3 PVs Only					
Section		PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c*	PVs	SU	Trk Tlr	Bus	Total No. PCEs	v/c**
	% Vehicle Distribution by Lane- Demand	0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		
West Spur 16W + 18W	Demand -pcph	0	669	1,401	899	2,969		2,991	0	0	0	2,991		2,991	0	0	0	2,991	1.4
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus		223	467	14,388			3,739						3,739					
	Vehicle Mix Per Lane @ Capacity					4,500	0.7					4,500	0.7	2,200				2,200	1.0
	Avg. Vehicle Occupancy		**1.0**	**1.0**	**48.0**			**1.3**						**1.7**					
	Total No. of Passengers(PVs and buses only)	14,388						3,739						3,739					
	% Vehicle Distribution by Lane-Capacity	0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		
East Spur 16E + 18E	Demand -pcph	0	882	1,847	1,185	3,914		3,942	0	0	0	3,942		3,942	0	0	0	3,942	1.8
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus		294	616	18,964			4,928						4,928					
	Vehicle Mix Per Lane @ Capacity					4,500	0.9					4,500	0.9	2,200				2,200	1.0
	Avg. Vehicle Occupancy		**1.0**	**1.0**	**48.0**			**1.3**						**2.2**					
	Total No. of Passengers(PVs and buses only)	18,964						4,928						4,928					
	% Vehicle Distribution by Lane-Capacity	0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		
		Lanes 1 & 2						**Lanes 3&4**						**Lanes 5 & 6**					
Combined	Demand -pcph	0	1,551	3,248	2,085	6,883		6,932	0	0	0	6,932		6,932	0	0	0	6,932	1.6
	Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus		517	1,083	33,352			8,665						8,665					
	Vehicle Mix Per Lane @ Capacity					9,000	0.8					9,000	0.8	4,400				4,400	1.0
	Avg. Vehicle Occupancy		**1.0**	**1.0**	**48.0**			**1.3**						**2.0**					
	Total No. of Passengers(PVs and buses only)	33,352						8,665						8,665					
	% Vehicle Distribution by Lane-Capacity	0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		

Table A-23
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
New Jersey Turnpike
Scenario #4, Exclusive AHS Lane for all Commercial and Transit Vehicles, Option C

OPTION C. **3 AHS Lanes**			AHS Lane 1 SU+ Trk Tlr(PCEs)						AHS Lane 2 PVs Only						AHS Lane 3 PVs Only					
Section			PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total		PVs	SU	Trk Tlr	Bus	Total	
		% Vehicle Distribution by Lane- Demand	0.0%	22.5%	47.2%	30.3%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*	100.0%	0.0%	0.0%	0.0%	No. PCEs	v/c*
West Spur	16W + 18W	Demand -pcph	0	669	1,401	899	2,970		2,991	0	0	0	2,991		2,991	0	0	0	2,991	
		Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus		223	467	14,388			3,739						3,739					
		Vehicle Mix Per Lane @ Capacity					4,500	0.7					4,500	0.7					4,500	0.7
		Avg. Vehicle Occupancy		**1.00**	**1.00**	**48.00**			**1.3**						**1.3**					
		Total No. of Passengers(PVs and buses only)	14,388						3,739						3,739					
		% Vehicle Distribution by Lane-Capacity	0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		
East Spur	16E + 18E	Demand -pcph	0	882	1,847	1,185	3,914		3,942	0	0	0	3,942		3,942	0	0	0	3,942	
		Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus		294	616	18,964			4,928						4,928					
		Vehicle Mix Per Lane @ Capacity					4,500	0.9					4,500	0.9					4,500	0.9
		Avg. Vehicle Occupancy		**1.00**	**1.00**	**48.00**			**1.3**						**1.3**					
		Total No. of Passengers(PVs and buses only)	18,964						4,928						4,928					
		% Vehicle Distribution by Lane-Capacity	0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		
			Lanes 1 & 2						**Lanes 3&4**						**Lanes 5 & 6**					
Combined		Demand -pcph	0	1,551	3,248	2,085	6,884		6,932	0	0	0	6,932		6,932	0	0	0	6,932	
		Demand - No. Occpts @ 1.25 PV; 1.0 Tks;48 Bus		517	1,083	33,352			8,665						8,665					
		Vehicle Mix Per Lane @ Capacity					9,000	0.8					9,000	0.8					9,000	0.8
		Avg. Vehicle Occupancy		**1.00**	**1.00**	**48.00**			**1.3**						**1.3**					
		Total No. of Passengers(PVs and buses only)	33,352						8,665						8,665					
		% Vehicle Distribution by Lane-Capacity	0.0%	22.5%	47.2%	30.3%			100.0%	0.0%	0.0%	0.0%			100.0%	0.0%	0.0%	0.0%		

Table A-24
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
VEHICLE-MILES & PERSON-HOURS SUMMARY
New Jersey Turnpike -East Spur

	No Build	Scenario # 1 Options A	Scenario # 1 Options B	Scenario # 1 Options C	Scenario #2 Options A	Scenario #2 Options B	Scenario #2 Options C	Scenario # 3 Options A	Scenario # 3 Options B	Scenario # 3 Options C	Scenario #4 Options A	Scenario #4 Options B	Scenario #4 Options C
No. of AHS Lanes	0	1	2	3	1	2	3	1	2	3	1	2	3
No. GULs	3	2	1	0	2	1	0	2	1	0	2	1	0
Hrly Roadway Capacity	6,600	8,900	11,200	13,500	8,900	11,200	13,500	8,900	11,200	13,500	8,900	11,200	13,500
Vehicle Classification		**VEHICLE-MILES**											
AHS													
Passenger Vehicles	0	19,710	19,710	39,420	12,715	26,280	39,420	17,330	0	36,100	0	19,710	39,420
Single Unit Trucks	0	0	4,410	4,410	2,205	2,940	4,410	2,205	0	4,410	4,410	4,410	4,410
Tractor Trailers	0	0	9,235	9,235	4,615	6,160	9,240	0	0	9,235	9,235	9,235	9,235
Buses	0	0	5,925	5,925	2,965	3,950	5,925	2,965	0	5,925	5,925	5,925	5,925
VMT Total	**0**	**19,710**	**39,280**	**58,990**	**22,500**	**39,330**	**58,995**	**22,500**	**0**	**55,670**	**19,570**	**39,280**	**58,990**
GULs													
Passenger Vehicles	13,425	2,430	11,000	0	12,210	4,475	0	7,600	0	0	22,000	11,000	0
Single Unit Trucks	4,410	4,410	0	0	2,210	1,470	0	2,210	0	0	0	0	0
Tractor Trailers	9,240	9,240	0	0	4,620	3,080	0	9,240	0	0	0	0	0
Buses	5,925	5,930	0	0	2,960	1,975	0	2,960	0	0	0	0	0
VMT Total	**33,000**	**22,010**	**11,000**	**0**	**22,000**	**11,000**	**0**	**22,010**	**0**	**0**	**22,000**	**11,000**	**0**
Roadway Total VMT	**33,000**	**41,720**	**50,280**	**58,990**	**44,500**	**50,330**	**58,995**	**44,510**	**0**	**55,670**	**41,570**	**50,280**	**58,990**
Vehicle Classification		**PERSON-HOURS**											
AHS													
Passenger Vehicles	0	524	524	1,049	821	1,095	1,048	821	0	1,069	0	524	1,049
Single Unit Trucks	0	0	31	31	25	33	31	25	0	32	31	31	31
Tractor Trailers	0	0	66	66	51	68	65	0	0	103	66	66	66
Buses	0	0	2,017	2,017	1,580	2,107	2,017	1,580	0	2,057	2,017	2,017	2,017
PHT Total	**0**	**524**	**2,639**	**3,163**	**2,478**	**3,303**	**3,162**	**2,426**	**0**	**3,261**	**2,114**	**2,639**	**3,163**
GULs													
Passenger Vehicles	1,643	821	821	0	821	548	0	821	0	0	1,642	821	0
Single Unit Trucks	49	49	0	0	25	16	0	25	0	0	0	0	0
Tractor Trailers	103	103	0	0	51	34	0	103	0	0	0	0	0
Buses	3,161	3,160	0	0	1,580	1,053	0	1,580	0	0	0	0	0
PHT Total	**4,955**	**4,133**	**821**	**0**	**2,478**	**1,651**	**0**	**2,529**	**0**	**0**	**1,642**	**821**	**0**
Roadway Total PHT	**4,955**	**4,657**	**3,460**	**3,163**	**4,955**	**4,954**	**3,162**	**4,955**	**0**	**3,261**	**3,757**	**3,460**	**3,163**

Using a 5 mile long section

Table A-24
FORECAST 2024 PEAK HOUR TRAFFIC OPERATIONS
VEHICLE-MILES & PERSON-HOURS SUMMARY
New Jersey Turnpike - Combined Section

	No Build	Scenario # 1 Options A	Scenario # 1 Options B	Scenario # 1 Options C	Scenario #2 Options A	Scenario #2 Options B	Scenario #2 Options C	Scenario # 3 Options A	Scenario # 3 Options B	Scenario # 3 Options C	Scenario #4 Options A	Scenario #4 Options B	Scenario #4 Options C
No. of AHS Lanes	0	2	4	6	2	4	6	2	4	6	2	4	6
No. GULs	6	4	2	0	4	2	0	4	2	0	4	2	0
Hrly Roadway Capacity	13,200	17,800	22,400	27,000	17,800	22,400	27,000	17,800	22,400	27,000	17,800	22,400	27,000
Vehicle Classification		**VEHICLE-MILES**											
AHS													
Passenger Vehicles	0	13,864	13,864	27,728	11,116	18,484	27,726	13,864	0	27,564	0	13,864	27,728
Single Unit Trucks	0	0	3,102	3,102	1,552	2,068	3,102	1,552	0	3,102	3,102	3,102	3,102
Tractor Trailers	0	0	6,496	6,496	3,248	4,332	6,496	0	0	6,496	6,496	6,496	6,496
Buses	0	0	4,170	4,170	2,084	2,780	4,170	2,084	0	4,170	4,170	4,170	4,170
VMT Total	**0**	**13,864**	**27,632**	**41,496**	**18,000**	**27,664**	**41,494**	**17,500**	**0**	**41,332**	**13,768**	**27,632**	**41,496**
GULs													
Passenger Vehicles	12,630	3,832	8,800	0	10,716	4,210	0	7,468	0	0	17,600	8,800	0
Single Unit Trucks	3,102	3,104	0	0	1,552	1,034	0	1,552	0	0	0	0	0
Tractor Trailers	6,498	6,496	0	0	3,248	2,166	0	6,496	0	0	0	0	0
Buses	4,170	4,172	0	0	2,084	1,390	0	2,084	0	0	0	0	0
VMT Total	**26,400**	**17,604**	**8,800**	**0**	**17,600**	**8,800**	**0**	**17,600**	**0**	**0**	**17,600**	**8,800**	**0**
Roadway Total VMT	**26,400**	**31,468**	**36,432**	**41,496**	**35,600**	**36,464**	**41,494**	**35,100**	**0**	**41,332**	**31,368**	**36,432**	**41,496**
Vehicle Classification		**PERSON-HOURS**											
AHS													
Passenger Vehicles	0	333	333	667	578	444	667	578	0	731	0	333	667
Single Unit Trucks	0	0	19	19	17	13	20	17	0	22	20	20	20
Tractor Trailers	0	0	40	40	36	28	42	0	0	72	42	42	42
Buses	0	0	1,235	1,235	1,112	855	1,283	1,112	0	1,407	1,283	1,283	1,283
PHT Total	**0**	**333**	**1,628**	**1,961**	**1,743**	**1,341**	**2,011**	**1,707**	**0**	**2,232**	**1,344**	**1,678**	**2,011**
GULs													
Passenger Vehicles	1,155	578	578	0	578	385	0	578	0	0	1,155	578	0
Single Unit Trucks	34	35	0	0	17	11	0	17	0	0	0	0	0
Tractor Trailers	72	72	0	0	36	24	0	72	0	0	0	0	0
Buses	2,223	2,224	0	0	1,112	741	0	1,111	0	0	0	0	0
PHT Total	**3,485**	**2,908**	**578**	**0**	**1,743**	**1,162**	**0**	**1,779**	**0**	**0**	**1,155**	**578**	**0**
Roadway Total PHT	**3,485**	**3,242**	**2,205**	**1,961**	**3,486**	**2,503**	**2,011**	**3,485**	**0**	**2,232**	**2,500**	**2,255**	**2,011**

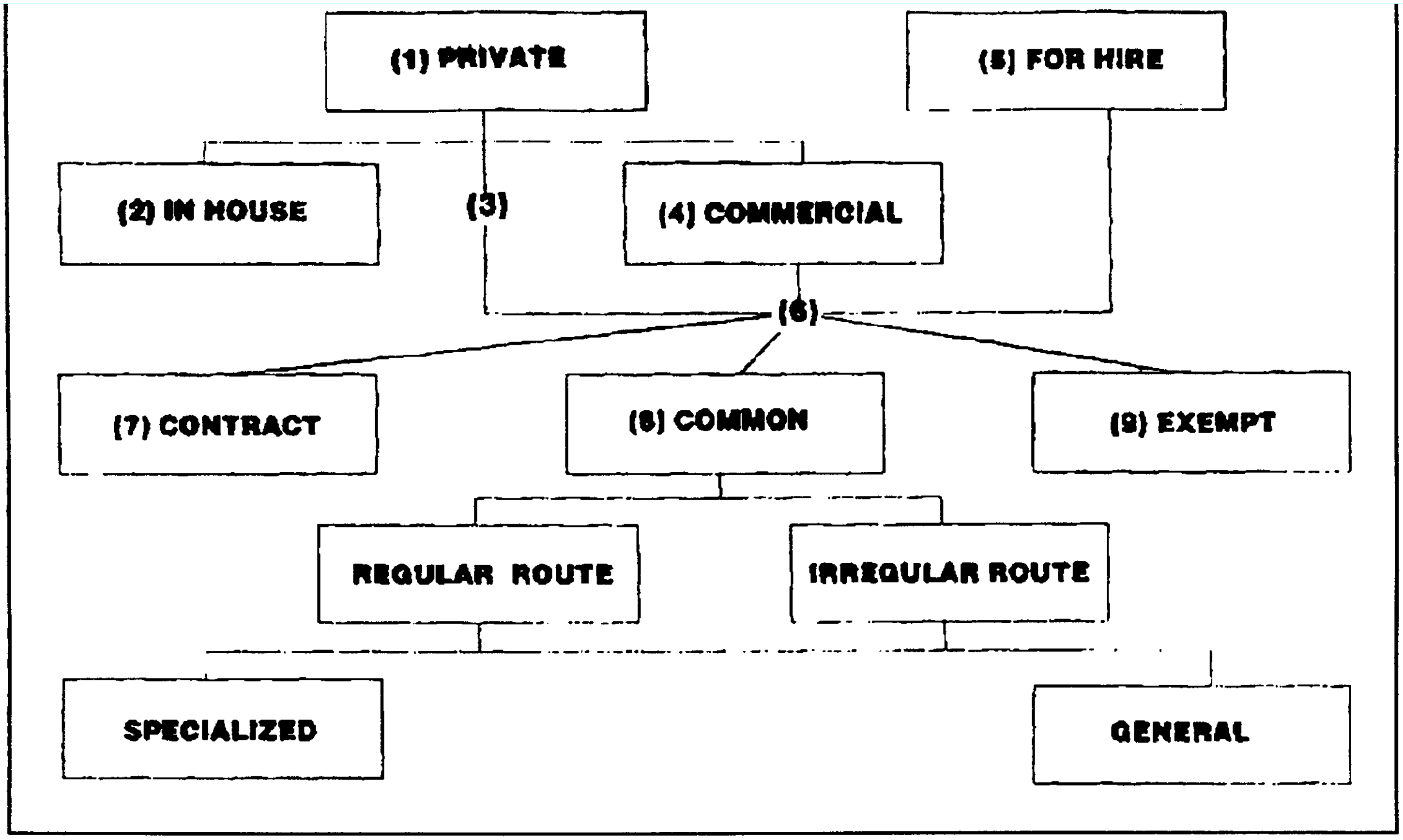


Figure A–1
The Trucking Industry

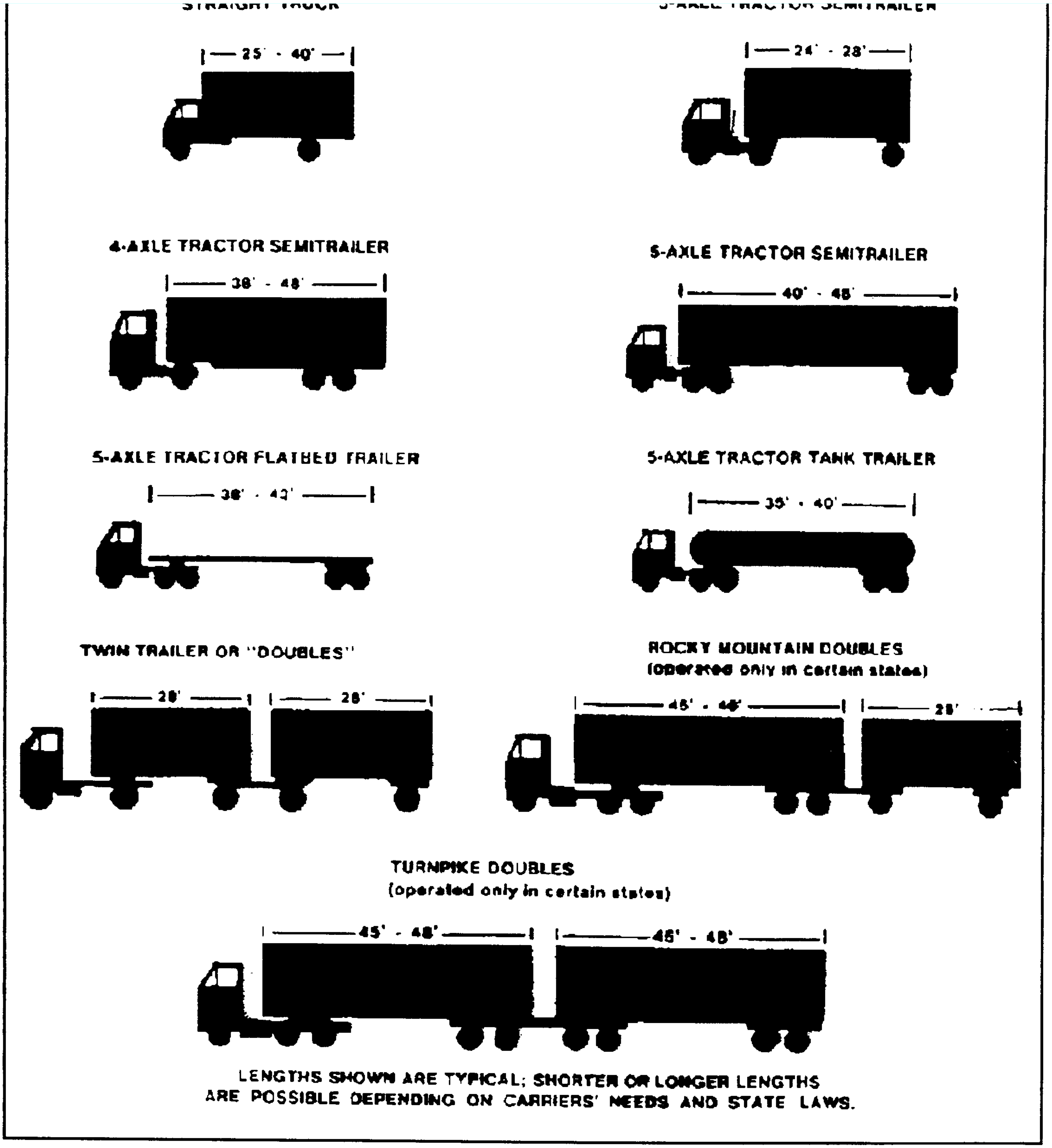


Figure A–2
Truck Types

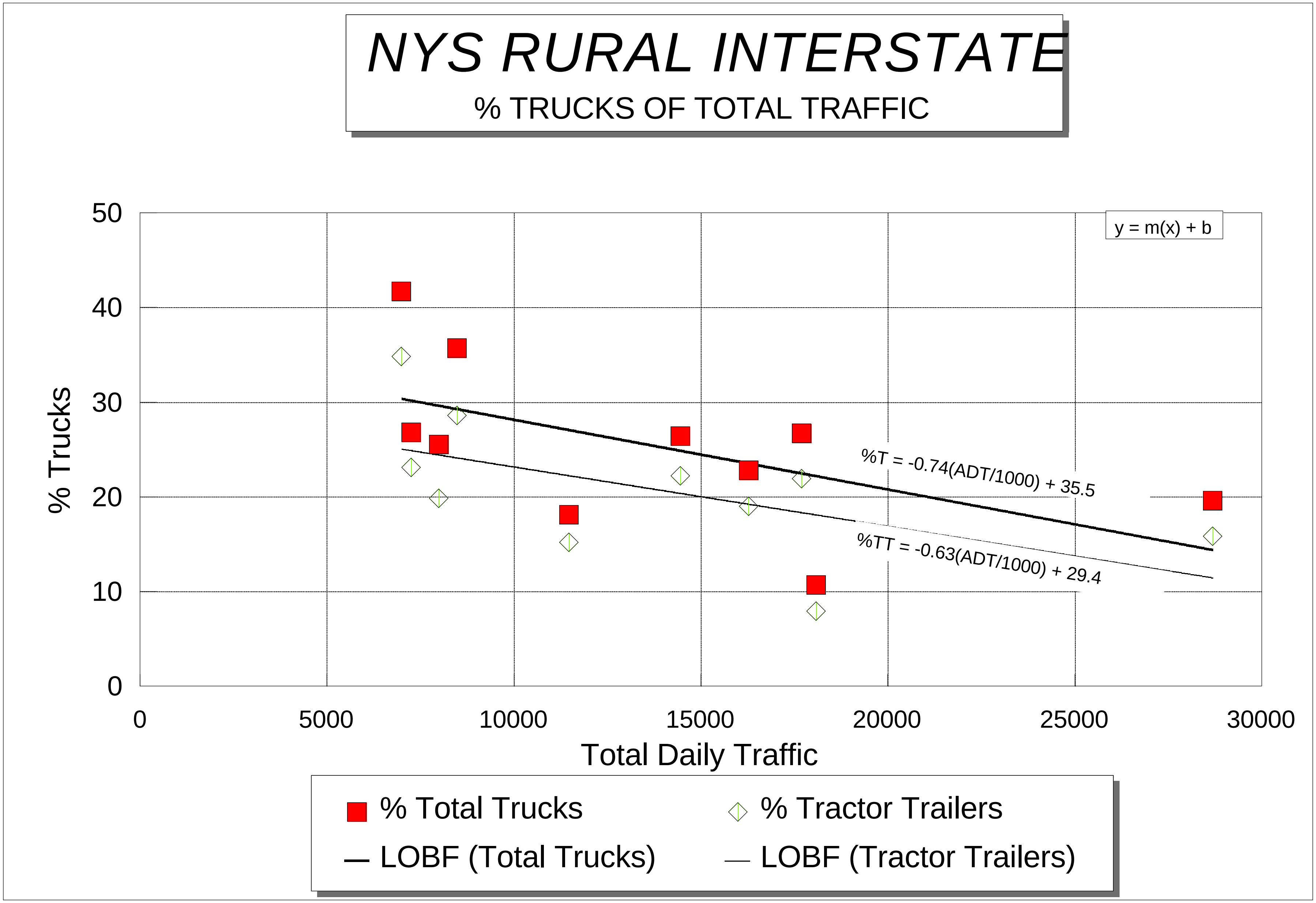
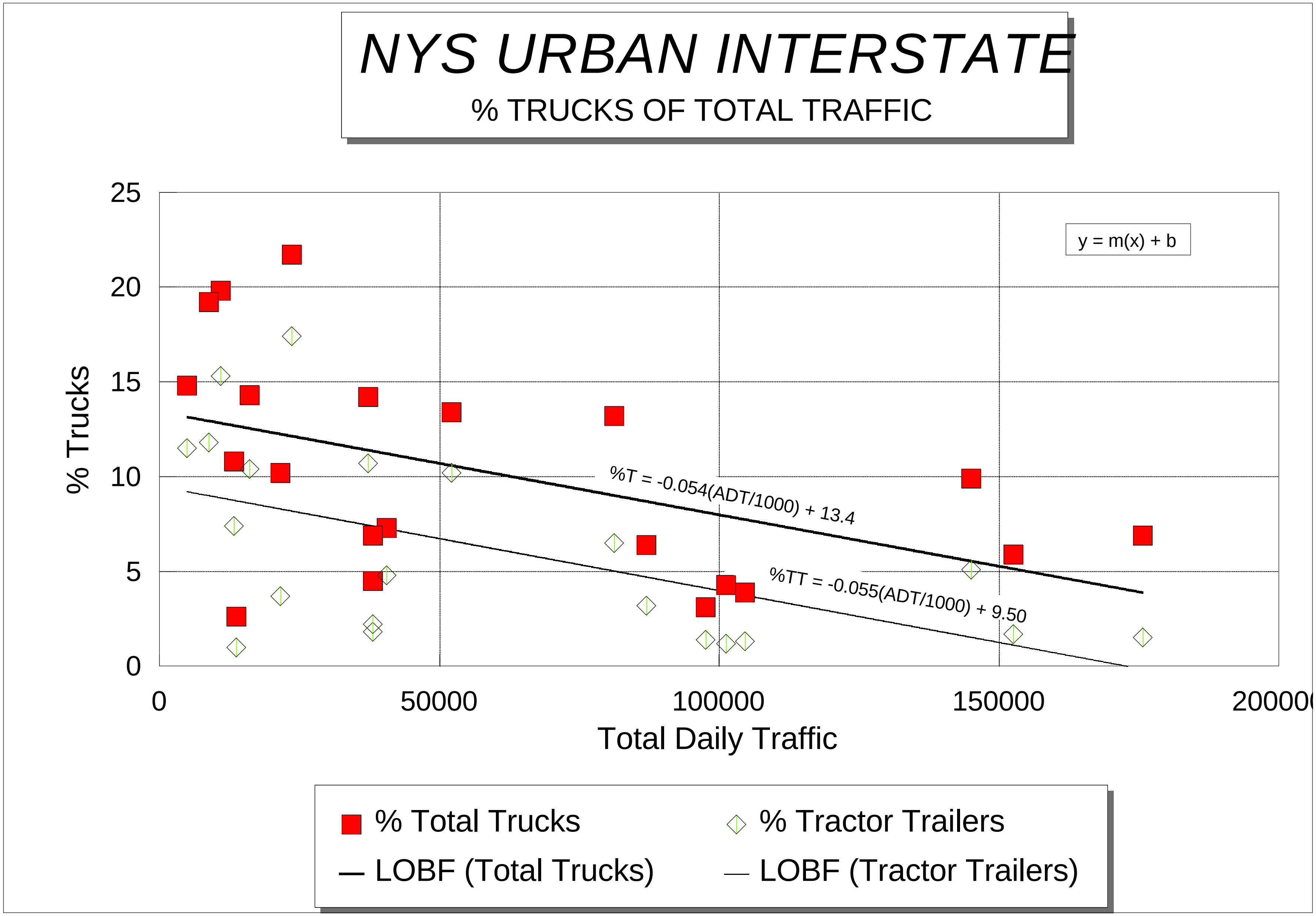

NYS RURAL INTERSTATE
% TRUCKS OF TOTAL TRAFFIC
y = m(x) + b
50
40
30
20
10
0
% Trucks
0
5000
10000
15000
20000
25000
30000
Total Daily Traffic
%T = -0.74(ADT/1000) + 35.5
%TT = -0.63(ADT/1000) + 29.4
% Total Trucks
% Tractor Trailers
LOBF (Total Trucks)
LOBF (Tractor Trailers)

Figure A-3


NYS URBAN INTERSTATE
% TRUCKS OF TOTAL TRAFFIC
y = m(x) + b
%T = -0.054(ADT/1000) + 13.4
%TT = -0.055(ADT/1000) + 9.50
% Trucks
Total Daily Traffic
0
5
10
15
20
25
0
50000
100000
150000
200000
% Total Trucks
% Tractor Trailers
LOBF (Total Trucks)
LOBF (Tractor Trailers)

&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990

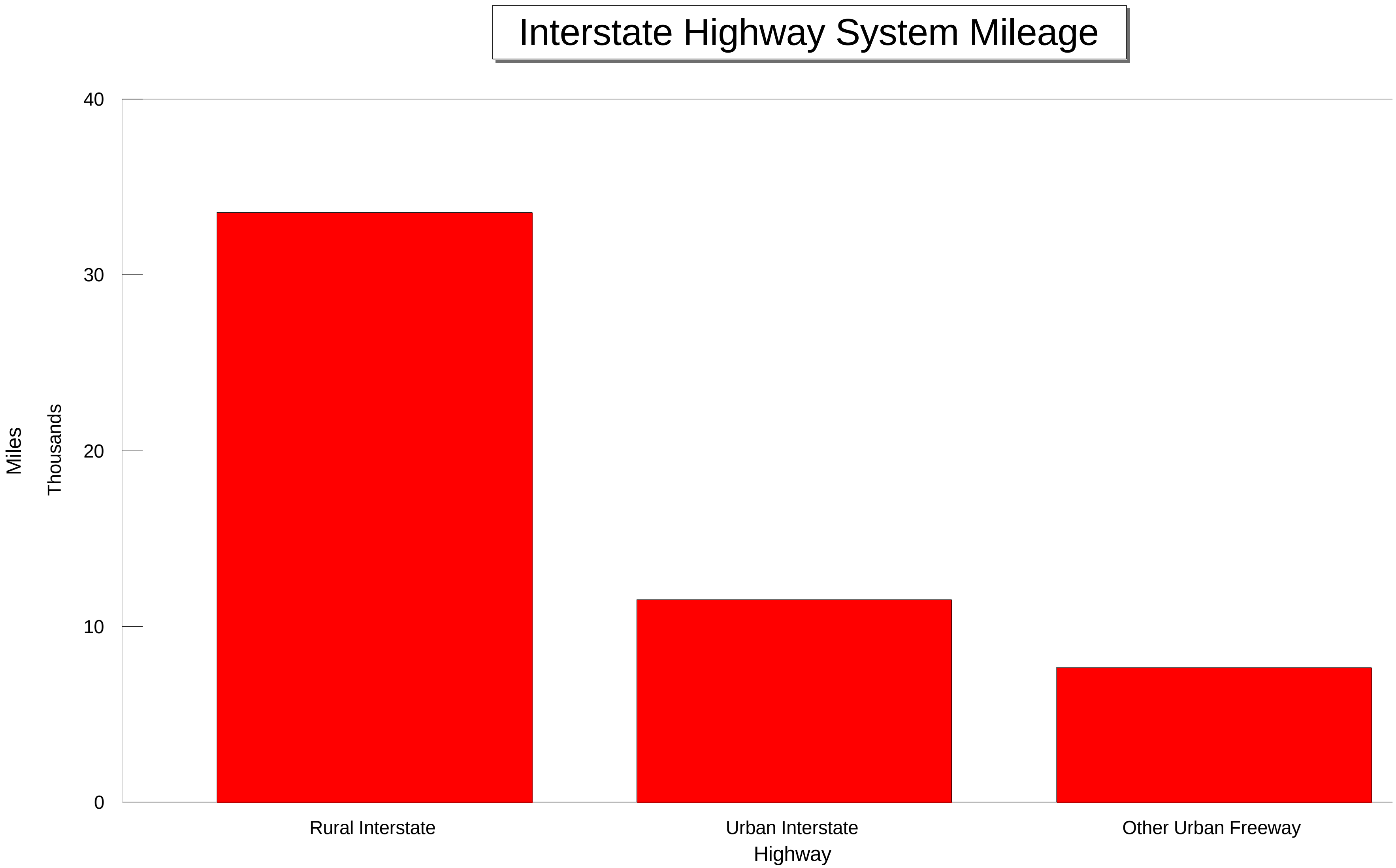
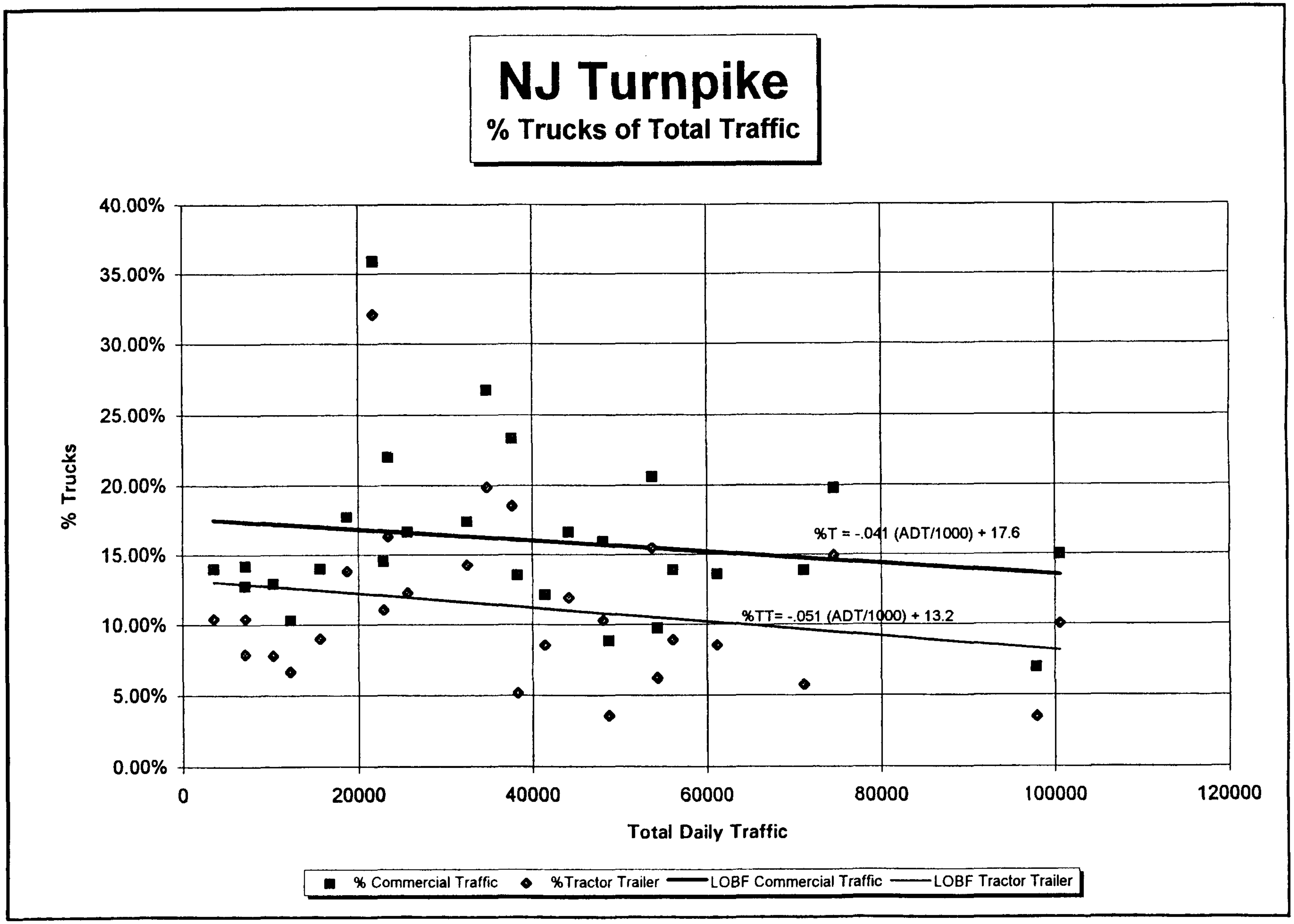
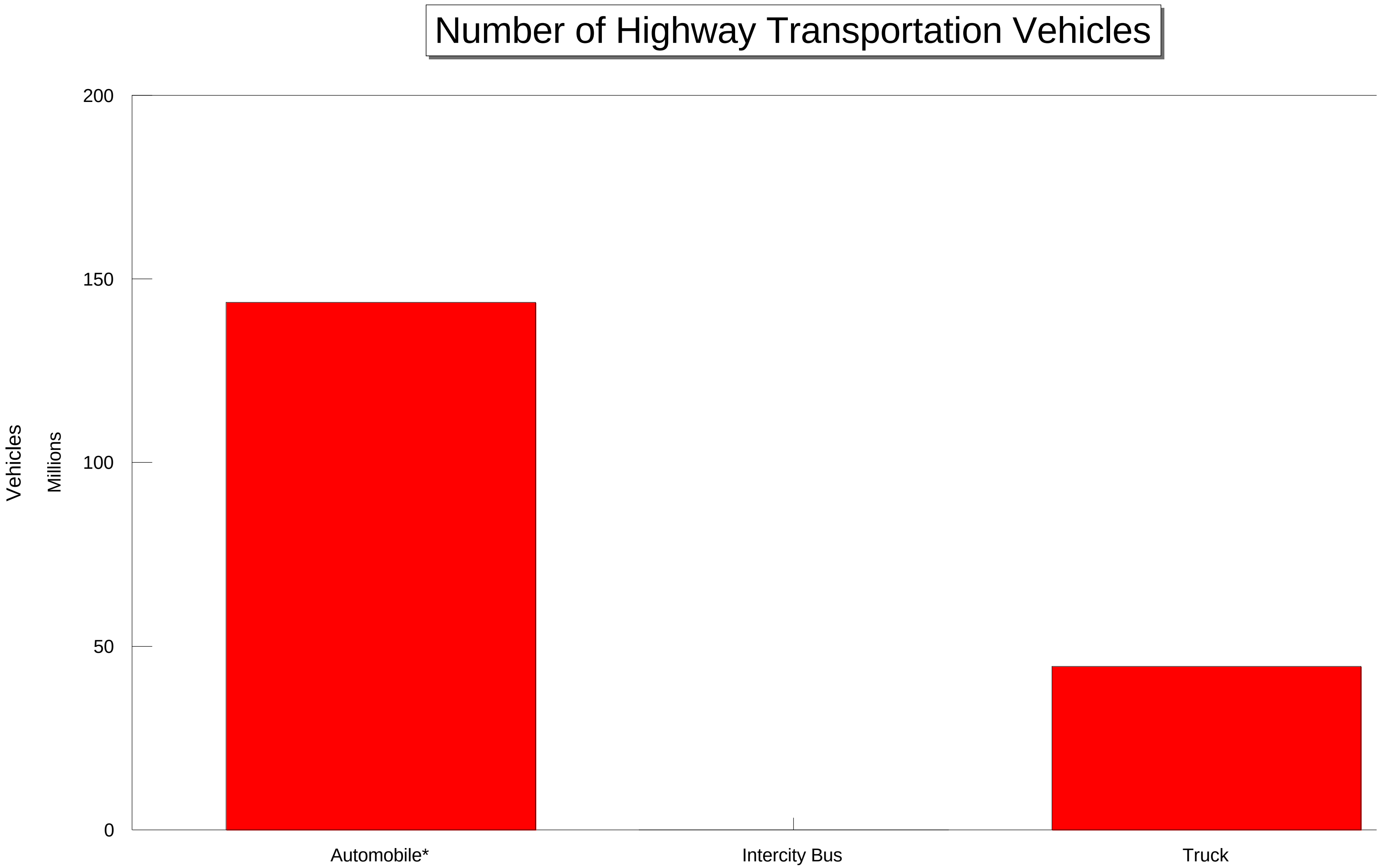


Figure A-5

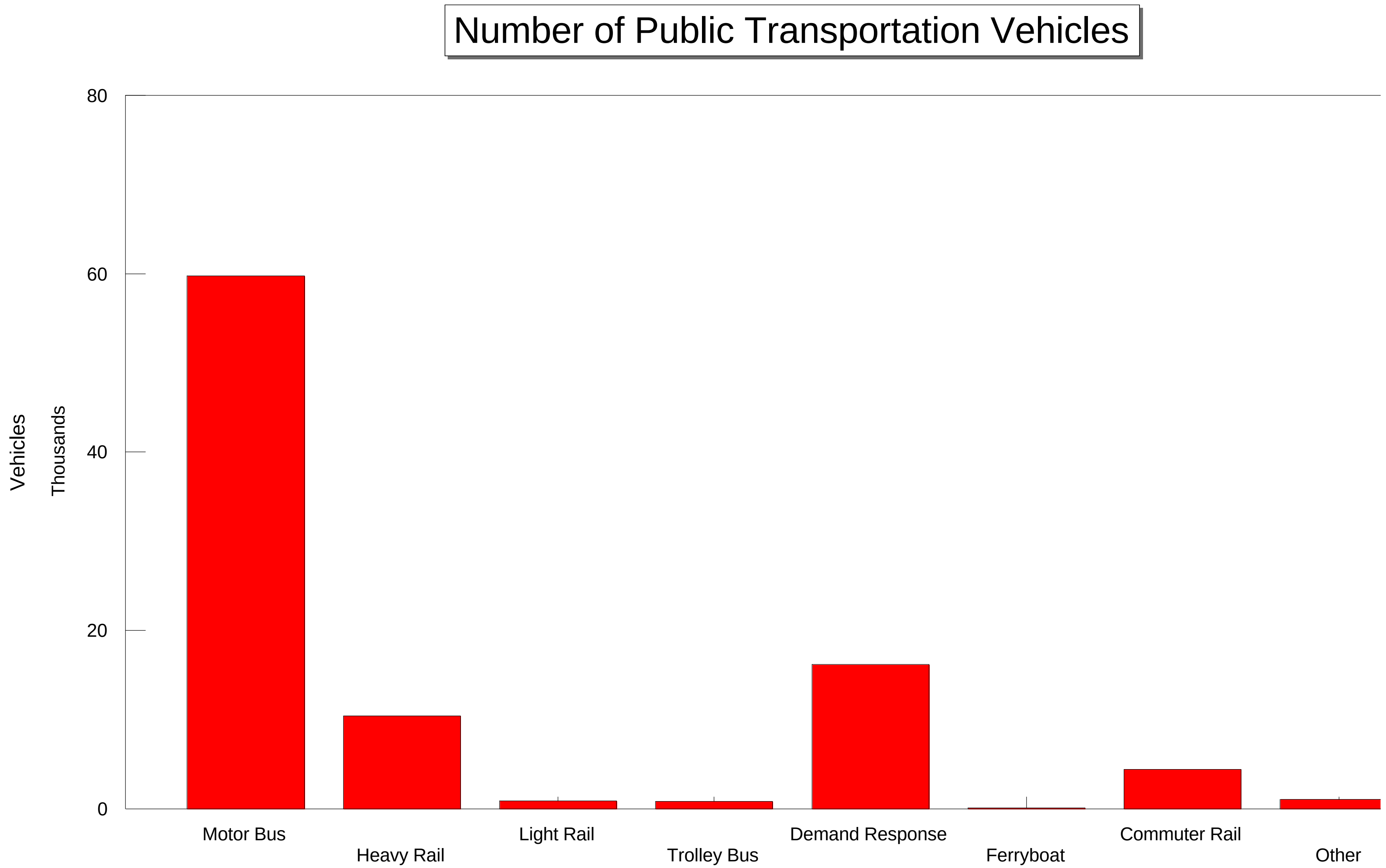


A43

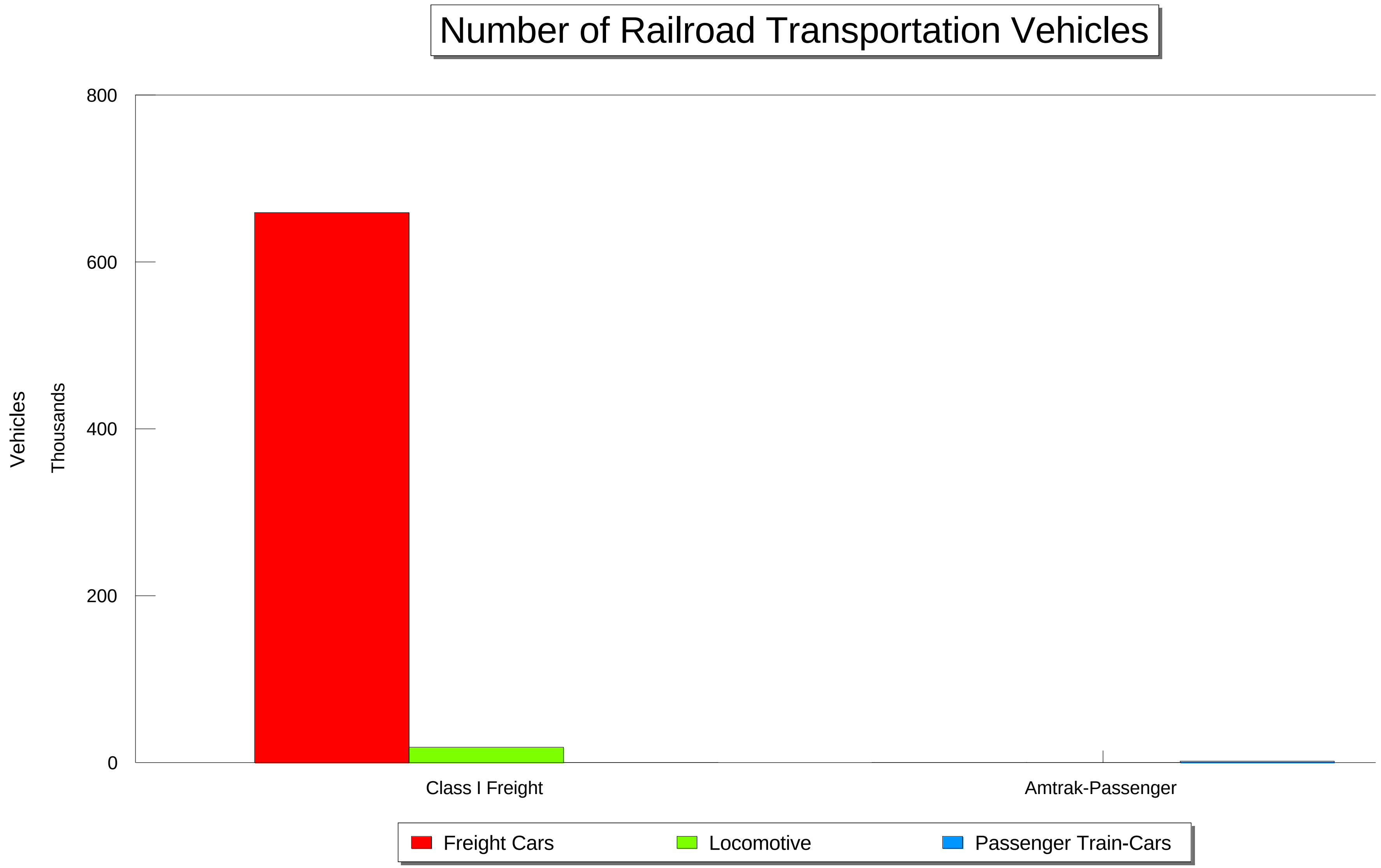
&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990



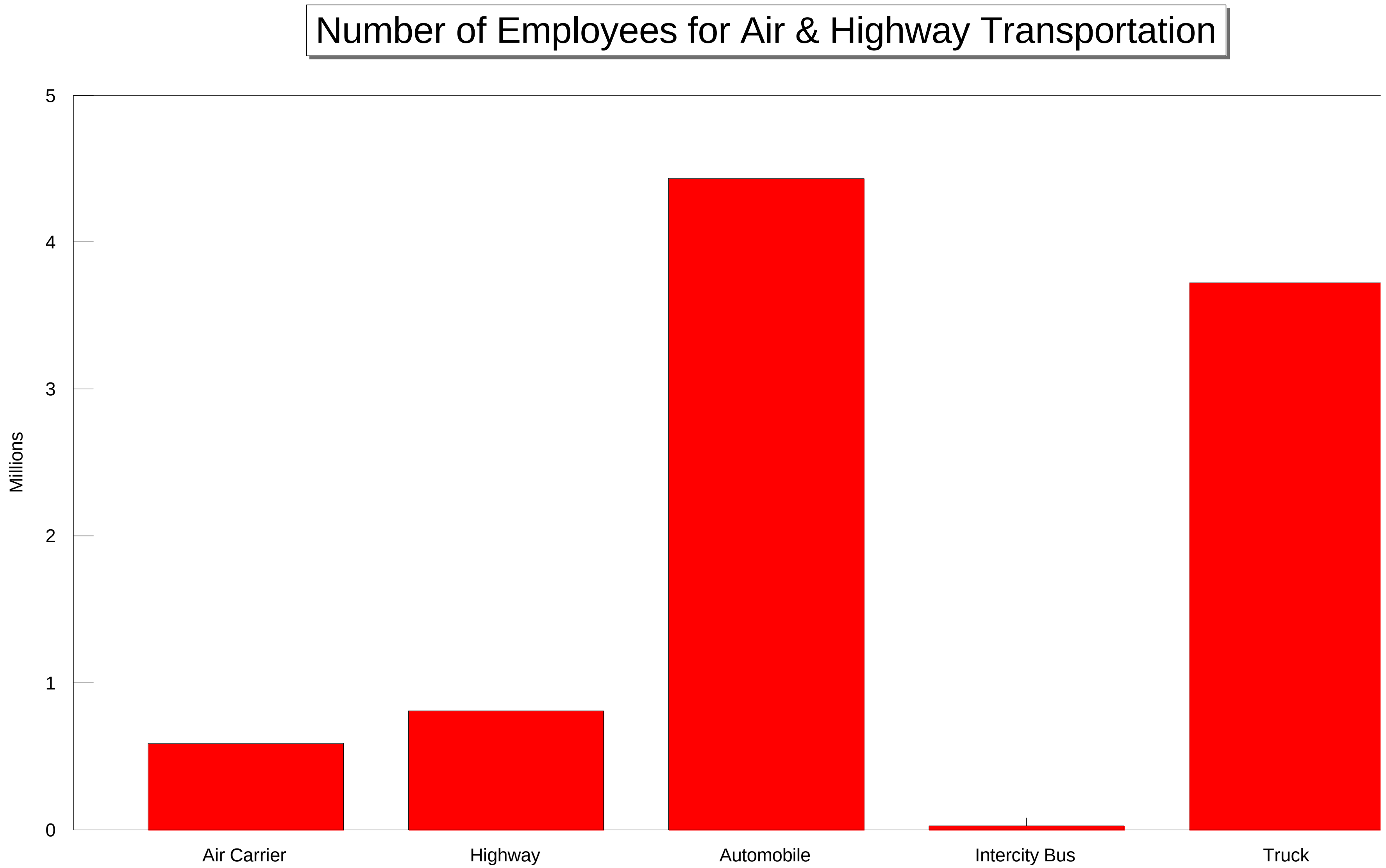
&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990



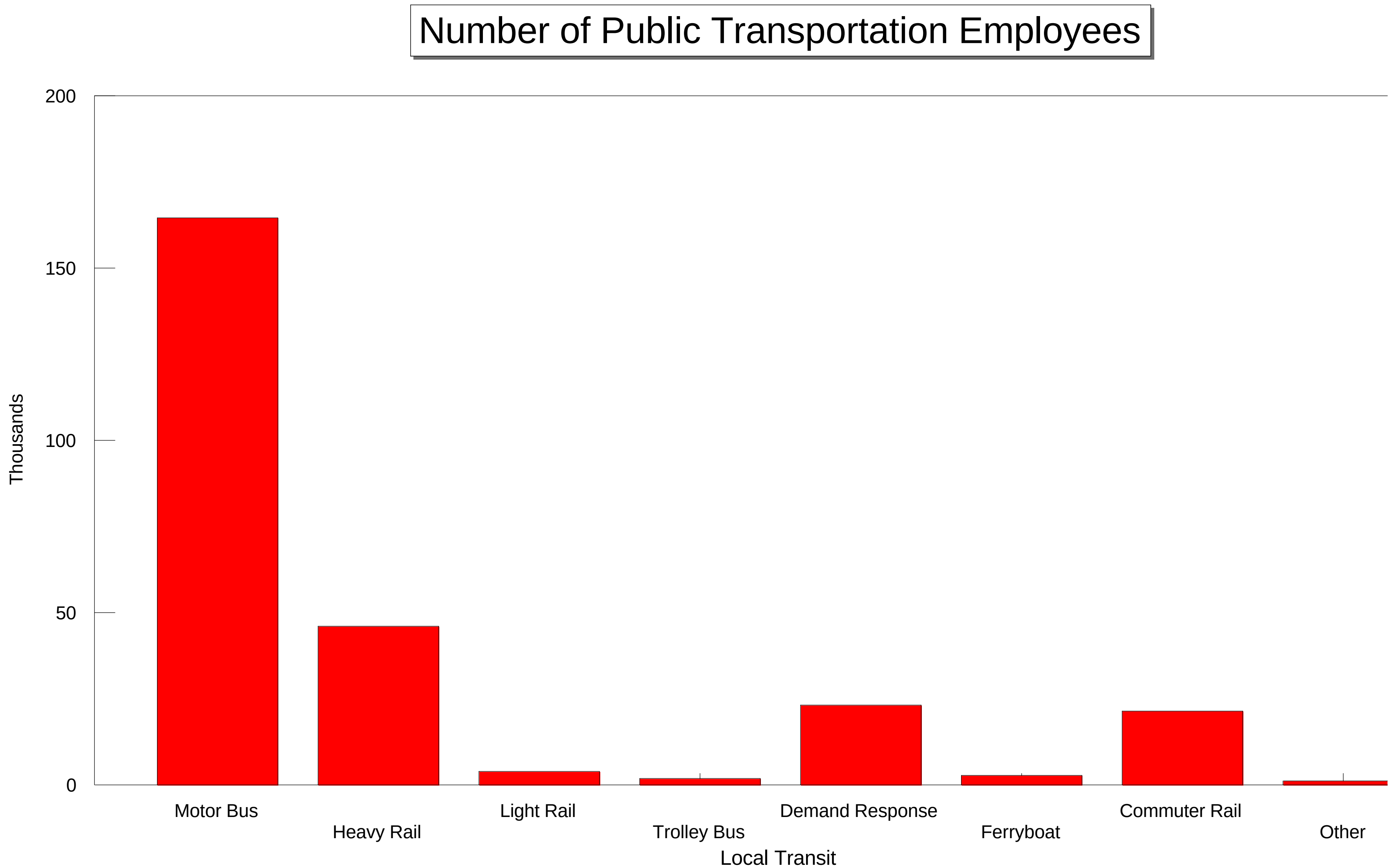
&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990



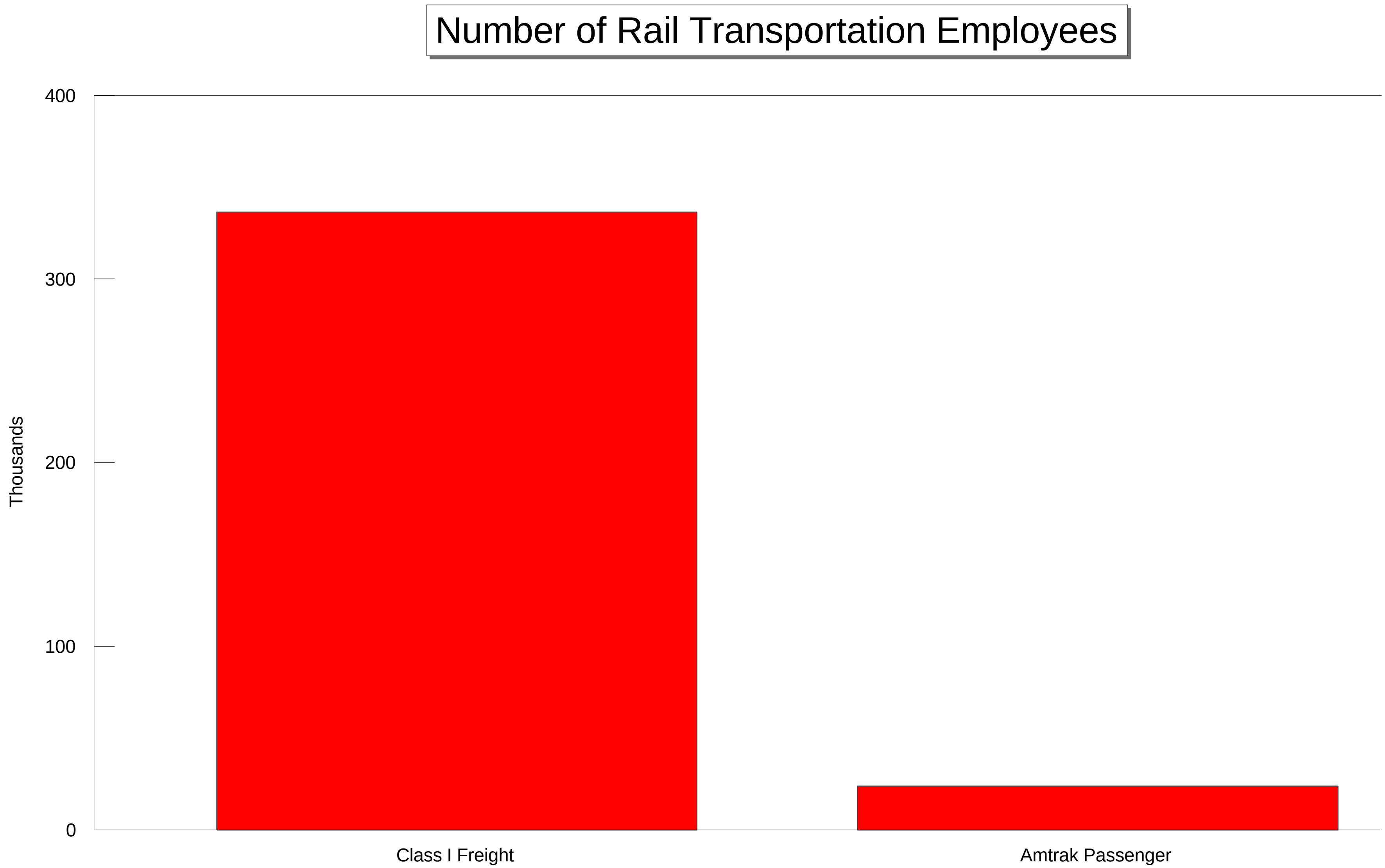
&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990



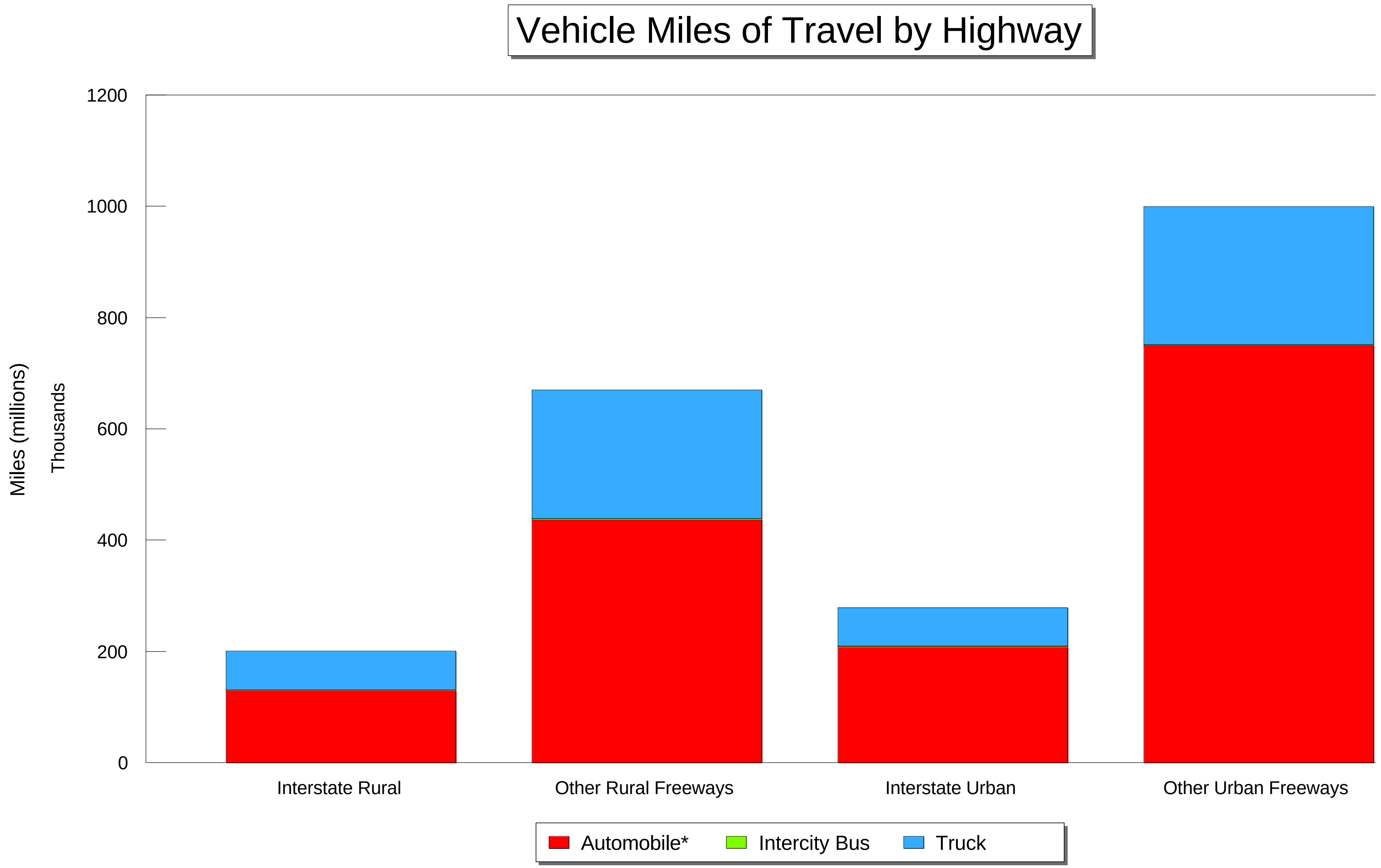
&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990



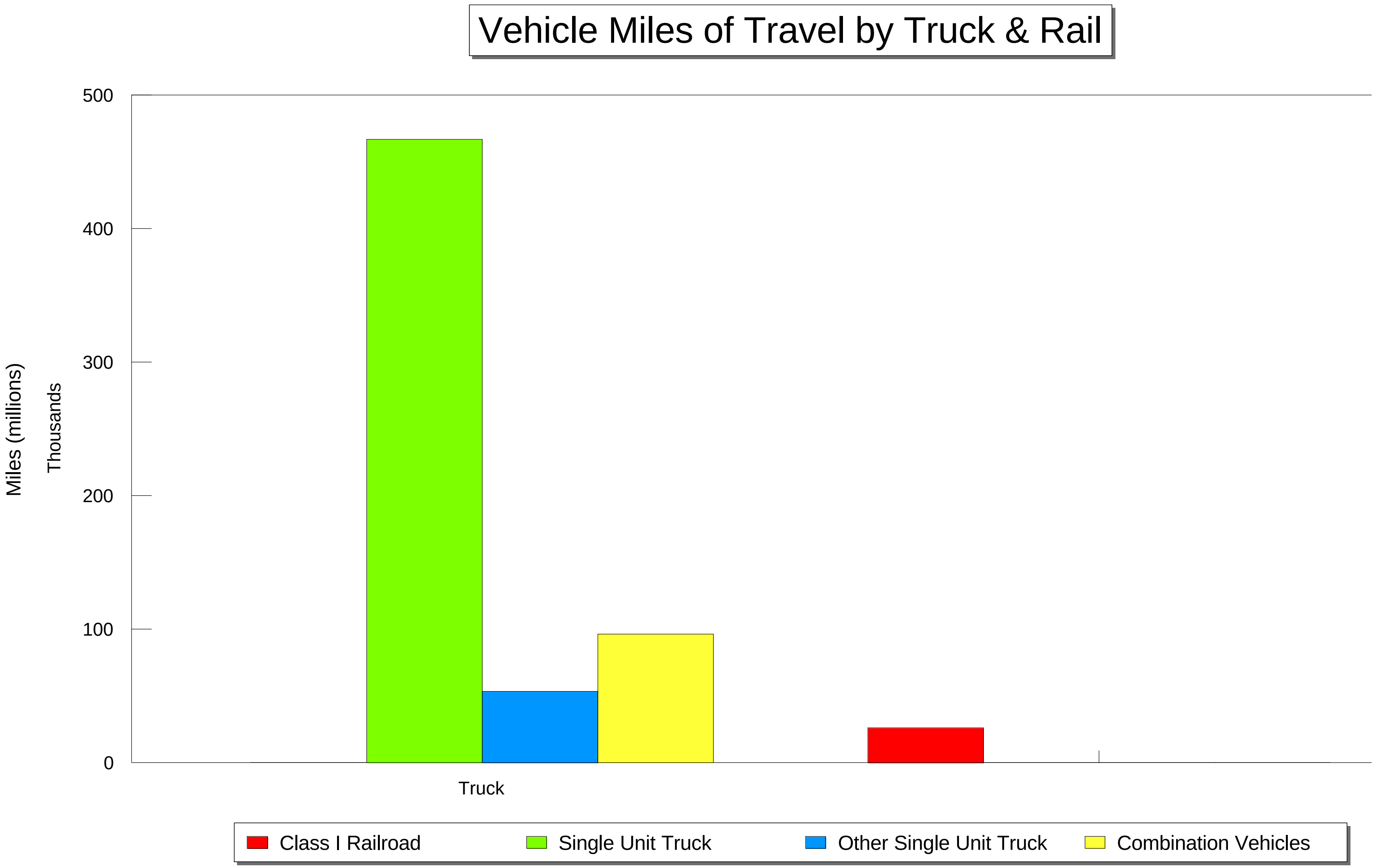
&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990



&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990

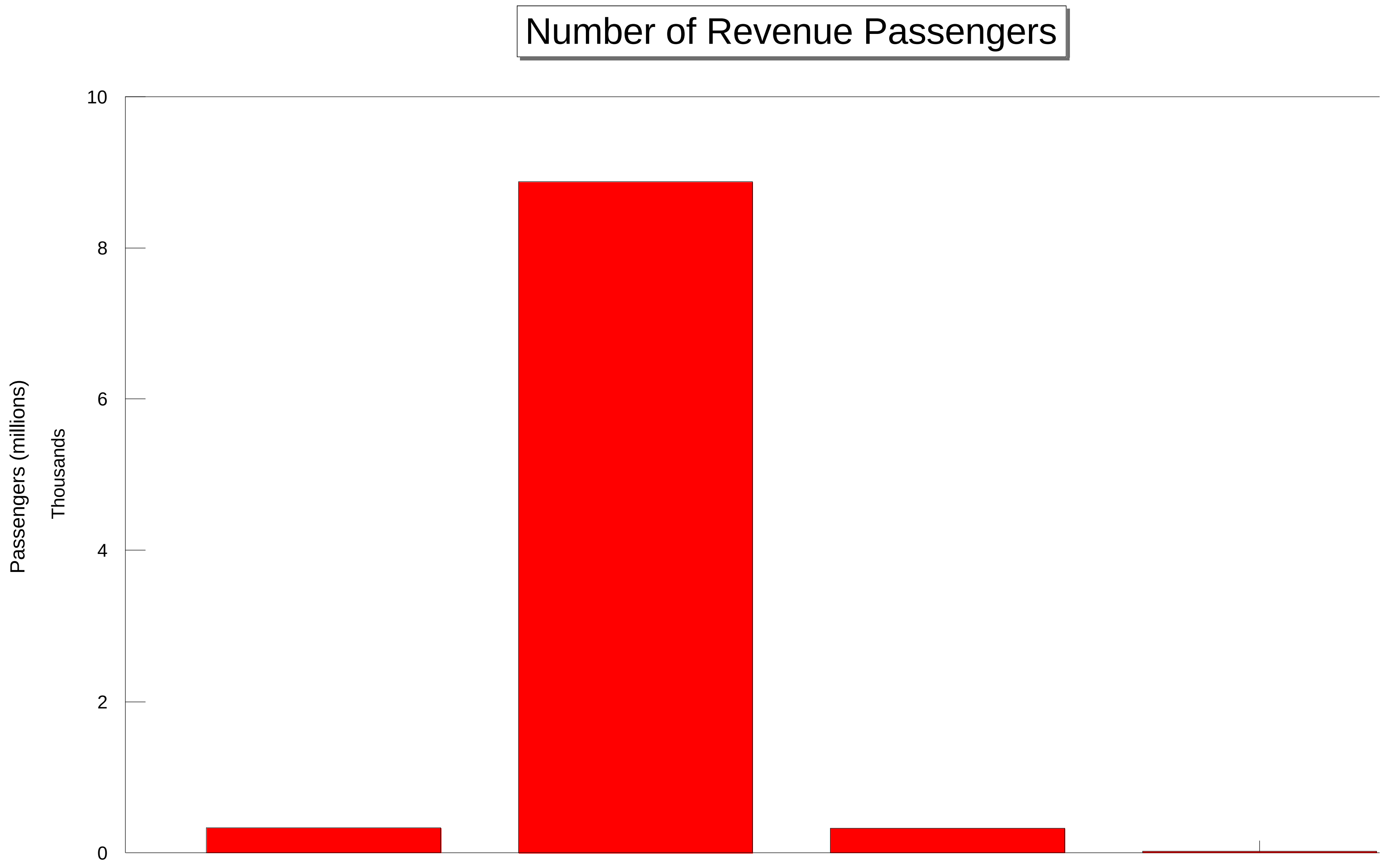


&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990

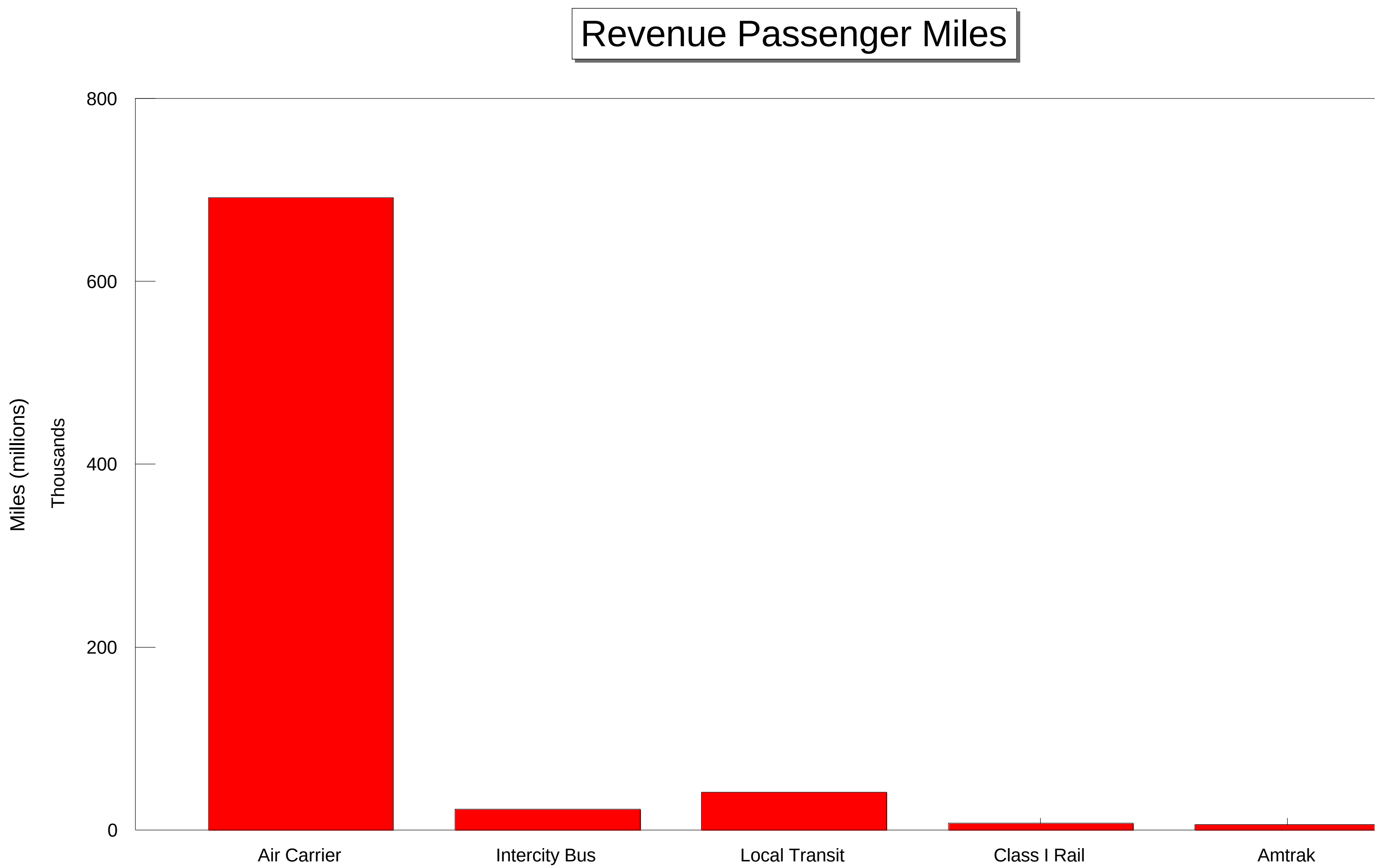


&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990

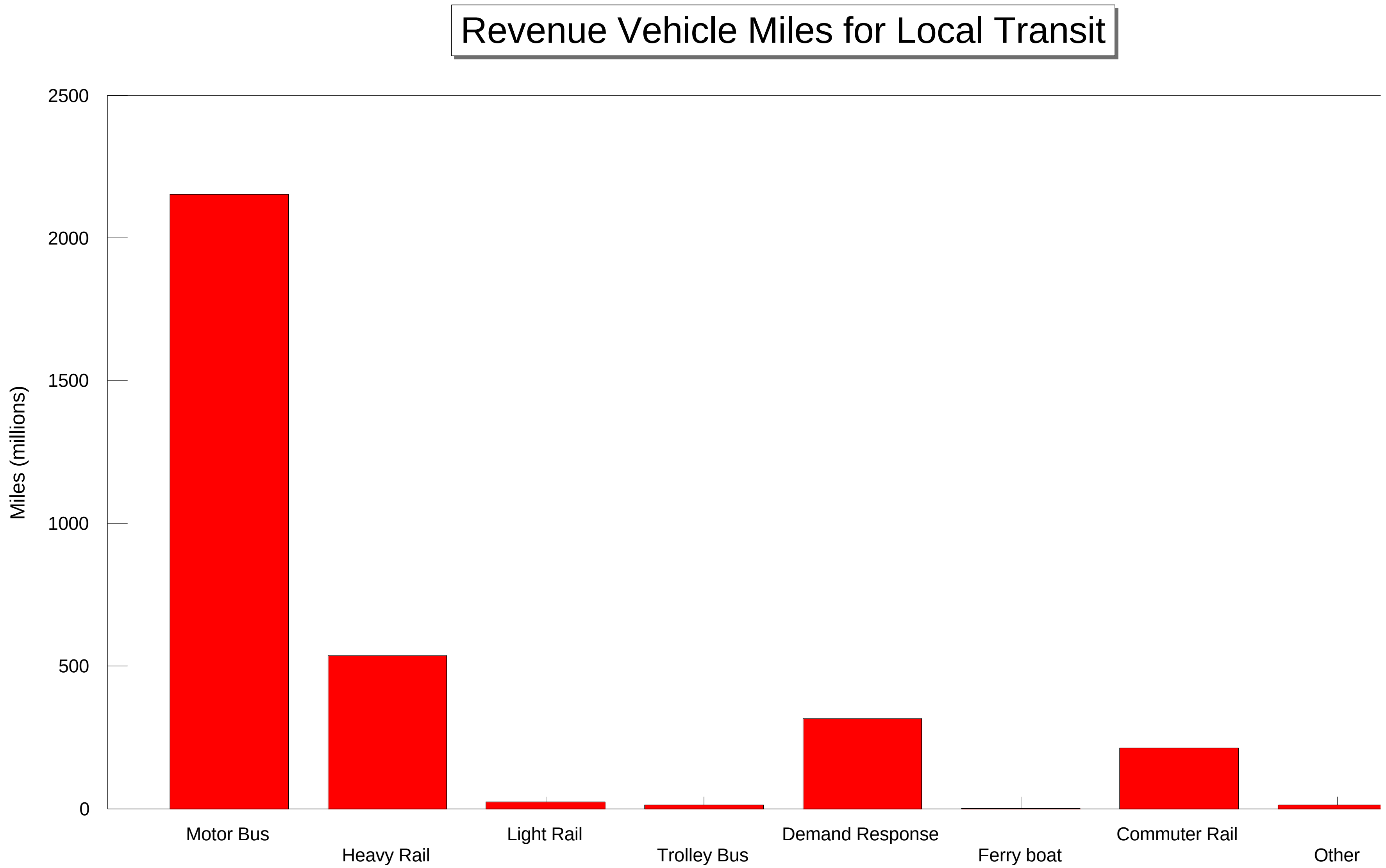
&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990



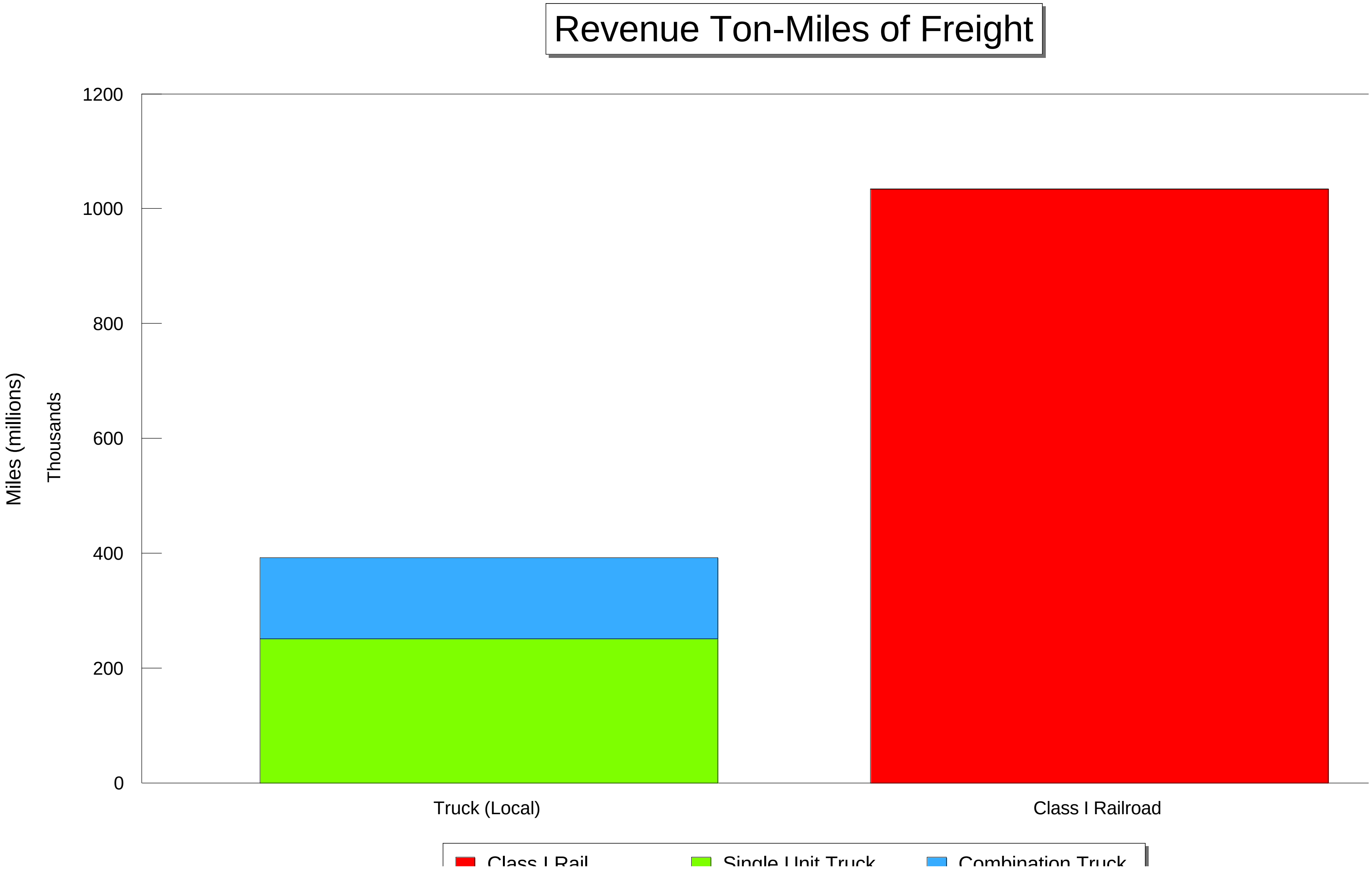
&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990

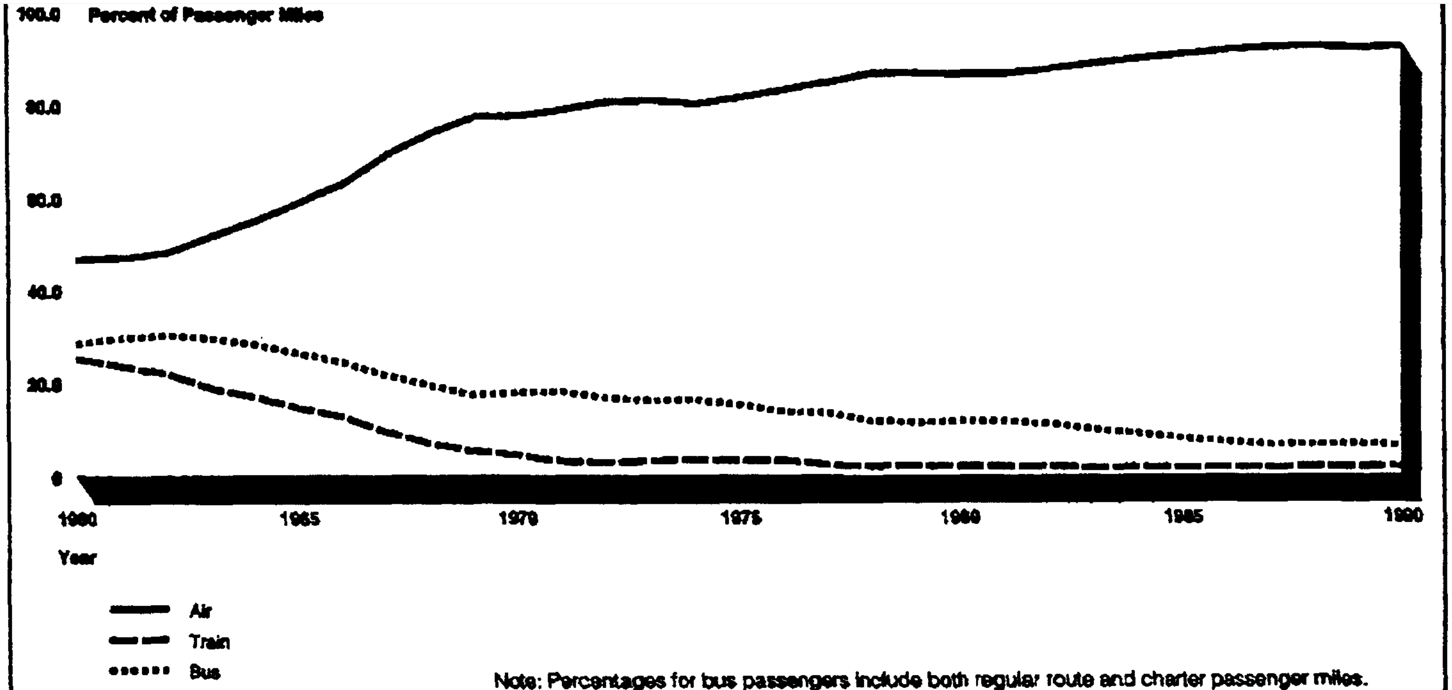


&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990



&16&BFigure A-6: Graph 1• ational Transportation Statistics for 1990

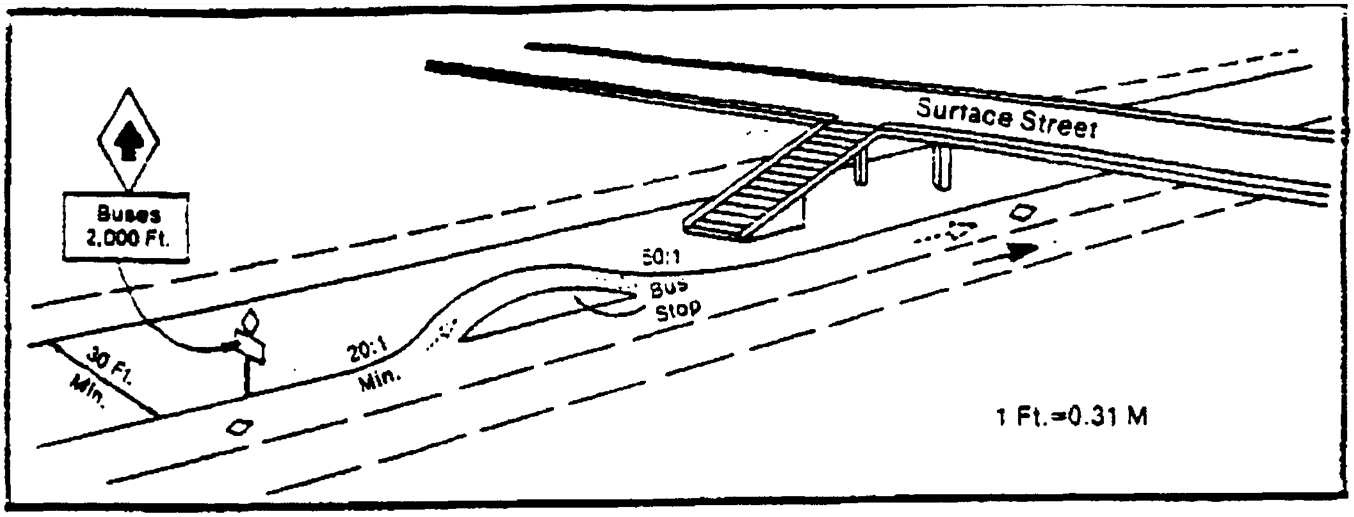




Note: Percentages for bus passengers include both regular route and charter passenger miles.

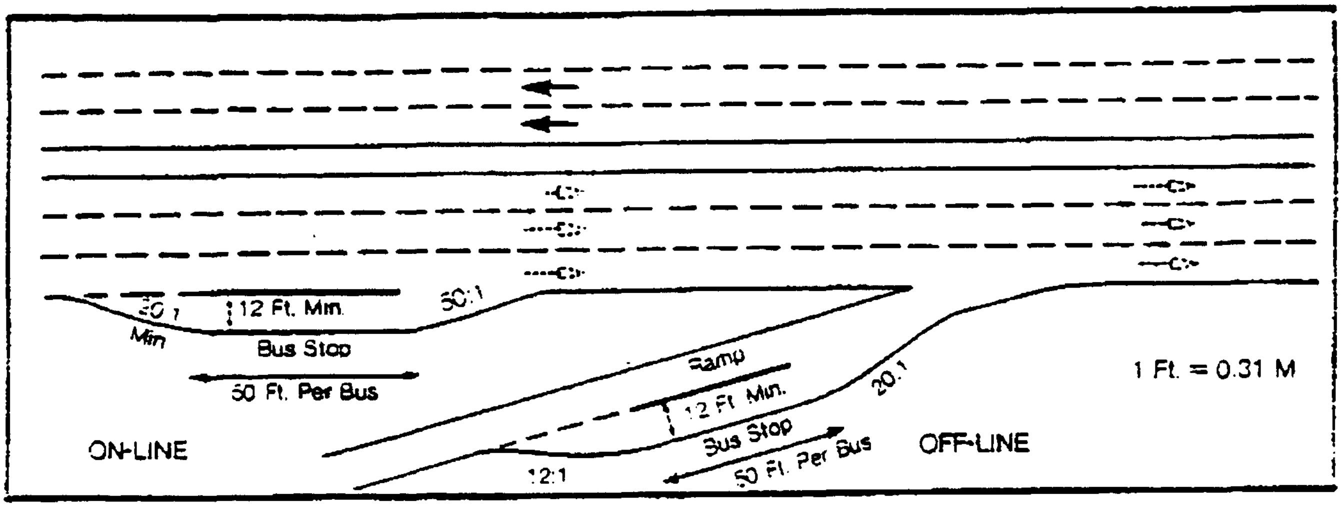
Source: Eno Foundation for Transportation, Transportation in America (Westport, Conn.: May 1991 and Dec. 1991) and Historical Compendium 1939-1985, (Westport, Conn.: 1986).

Modal Comparison of Domestic Intercity Passenger Miles, 1960-90
Figure A–7



MEDIAN BUS STOP

Source: High Occupancy Vehicle Facility Development, Operation and Enforcement.



BUS TURNOUTS

Source: High Occupancy Vehicle Facility Development, Operation and Enforcement.

Figure A–8
Express Bus/HOV Station Stops

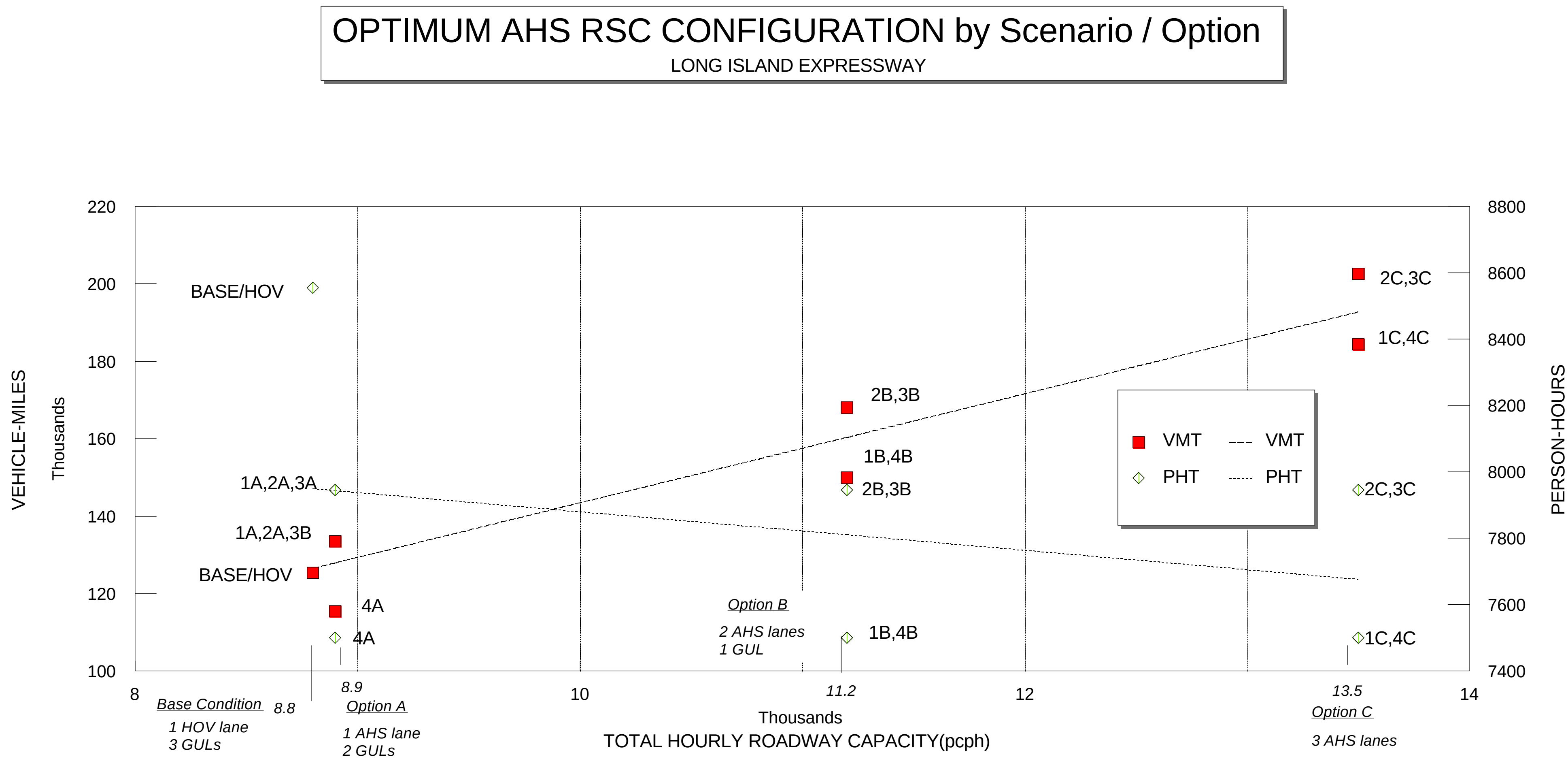
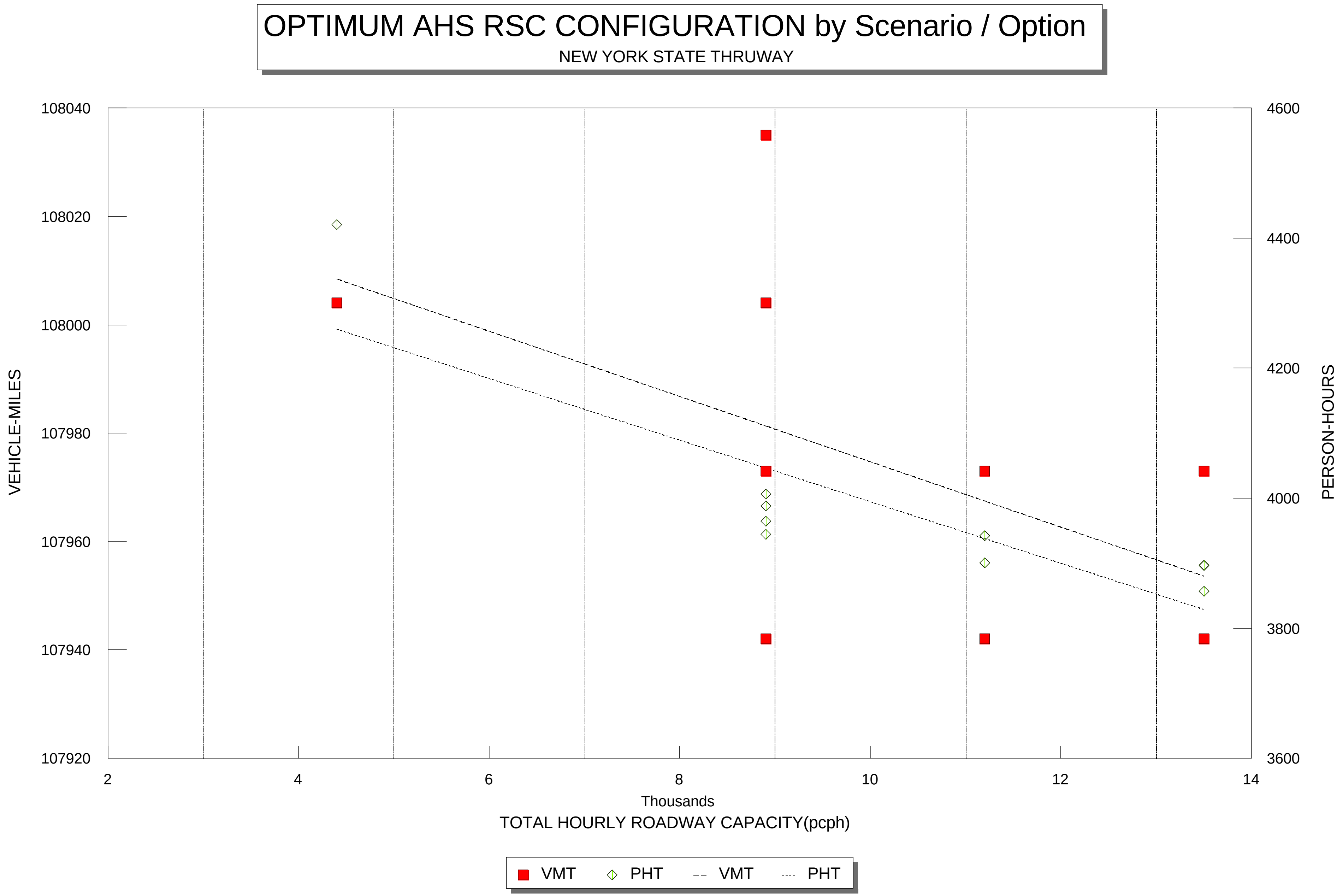
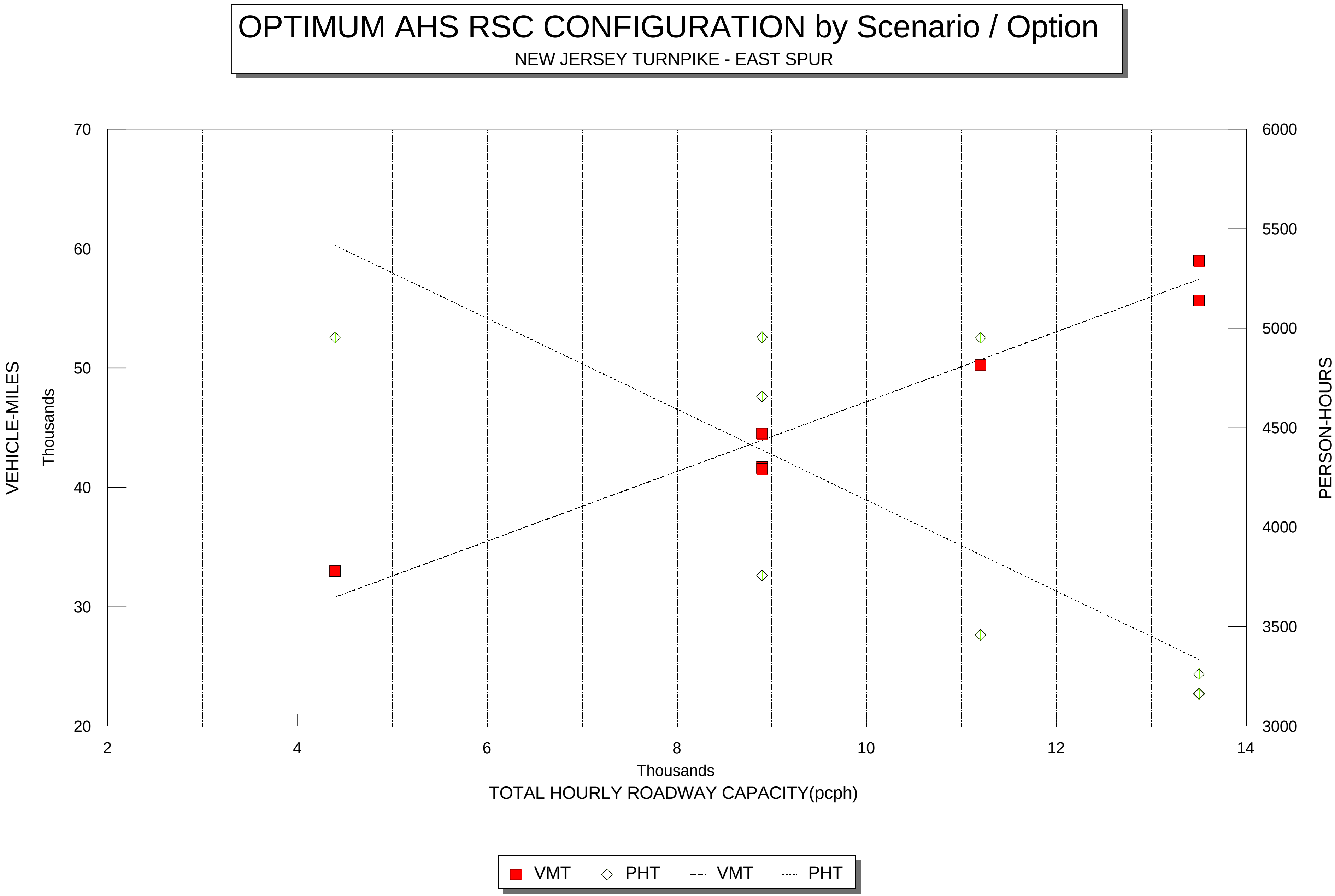
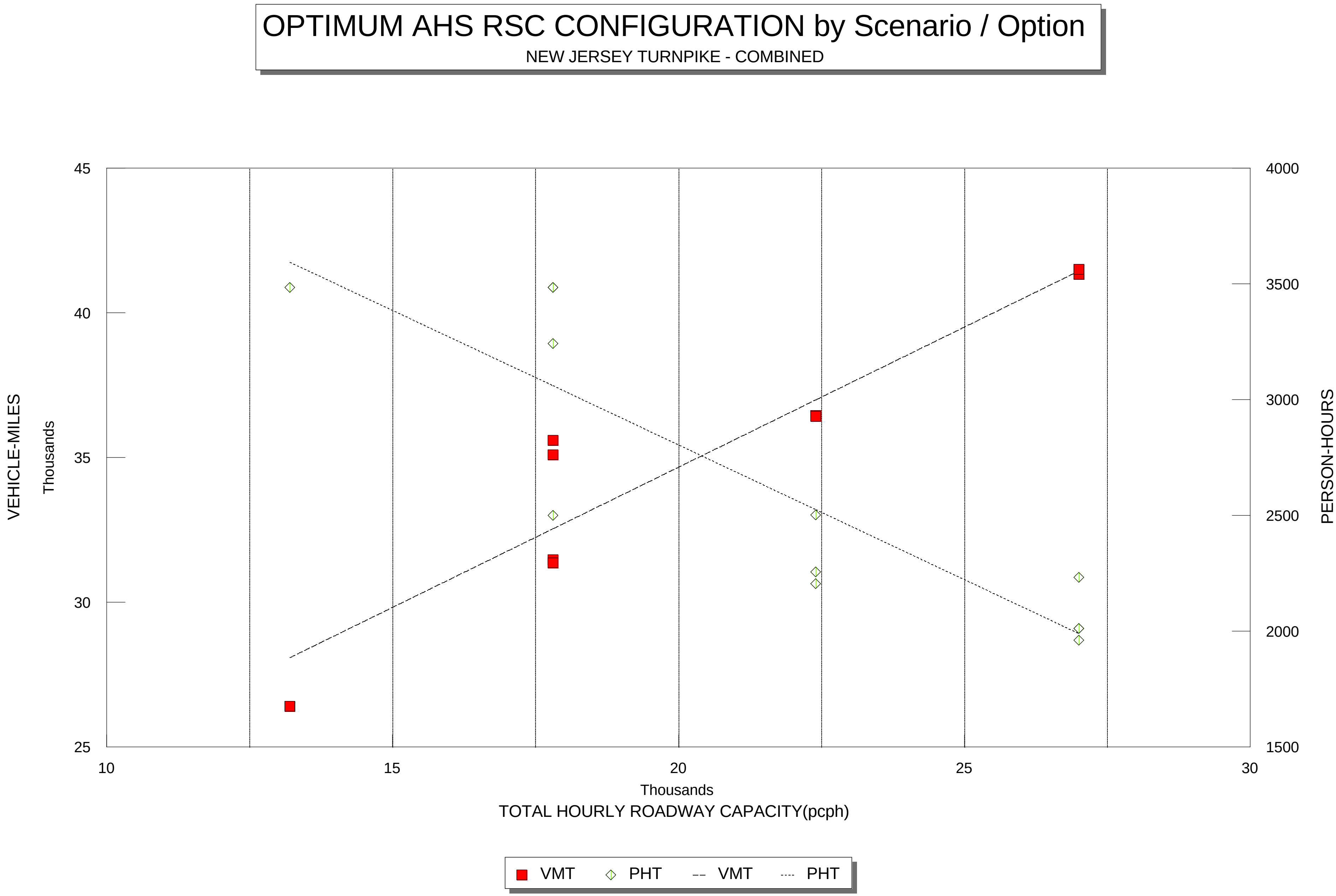

OPTIMUM AHS RSC CONFIGURATION by Scenario / Option
LONG ISLAND EXPRESSWAY
VEHICLE-MILES
Thousands
PERSON-HOURS
TOTAL HOURLY ROADWAY CAPACITY(pcph)
Thousands
220
200
180
160
140
120
100
8800
8600
8400
8200
8000
7800
7600
7400
8
10
12
14
8.8
8.9
11.2
13.5
BASE/HOV
1A,2A,3A
1A,2A,3B
BASE/HOV
4A
4A
2B,3B
1B,4B
2B,3B
1B,4B
2C,3C
1C,4C
2C,3C
1C,4C
VMT
PHT
VMT
PHT
Base Condition
1 HOV lane
3 GULs
Option A
1 AHS lane
2 GULs
Option B
2 AHS lanes
1 GUL
Option C
3 AHS lanes

Figure A-9


OPTIMUM AHS RSC CONFIGURATION by Scenario / Option
NEW YORK STATE THRUWAY
VEHICLE-MILES
PERSON-HOURS
108040
108020
108000
107980
107960
107940
107920
4600
4400
4200
4000
3800
3600
2
4
6
8
10
12
14
Thousands
TOTAL HOURLY ROADWAY CAPACITY(pcph)
VMT
PHT
VMT
PHT


OPTIMUM AHS RSC CONFIGURATION by Scenario / Option
NEW JERSEY TURNPIKE - EAST SPUR
VEHICLE-MILES
Thousands
70
60
50
40
30
20
PERSON-HOURS
6000
5500
5000
4500
4000
3500
3000
2
4
6
8
10
12
14
Thousands
TOTAL HOURLY ROADWAY CAPACITY(pcph)
VMT
PHT
VMT
PHT



OPTIMUM AHS RSC CONFIGURATION by Scenario / Option
NEW JERSEY TURNPIKE - COMBINED
VEHICLE-MILES
Thousands
45
40
35
30
25
PERSON-HOURS
4000
3500
3000
2500
2000
1500
10
15
20
25
30
Thousands
TOTAL HOURLY ROADWAY CAPACITY(pcph)
VMT
PHT
VMT
PHT

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APPENDIX B: ANALYSIS OF COMMERCIAL AND TRANSIT MARKETS FOR AHS SERVICES (PRINCETON UNIVERSITY)

B.0 EXECUTIVE SUMMARY

As described in the Abstract of the Technical Report Documentation Page, this task was performed as two efforts. The Executive Summary that follows represents the second of two parallel studies. The detailed results are reported in the remainder of Appendix B.

This section investigates how commercial and mass transit versions, as opposed to privately-owned, single-vehicle-equivalent (SVE) versions, of AHS can serve the commercial segments of the nation's transportation demand.

The analyses are user-oriented. They focus on the user (shippers and transit riders) demand for transportation. They seek to determine the extent to which those user needs are met by the services offered by public or private commercial operators of the various representative system configurations (RSC) of AHS. These analyses identify which AHS technologies have the best chance of providing user benefits to transportation providers (carriers, operators) and market-competitive services that will be purchased by transportation users (shippers, riders).

The analyses use various data bases that explicitly represent the existing spatial and temporal characteristics of commercial and transit transportation markets. It is these fundamental characteristics that AHS must serve competitively if AHS is to achieve a significant market penetration.

Separate analyses are carried out for each of the following commercial an transit market segments:

Inter-city Commercial Freight Traffic
Intra-city Commercial Freight Traffic
Commercial For-hire Inter-city Passenger Transport, and
AHS - based Urban Transit

Identified in each market segment were the fundamental market characteristics that could be better served with an AHS as compared to conventional technology. For example, the demand for inter-city freight transportation is widely distributed geographically. There exist no major corridor that serves even just a few origins and destinations. In general each stretch of road serves a large watershed of widely dispersed origins and destinations. For this reason, the initial stages of an infrastructure-based AHS is relegated to being able to serve only a short stretch of most shipments that travel over that segment. On the other hand, a vehicle-based AHS that can be used ubiquitously across the conventional highway infrastructure can serve essentially the entire trip length of all shipments served by even the first truck so equipped. Thus, a vehicle-based-RSC AHS has an enormous advantage in the initial stages of implementation.

For each of the market segments, the full array of AHS Representative System Configurations were analyzed to determine the extent to which they could effectively serve these markets. For those that were deemed to have the potential of achieving a significant market penetration an attempt was made at establishing some fundamental market parameters and potential market size. The perspective taken was to assume that the RSCs were operated by private or public entities that would offer to transport freight or passengers for a fee. The analyses were conservative in that they focused on only AHS's opportunities to serve existing demand. No attempt was made to try to forecast the growth or changes in demand that may be stimulated by the availability of the superior transportation services offered by AHS.

The analyses reached the following conclusions and findings:

For Commercial AHS Service of Inter-city Freight:

- The commercial freight inter-city market has most of its driving cycle on rural, uncongested interstate highways.
- Class 8 trucks, on average, log more than 125,000 miles per year of travel, of which 100,000 is on the interstate highway system.
- The market for class 8 trucks (over 33,000 pounds) is approximately 20,00 per year.
- Motor carriers have aggressively bought new technology that provides improved safety, comfort and convenience for the driver and advanced communication systems that improve the management of the truck fleet.
- A vehicle-borne, infrastructure-free RSC 2-type system that would be usable on much of the nations interstate and expressway highway system without any infrastructure improvement would be extremely attractive to motor carriers (and the inter-city bus industry). A good price point for these systems would be a capital outlay of about $5,000 , and a maintenance cost of less than $500 per year. At this level this adds about one cent per mile to a truck's operating costs.
- At a 50% market penetration of new sales, there is a $250 million annual market for a $5,000 vehicle-borne RSC-2 type system that is installed as optional equipment on new class-8 trucks. Conversions of existing trucks increases proportionately the size of this market.
- An infrastructure-based, RSC 8-12-type AHS has a clear evolutionary path starting with dense 1,200 mile corridor along I-80 between Chicago and Salt Lake City. Each mile of such a system could serve as many as 1.8 million truck movements per year if the economics are right. Because such a system would serve only a small portion of the driving cycle of most trucks using the system, the on-vehicle hardware costs can't be amortized over as many miles as an RSC 2, infrastructure-free system. It will be paramount to keep the on-vehicle costs extremely low so as not to stifle market entry by those trucks that could otherwise use the system.
- Future evolu tions of an RSC 10-11-type AHS could grow to an 11,000 mile system that could serve roughly 50% of the current truck-served, inter-city freight market.
- Even by assuming a 100% market penetration, the 11,000 mile RSC 8-12-type AHS would only generate toll revenues of $110,000 per route mile at toll rates of $.10 per mile. This level of tolls can service the capital debt of about $1 million per mile. It is unlikely that motor carriers would be willing to pay AHS tolls that are much greater than $.10 per mile
- A driverless, SVE, RSC-8/9-type, Phase 3 AHS concept could serve a substantial amount of LTL demand. If toll charges are limited to approximately $.10 per vehicle mile, then, LTL demand patterns, shipment size, vehicle costs and existing freight rates suggest that each mile of such a system could serve as many as 600,000 of

these shipments per year. Assuming a 50% market penetration, traffic densities on a Phase 3 network could generate toll revenues of about $30,000 per route-mile per year.

- Comparing the basic economics of the market for a driverless, RSC-2-type AHS with an infrastructure-intensive RSC 10-11-type AHS suggests that an RSC 2-type system is much more attractive to the inter-city freight industry. It's on-board costs can deliver benefits over much more of the driving cycle, the system has a much lower cost of entry (infrastructure does not have to be built), and even a mature RSC 10-11-type AHS does not serve enough volume, even at a large toll ($.10/mile) to service the cost of the infrastructure. This finding suggests that R&D investment focused on reducing the cost of reliable vehicle-borne, infrastructure-free RSC-2 type systems is the best way to have AHS successfully serve the inter-city freight market.

For Commercial AHS Service of Intracity Freight:

- Intra-city freight and the collection and distribution of inter-city freight are extremely difficult to serve with automation. The small shipment size and the multiple stop character of the operation are not conducive to automation.
- As with inter-city commercial bus operation, the driver performs more functions than simply driving the truck. The driver is the service interface with the customer.
- The geographic diffusivity of this traffic is such that much of the intra-city goods movement driving cycle takes place on road segments that are not compatible with an RSC-2 type AHS. Because each vehicle logs relative low annual mileage vehicle-borne AHS hardware can be amortized only over those few miles. An infrastructure-intensive RSC 8-12-type AHS serve even less of the driving cycle.
- AHS does not seem to be particularly attractive to this market.

For Commercial AHS Service of the Inter-city Passenger Market:

- The commercial inter-city market is small in comparison with the inter-city passenger market served by the private automobile.
- The only likely short term commercial inter-city passenger market for AHS is that of inter-city bus. This is a very small market. Only 1,000 new inter-city buses are sold each year. However, the driving cycle of an inter-city bus is similar to that of an inter-city truck. Thus, it could provide a good secondary market for an RSC 2-type AHS that was designed to serve the inter-city freight market.
- The bus market is less conducive to a driverless AHS because the driver provides substantial benefits other than driving.
- An infrastructure intensive AHS has better opportunities than commercial freight to serve geographically contained sub-markets, because commercial buses can be managed to operate in constrained corridors. Such a system could better serve geographic segments of the automobile market because the driving cycle of a particular automobile is much more geographically constrained than that of an inter-city truck.

- The large inter-city market is served by the private automobile. Unfortunately, on average, the private automobile travels too few miles on inter-city expressways to justify spending even a modest amount for an RSC 1/2 type system. However, there may exist some significant sub-markets, such as traveling salesmen, that could easily justify investment in an RSC 1/2 type system. Such systems also become more attractive if they could be used for the daily commute portion of the automobile's driving cycle.

For Commercial AHS Service of the For-hire, Intra-city Passenger Market (Transit):

Three major AHS technologies were analyzed for potential service of intra-city passenger traffic: automation of conventional mass transit, dual-mode transit and guideway-captive small vehicle automated guideway transit. For conventional transit, automation of the exclusive bus lane leading to the Lincoln Tunnel served as a case study. For dual-mode and analysis was performed that assessed the service potential of an state-wide dual-mode system in New Jersey. The following conclusions were reached:

Conventional Mass Transit-Automation of the Lincoln Tunnel - I-495 Exclusive Bus Lane:

- This system has the enormous people moving capacity of over 30,000 people per hour
- Technology requ irement are relatively modest
- Infrastructure requirements are very modest
- Such a system is potentially the best candidate for an early successful implementation

Dual-mode "Mini-bus" System for New Jersey.

- This analysis shows that a relatively small 538 mile dual-mode AHS network could serve more than 70% of NJ's work trips that are currently taken by auto and are greater than 5 miles in length. This is a very strong finding. It needs to be moderated somewhat because we only analyzed ability to serve. We did not attempt to determine how many of those trips would likely divert to a dual-mode system if such a system were to be built and the service offered.
- This analysis does highlight the fact that many work trips are close by in origin, destination and time. A service that would easily enable dynamic ride-sharing through the use of automation has a large market potential. It can attain enormously high average occupancy levels that can reach 4.5 passengers per vehicle in the peak period.
- Because NJ's work trip patterns are thought to be similar to those that exist in many metropolitan areas, the dual-mode concept may have wide applicability.

Analysis of Driverless AHS Transit Opportunities:

- In summary, driverless AHS systems would require an exclusive AHSway as envisioned in RSC 9-12.
- The driverless feature is not attractive to providers of inter-city passenger transportation and intra city freight transportation because the driver provides substantial services beyond those of "driving" that can not otherwise be automated.

- On the other hand, inter city freight and intra-city passengers can do without a driver, if the difficulties of access can be dealt with. In these situations, a driverless AHS may gain a significant cost advantage while providing comparable user service.

Conclusions for the Transit Market:

- Urban transit, that is, for-hire, intra-city passenger transportation is only a small fraction of intra-city person transportation which is dominated by the private automobile. Nationally, transit serves only 3% of intra-city person trips.
- Only the express bus sub-market of transit is conducive to the early stages of AHS. A particularly attractive example of such a system is the exclusive counter-flow bus lane leading to the Lincoln Tunnel. This is the busiest bus corridor in the US
- There are several fundamental characteristics that make the Lincoln Tunnel XBL a particularly good application for AHS. First, there is a monumental problem on the horizon if a substantial capacity improvement is need in this facility. There is no place to put another access lane and the cost of boring another tube is enormous. Thus, capacity through automation would surely be the most cost effective solution. Even without need for capacity improvement, automation would smooth out the flow of buses and improve the travel time reliability of the buses. The application is on a very short corridor, less than five (5) miles, and the same busses use the facilities repeatedly. The institutional challenges are "minimal". All buses are the property of NJDOT and were purchased with PANYNJ money. NJDOT and PANYNJ have authority over all operations and construction in the corridor. For these major reasons, this is an excellent candidate "early winner" for AHS
- A Dual-mode service over a 750 mile NJ AHS network could provide auto-like service 780,759 passengers (71 %) out of NJ's 1,116,985 daily auto-based work trips that are greater than 5 miles in length. A $.10 per passenger mile fare would generate annual revenues of about $800 million. It may well be that fares would need to be more like $.20 -$.25 per mile for such a system to begin to contribute to the debt service payments for the AHSway.
- The average vehicle occupancy is 4.68 passengers per dual-mode vehicle. This is an enormous average vehicle occupancy, especially when compared with that of the current automobile's value of 1.1 for work trips. Because of this high average vehicle occupancy, the densest link on the network needs to serve a maximum of only 2,000 vehicles per hour.
- Dual-mode is an interesting transit concept for a mature AHS. It needs to have access to an rather extensive network of AHSways in order to serve a significant portion of urban/suburban travel demand.
- A driverless AHS transit application could piggy-back onto the economies of scale associated with private vehicle development and the AHSway construction.
- A driverless AHS transit system could serve metropolitan trip demand nearly as well as dual-mode without the need of drivers and with less confusion in the collection and distribution. This concept make more sense as the size of the network of AHSways grows, thus, reducing the access problem.

B.1 BACKGROUND AND APPROACH TO THE COMMERCIAL & TRANSIT MARKET SEGMENT

This section investigates how commercial and mass transit versions, as opposed to privately-owned, single-vehicle-equivalent (SVE) versions, of AHS can serve various segments of the nation's existing transportation demand.

The analyses are user-oriented. They focus on the user demand for transportation and attempt to determine the extent to which those user needs are met by the service capabilities that could be offered by public or private commercial operators of various representative system configurations (RSC) of AHS. Analyses are carried out that seek to determine which AHS technologies have the best chance of providing competitive services that will be purchased by the nation's transportation providers (carriers, operators) and users (shippers, riders). The analyses use various data bases that explicitly represent the existing spatial and temporal characteristics of these markets. It is these fundamental transportation characteristics that AHS must serve competitively if AHS is to achieve a significant penetration into the commercial and transit markets.

The analyses focus on major transportation market segments. The demand for transportation can be classified into market segments that are served by transportation technologies that meet their particular needs. These market segments can best be visualized as areas in a two-dimensional space of commodity (people, freight) and geography (intra-city, inter-city), as is depicted in figure B1. For example, the mass transit serves people traveling within cities, while the less-than-truck load carriers serve portions of the inter-city freight market.

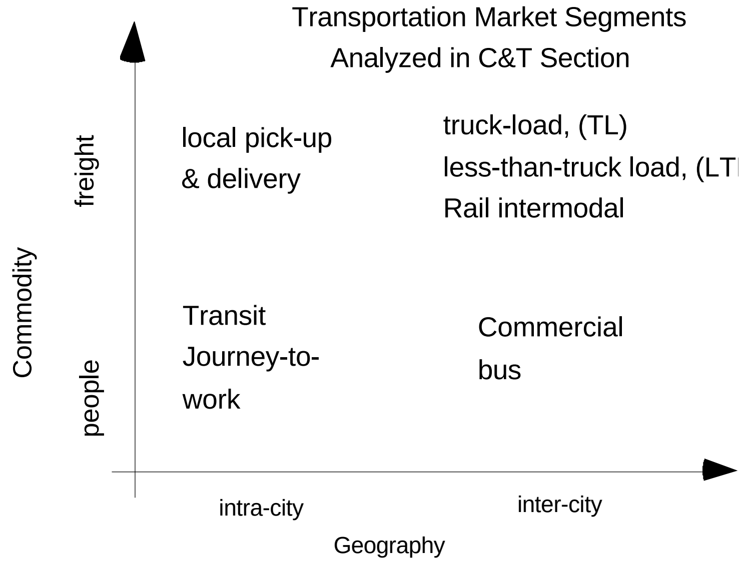

Figure B1. Transportation Market Segments Analyzed in the C & T Section

The supply side of transportation is the technology itself and how it operates to serve the demand. It models the operational and service characteristics of the various technologies that compete to serve the demand. In the AHS context, it encompasses the various RSCs.

This commercial & transit section focuses on the RSCs, operated by private or public entities, that would offer to transport freight or passengers for a fee. These markets are now served by the following modes. The private automobile and mass transit serve the intra-city movement of people. Local pick-up & delivery trucks serve the intra-city movement of freight. Many modes serve the inter-city movement of freight. The special needs of very large inter-city shipments of low-valued commodities and small shipments of very high-valued commodities probably can't be served competitively by any of the AHS RSCs. This leaves truck-load (TL), less-than-truck load (LTL), and rail intermodal as the only modes that serve inter-city freight demands that may be susceptible to diversion to AHS. Commercial bus traffic is the only form of inter-city personal travel that can conceivably be served by a for-hire AHS. Private automobile inter-city travel can be served by a SVE of AHS, but this analysis is not part of this section. It was assumed that AHS could not effectively compete for inter-city air passengers.

Our analyses are conservative. They focus on only AHS's opportunities to serve existing demand, even though one should forecast the demand that will exist for transportation at the future time when AHS will be providing service. This is a very challenging task. A precise forecast is nearly impossible to generate, on the other hand, the fundamental character of the demand doesn't change very much, especially when viewed from the needs of the user. That is, certainly the geographic patterns of the demand evolve over time, as well as the numbers and types of unique users, but the general demands of the market place do not. To reflect opportunities created by the introduction of service-improving technologies like AHS, the forecasted demand can be considered as a combination of the existing demand plus its expansion over time and finally latent demand, demand that will be created by new efficiencies and opportunities delivered by the new technology. For example, the freight and passenger demands of 45 years ago in 1949 were fundamentally not very different than those that exist today in 1994 from a user point of view. People had to go to work, shop; global logistics existed. Today's underlying demand is quite similar, but the scale is expanded and new markets have been created and served. Extrinsic effects such as population growth and a growth in real disposable income account for a large portion of the scale increases in the demand for transportation. The new markets were a response to the new service opportunities.

Estimating the share of the demand that a particular modal technology will capture is also challenging. For a new technology, much of its early demand is due to a modal shift of traffic from existing modes. Following some modicum of success the new technology begins to be capable of generating some latent demand associated with the extension of old and the creation of new markets. Only after the technology is mature, can the latent demand evolve to become a major contributor to the market success of the technology.

This demand evolution was experienced by our current transportation technologies. The large increase in inter-city passenger transportation that was afforded by the creation of the interstate highway system and the development of air transportation technology evolved progressively. It first shifted the horse & buggy and train trips, then expanded the scope and scale of those trips and finally created new trip demands that could never have been served by those displaced technologies. Thus, a complete market study of a new technology can be structured in three progressively more difficult steps. The first focuses on diversions from existing modes, the second scales those shifts to reflect future expansions of the economy and the third attempts to identify the new markets that will emerge as a result of the fundamental service advantages of the new technology. Of these three steps only the first can be carried out with some confidence; and then only if one has access to existing demand data. The second step requires assumptions, that contain a great deal of uncertainty, about many macro economic variables such as general economic growth and changes in disposable income. The third, the identification of latent demand is extremely speculative.

This report focuses on only the first of these market studies, that of service to existing user demands. In such a study it is important to focus on the needs of the eventual users and not on the contemporary supply-side technologies that currently serve that demand. Simply because certain commodities move in large trucks today doesn't necessarily mean that the underlying demand for that commodity is for shipment in large, intermittent volumes. In fact, it may be that the shipper is better served by smaller, more frequent, deliveries of this good in a more "just-in-time" manner. It may simply be that the economies of the current mix of transport technologies made it more economical for the shipper to absorb inventory inefficiencies in return for a volumetric economy of scale. The economic tradeoff between inventory levels and shipment size may have significant implications on the relative competitiveness of the various representative system configurations (RSC) of AHS. A driverless AHS concept alleviates much of the driver productivity economies that are the motivating economic forces for ever increasing truck sizes and weights in our existing highway system. Users may prefer smaller rather than larger AHS vehicles. This is not such a radical notion. One need only look back to the end of the last century at the transport of people to work in cities. The technology was evolving to ever-larger electric trolleys that took increasing advantage of the labor productivity of trolleys operated by a single person. From a transportation supply-side perspective, one would have thought that all of those goods (people) wanted to travel together. Not so! The private automobile eliminated the cost of the driver and it's associated economies of scale. It thus enabled user-oriented non-stop no-wait on-demand characteristics to become dominant. With the growth in the ubiquity of travel choices in space and time provided by an increasing highway infrastructure, the private automobile unleashed a vast amount of latent demand that could not have been forecasted at the turn of the century. Many, if not most, of today's auto trips would be viewed as unjustifiable from that perspective .

B.2 OPPORTUNITIES FOR AHS SERVICE OF THE COMMERCIAL INTER-CITY FREIGHT MARKET

B.2.1 Characteristics of Inter-City Commercial Freight Traffic

All modes of transportation, including truck, rail, air, water, and pipelines, serve the inter-city freight market. This market is extremely broad and heterogeneous, with almost each commodity having needs that require specialized supply-side characteristics. Many commodities require special vehicles. Certain modes serve only special groupings of commodities, such as liquids in pipelines, large bulk commodities in water-borne vessels and small packages in airlines. Transportation technologies have evolved by making tradeoffs that better serve the particular needs of certain commodities, while leaving other commodities to be served by other technologies. In this way, each has carved out a market in which it thrives. The most basic tradeoff is between frequency/speed and volume. This tradeoff is driven by the economies of the vehicle/vessel, the way (roadway, waterway, railway, etc.) and the operations (labor and energy). Since one hasn't been able to devise an inexpensive, yet fast mode of travel, the existing modes have evolved to provide services at various tradeoff levels between speed and cost. Thus, air transport is fast but expensive, and since "time-is-money" they have evolved to serve high-valued commodities, i.e., those that have high inventory costs (figure B2). Motor carriers serve relatively high-valued goods. Railroads and pipelines serve moderately low-valued goods and waterways serve low-valued goods. The figure below depicts the relative range of inventory value / Origin-Destination volumes that are served by current modes of freight transportation. High valued goods have low O-D volumes and are served by air. Motor carriers serve relatively high time sensitive goods in markets having moderate volumes. In markets where volumes are higher, the economies of rail-highway intermodal services have diverted this traffic from the all-highway mode. For goods having lower values than conventional rail, pipeline and/or barge is the dominant mode.

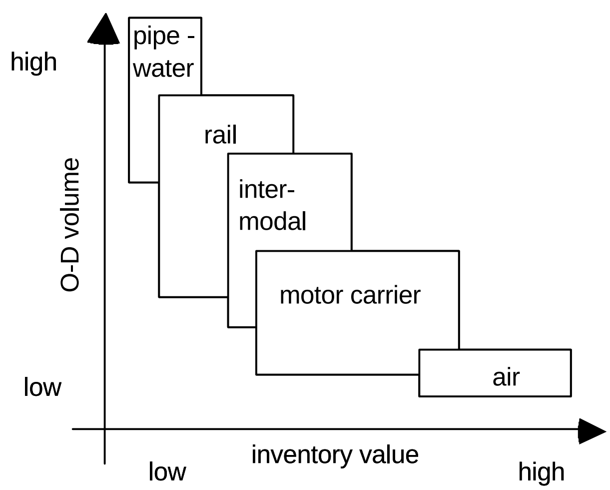

Figure B2. Volume - Inventory Tradeoff for Major Modes of Freight Transportation

In a gross sense, the 2.9 trillion ton-miles of inter-city freight transportation in 1991 was modally distributed as follows: rail 37.4%, truck 26.3%, waterborne 16% and air 0.4%. To assess how much of this traffic AHS is likely to be able to serve, one must determine which of these modes has service and cost characteristics that are likely to be comparable or worse than AHS. Certainly AHS has service and, will need, cost characteristics that are comparable to inter-city motor carrier transportation. If costs can be contained, AHS's service advantage should allow it to compete with rail intermodal service. Otherwise, AHS cannot compete with air's fast service, or the low cost of general merchandise and unit train operations, inland barge operation or pipeline operations. Thus, only truck and possibly the intermodal portion of rail traffic can be viewed as having any possibility of being served by an inter-city AHS. While a lot is excluded, these are still very large markets whose combined volume is approximately 30% of the nations inter-city ton-miles.

Now that we have identified the users that could benefit from the favorable service and cost characteristics of AHS, one needs to understand the geographic scope that AHS operations will need to serve in order to capture some of these markets. If the traffic is concentrated on a few corridors, then with rather modest geographic scope, one may be able to deliver competitive AHS service; however, if the traffic is widely distributed, then one will need to develop an evolutionary investment and operations plan that initially captures a significant sub-market. Once launched, an orderly geographic expansion of services can be planned. This can be accomplished by understanding the operational and geographic characteristics of truck and rail-truck intermodal services.

B.2.1.1 General Characteristics of Inter-City Truck Operations

Inter-city truck operations have several characteristics that are very relevant to the design of a commercial freight AHS operation. The following general characteristics were obtained from interviews with operating management from several inter-city TL and LTL companies.

B.2.1.1.1 Utilization Rates

Most class-8 tractors travel between 100,000 and 200,000 miles per year. For most companies the fleet average is roughly 125,000 miles per year per tractor. Most of these miles are driven on major highways. For any particular tractor, that mileage is distributed over many different road segments rather than being repetitively traversed over the same corridor. This observation has important consequences on the market potential of various RSCs for inter-city commercial freight. Vehicle-intensive/infrastructure-free RSCs can provide service over most of the tractor's driving cycle, and they can provide this service from the day that the technology is installed in the tractor. An infrastructure-intensive/vehicle-free RSC will serve only a small portion of any trip but it can serve all trucks as soon as the infrastructure investment is complete. As more infrastructure is made available, more of each trucks driving cycle can be served. For RSCs that require both infrastructure and vehicle technologies, opportunities are more limited. Infrastructure has to be built and on-board hardware has to be acquired whose value is limited to the portion of the driving cycle that travels over the infrastructure.

B.2.1.1.2 Driver Turnover

Driver retention is a major headache for inter-city trucking companies. Driver turnover rates are typically around 100% per year. Working conditions are not very good. The irregularity of shipment origins and destinations makes it difficult for drivers to be assigned to loads that allow them to return home on a regular basis. The monotony of driving coupled with the need to react instantly to the rare emergency situation places high stress on the driver. Taken together, today's truck driver has a poor work environment which manifests high turnover rates. Motor carriers have instituted many programs to try to improve working conditions. The investment in satellite communications, anti-lock brakes and cruise control are not only justified by direct safety and performance benefits, but also by the improvement in working conditions for drivers.

B.2.1.1.3 Investment in New Technology

Motor carriers are in many ways leading in the implementation of in-vehicle IVHS technology. Qualcomm has sold its satellite-based communications and tracking system to more than 315 trucking companies. 85,000 inter-city trucks are so equipped today. Also, essentially all new class-8 trucks are equipped with the standard option of anti-lock brakes and cruise control. Computers are replacing log books in most truck cabs and electronic documents and permits are speeding trucks through weigh stations and border crossings. Thus, the industry has a track record for investing in technology that improves safety, productivity and driver comfort and convenience.

B.2.1.1.4 The Cost of a Truck Driver

The current market rate of pay for an inter-city truck driver is between $.27 and $.32 per mile plus benefits. Those with more experience get the higher rate. Union drivers and those transporting hazardous materials generally get a little more. Fringe benefits, which include vacation, medical insurance and social security payments can increase the driver cost by as much as 30%. Management overhead on the driver can add another 20%. This brings the total cost of the driver to the $.40 - $.50 per mile range.

B.2.1.1.5 Market Size

The inter-city truck market is served primarily by class-8 (over 33,000 pounds) tractor-trailers. There are some 2 million of these trucks registered in the US. Domestic sales of new class 8 trucks were 108,000 in 1992 with a 5-year average between 1988 and 1992 being 112,000.

B.2.1.2 O-D and Geographic Characteristics of Inter-City Freight Traffic

A phased implementation plan for infrastructure-intensive RSCs should focus first on the most densely used truck corridors and progressively grow until a point when diminishing returns no longer justify additional investment. A first estimate of such a staged implementation can be obtained by studying the geographic distribution characteristics of inter-city truck and rail-truck intermodal traffic.

The geographic distribution of inter-city truck and intermodal freight traffic was studied using the Princeton Transportation Network Model and Geographic Information System (PTNM/Iris) Erera, 1994. This is a general purpose network analysis software package that has convenient computer graphic network editing and presentation modules. It executes on Iris series Silicon Graphics workstations. It contains a detailed network description of the North American highway infrastructure and routines that route traffic over the network, given demand data that specifies shipment origins and destinations. The traffic flow analysis uses a shortest path computation to assign the traffic demand to the network. The software outputs bi-directional volumes on each link of the network that it readily displays using traffic density maps.

The network used was the US portion of the PC*Miler ver. 7.0 highway network. This network is widely used in the motor carrier industry to route trucks and compute driving distances between arbitrary locations in North America. This network is composed of more than 80,000 links representing some 450,000 miles of roads. Link attributes include distance, road type, number of lanes and tolls and its range of node attributes allow many traffic data bases to be readily assigned to the network. Nodes represent over 200,000 places. Node attributes include latitude, longitude, place name, state, 5-digit ZIP code, and standard point location code.

Data depicting recent inter-city freight movement is not readily available. The best data is the Interstate Commerce Commission's Rail Carload Waybill Sample. Federal statutes require each class-1 railroad to submit to the ICC detailed movement data on 2.5% of its terminated carload shipments. Data elements include origin, destination, shipment size, commodity and revenue. Since no similar statutory requirement exists for the trucking industry, there are no good public data sources that contain detailed truck shipment information. The last nation commodity flow survey was conducted in 1977. Results of a new commodity flow survey are to be released in early 1995. Private data sources do exist. They are notoriously biased; however, they are the "only game in town". It was assumed that while biased, these data sources properly reflected the geographic distribution of truck traffic. Volumes were adjusted so as to match national ton-mile totals.

B.2.1.2.1 Description of the Inter-City Freight O-D Data Sets

B.2.1.2.1.1 ICC Carload Waybill Sample (CWS)

The best inter-city freight data is the freight railroad "Carload Waybill Sample" collected and maintained by the Interstate Commerce Commission, (Mody, 1993). This "2.5%" sample of individual carload movements has been collected on an annual basis since 1973. It contains numerous attributes for each sampled movement including origin, destination, commodity, shipment size and the freight revenue obtained by the railroad for transporting the shipment. This is the best publicly available freight database. Much of conventional rail freight traffic is transported in volumes that are too large to be serviced by an AHS; however, rail intermodal traffic which is contained in this data base could be served by an AHS.

There are 144,207 intermodal shipment data records out of 396,851 data records in the 1992 CWS. These represent some 6 million trailer movements for the year 1992.

B.2.1.2.1.2 Private Data Sources for Motor Carrier Traffic

While no government agency maintains data on nation-wide motor carrier traffic, there does exist some private sources for some of that traffic. Each of these sources suffers from a major flaw in that they are subsets of the total motor carrier picture and not a sound statistical sample of all nationwide movements. This is a severe limitation; however, one has no alternative.

The best of these data is the National Motor Truck Data Base (NMTDB) truck stop survey sponsored by the Association of American Railroads. This survey, conducted by Forest Baker between the years 1977 and 1988, surveyed drivers at strategically located truck stops mainly in the western part of the country. These surveys capture truck origin, destination and commodity. The main value of this data is that it does capture a good representation of the length of haul and geographic distribution of the traffic that flows through these truck stops. There are 108,650 shipment records in the NMTDB.

A second source of O-D motor carrier traffic data is the file obtained from a freight payment firm, called the TRANZACT file. This file contains excerpts from the actual computer-encoded bills of lading that have been submitted to this freight payment firm. As such these data are more reliable since the source is the actual movement records that the shipper has authorized payment for transportation. The limitation of this data source is that it's relationship to the broader movement of all motor carrier traffic is unknown.

The file contains 543,535 shipment records. The file contains a carrier code that classifies the carrier as either a truck-load (TL) carrier or a less-than-truck load (LTL) carrier. This code was used to segregate the data into two distinct files; one that represents the shipper demand served by TL carriers and the other to represent the demand served by LTL motor carriers. Each of these files were factored to reflect 1992 gross ton-mile totals reported by DOT.

B.2.1.2.2 Geographic Distribution of Inter-City Freight Traffic

The traffic data was flowed over the US highway network using the PTNM/GIS. The results of that traffic assignment process is displayed graphically in the form of traffic density charts contained in figures B3 through B6. In each figure the line thickness is proportional to the volume of traffic moving over that section of highway. The line thickness along any segment is made up of two bands, one drawn on each side of the link to represent the volume of traffic in each direction. When facing along one direction, the line thickness to the right of the link is proportional to the link volumes traveling in the facing direction. The line thickness to the left is proportional to the link volume in the opposite direction. This graphic feature readily exhibits the road segments that serve many trips as well as the prevailing direction of those trips.

Figure B3 displays the traffic density map of annual nation-wide truck-load traffic from the NMTDB file. It is recognized that this data source is biased by the limited survey locations where these data are collected. Fig. B5 shows this bias. Flows are much higher in corridors containing the survey stations. This is particularly evident on the I-80 corridor in the western portion of the US, the I-5 corridor along the west coast in California, and the I-70 corridor in the midwest. Two of the major survey locations are at truck stops on I-80 in Utah, I-5 in central California, and I-70 in Ohio. Since the is no survey location along I-95 this explains the low volumes displayed by this data source. These biases suggest that the NMTDB data may not be the best data source for a national freight analysis; however, it does exhibit some of the fundamental characteristics of the geographic distribution of long-haul freight traffic in the US. One of the major characteristics is the extent to which a great deal of traffic is concentrated on relatively few corridors. This is a good finding for AHS because it suggests that there are corridors of concentrated traffic density that can be designated as the initial segments of an evolving AHS network.

Figure B4 displays the traffic density map of the rail portion of annual nation-wide rail-truck intermodal traffic from the ICC waybill sample. These data were flowed on the highway network to depict the road segments that would be utilized if the rail portion of this traffic were to divert to the highway. The map shows that the railroads have diverted a great deal of east-west long haul traffic away from the highway mode. The traffic density map readily shows that:

1. the flows are rather balanced directionally, this is a response to the market place which has adjusted back-haul rates so as to generate balanced flows.
2. the dominant flows are east-west and not north-south. This is in part due to the fact that a significant portion of the intermodal rail traffic is part of trade flows from the Far East.
3. flows are much larger in the western portion of the United States than in the eastern portion. This is also a response to existing market forces that are such that intermodal traffic is competitive at relatively large lengths of haul. Rail intermodalism has become market dominant in distances

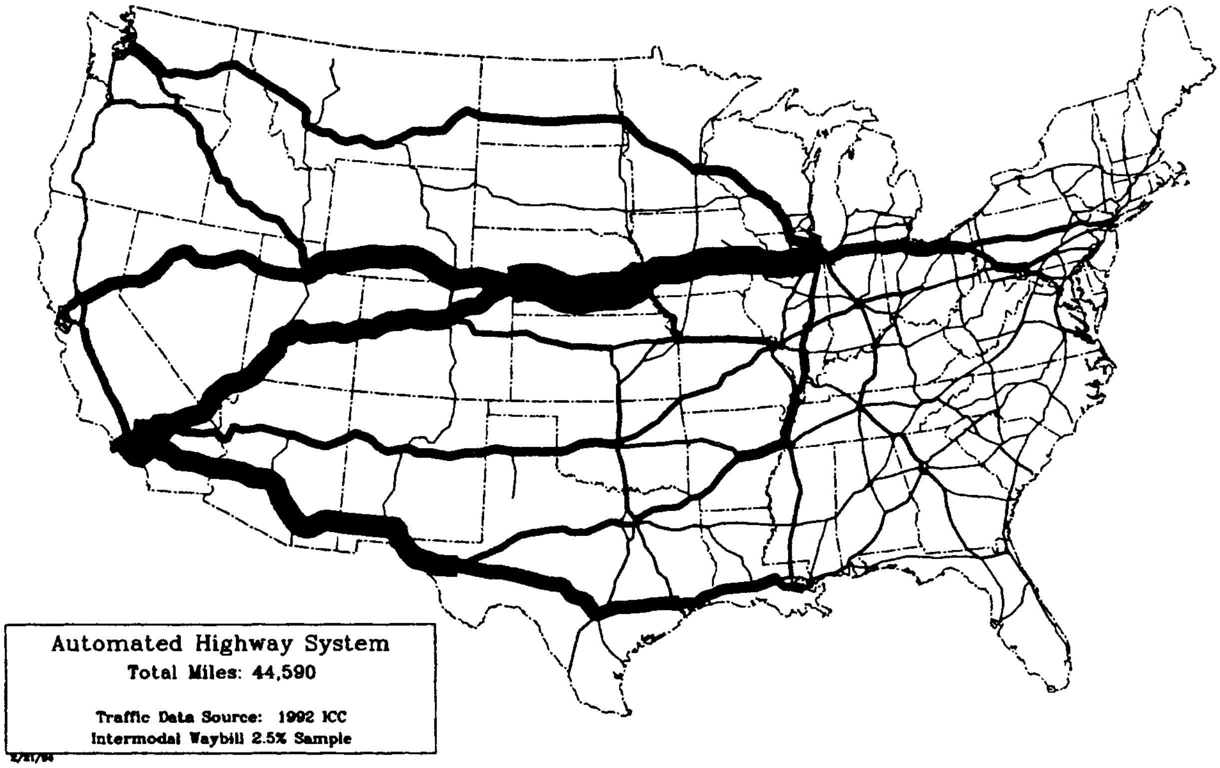

Figure B3. Geographic Distribution of NMTDB Traffic

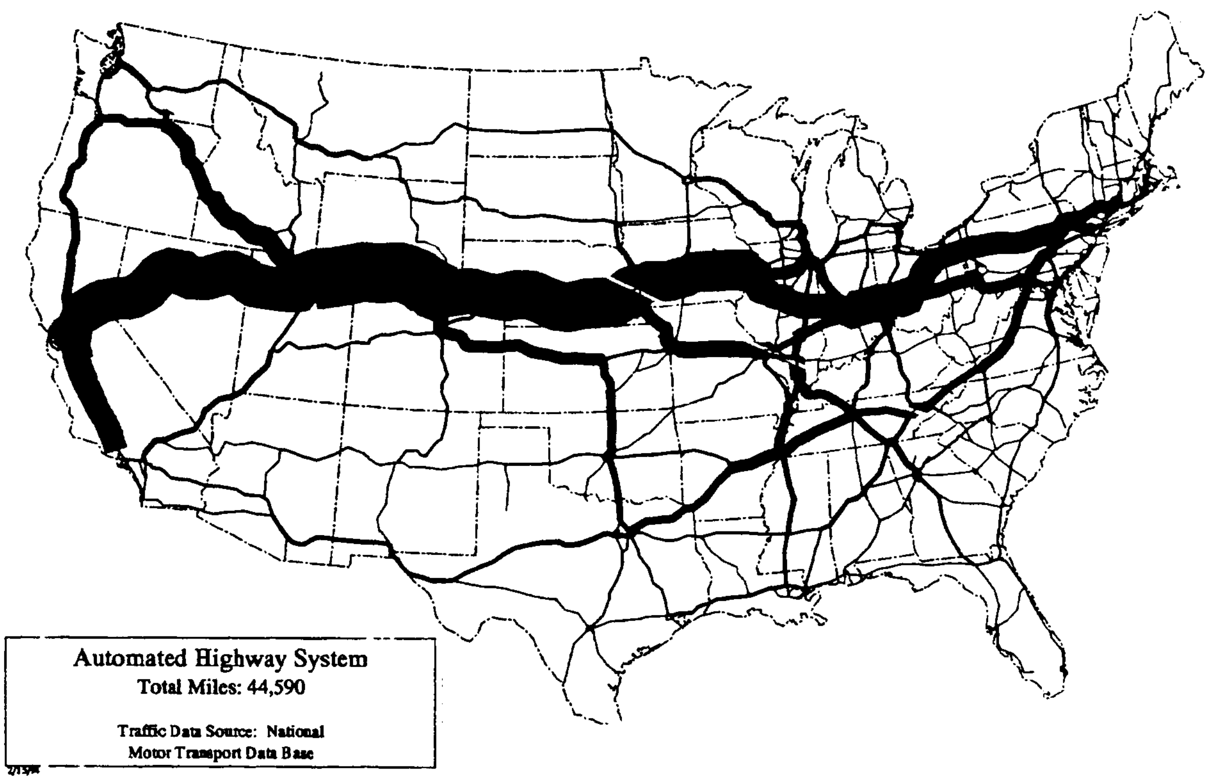

Figure B4. Geographic Distribution of Rail Intermodel Traffic Flowed on the US Highway Network for Year 1992

above 1000 miles. Significant volumes of these trip lengths mostly occur between the west and the midwest portion of the US.

4. The traffic flows show a concentration in the western portion of I-80, I-70 and I-10.

Figure B5 displays the traffic density map of annual nation-wide truck load traffic from the TL TRANZACT traffic file. These data are thought to be more representative of the nationwide distribution of truckload traffic because their source is a broad cross-section of the nations shippers. These data have been scaled to represent total annual ton-miles as reported by DOT (DOT, 1993). The measure of flow used in this, as well as the next, figure is truck loads, or more precisely, trailer equivalent units, TEUs. This conversion from ton-miles per mile makes the traffic density chart easier to relate to common knowledge.

The traffic densities displayed in Fig. B5 show that the highest density long-haul corridor is the I-80 corridor spanning the Chicago and New York metropolitan areas. Other dense corridors include the I-81 corridor through the Shennendoah Valley, the I-70 corridor to St. Louis and through to Kansas City and the I-5 corridor in California. The east-west corridors are relatively lightly traversed, in part because much of their former truck-load traffic has been diverted to rail intermodal. The I-80 corridor serves consistent densities of over 750,000 truck loads west bound and over 900,000 truck loads east bound per year. This compares to truck load volumes in the 500,000 - 700,000 range in the I-81 and I-70 corridors and the 500,000 range in the I-5 corridor.

Figure B6 displays the traffic density map of annual nation-wide less-than-truck load traffic from the LTL TRANZACT file. Readily evident from comparing the volumes in this figure with those shown in the previous figure is that LTL volumes are substantially less. TL volumes are approximately five (5) times those of LTL volumes. The geographic distribution of the LTL traffic is similar to that of TL. But there are differences. The highest density corridor is the I-81 which serves between 140,000 and 180,000 TEUs as compared to the I-80 corridor in the midwest that serves between 140,000 and 170,000 TEUs per year. The I-70 is also a heavily used corridor to/from St. Louis.

B.2.1.2.3 Summary of O-D Characteristics of Inter-City Freight

In summary, the geographic distribution of existing freight traffic that could be served by AHS is what one would expect. These corridors connect the major metropolitan areas of the northeast and the west coast. I-80 is a major corridor along with I-95 in the northeast and I-81 through Virginia. The traffic density charts contained in figures B3 through 6 convey the feeling that there does exist a rational evolutionary path for the construction of an infrastructure-based AHS whose initial modestly long corridors could serve a significant market. While I-95 is one of these corridors, it has high density over a rather short portion of its length. The I-80 and I-81 corridors have similarly large volumes over much longer stretches. More importantly, these stretches are through less developed land that may be more conducive to the construction of AHS infrastructure.

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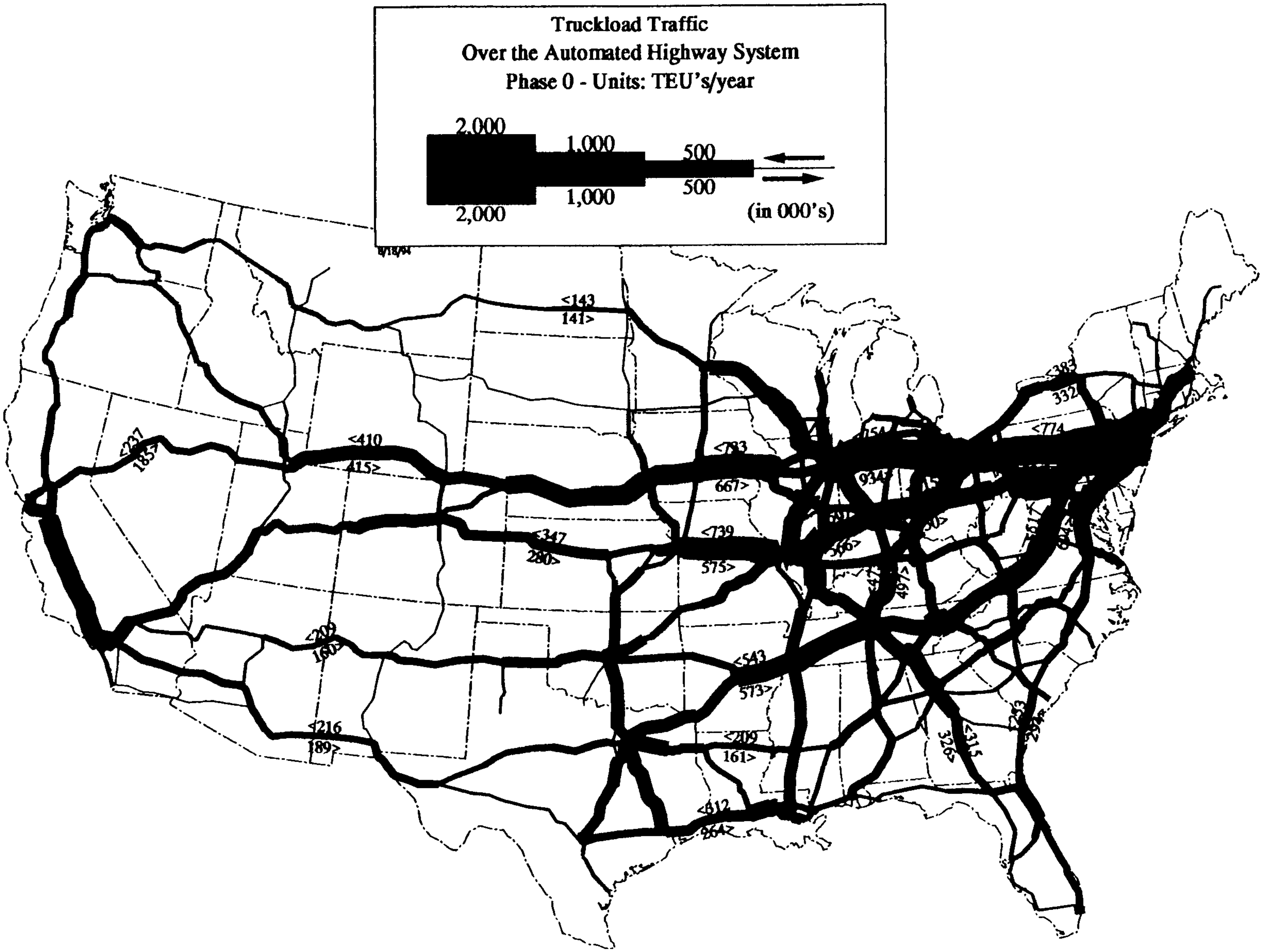

Figure B5. Geographic Distribution of TRANZACT Truck-Load Traffic Factored to Year 1992

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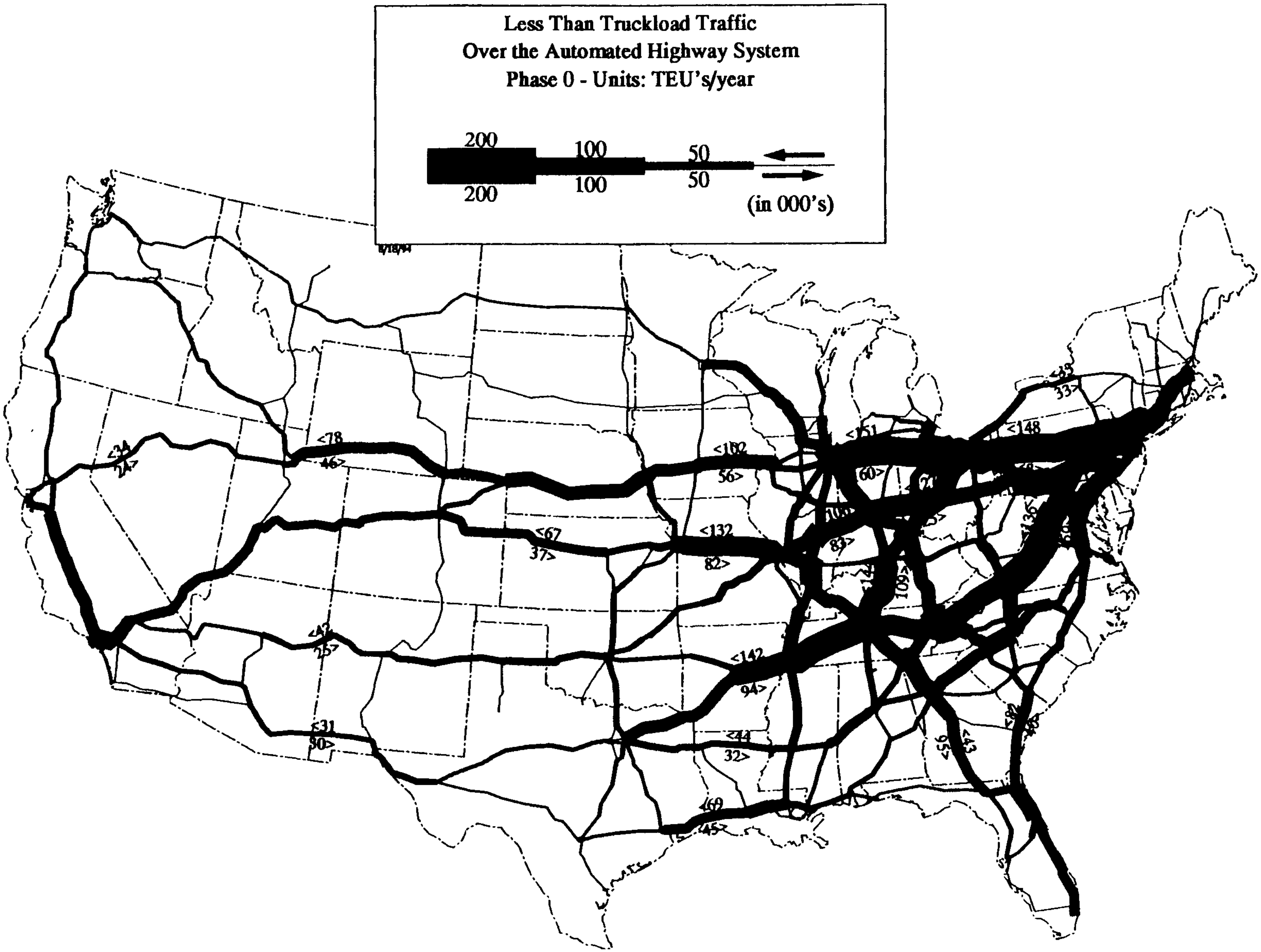

Figure B6. Geographic Distribution of TRANZACT Less-Than-Truck-Load Traffic Factored to Year 1992

A O-D characteristic that does not show up on the traffic density chart is how trucks serve a sequence of loads in time. Operationally, the linking of trips tends to be more like Brownian motion rather than "back-and-forth". This is especially for truck-load drivers that often don't know their next load until they are about to serve it. The linking of trips that get the driver back home even once a week is a major challenge for most motor carriers. This characteristic implies that for even the highest density corridor, "many trucks will use that corridor some of the time, but few will use it much of the time". Furthermore, this suggests that any infrastructure-intensive AHS will not be able to require any significant in-vehicle investment; otherwise, most trucks that could use the system some of the time will have difficulty using it enough to justify amortizing much of an in-vehicle investment.

B.2.2 Freight Traffic Analysis of Evolutionary Inter-City AHS Networks

If AHS is to require the modification of existing, or the building of new, infrastructure, then an important question is: How extensive does that infrastructure need to be to serve the demand patterns of shippers that are currently using conventional truck or intermodal transportation? A second question is: How should that infrastructure evolve in order to serve the most demand at each stage of the evolutionary process? These are critical questions when considering RSC 8-13. Each require a dedicated AHSway.

The purpose of this analysis was to determine the freight market potential of an evolutionary sequence of rural interstate AHS network segments that would best serve existing inter-city freight movements. A contiguous set of the higher density links were selected to form progressively larger AHS networks. The analysis re-flowed each of the traffic data bases on each of the evolved networks. In re-flowing the data, each link of the AHS network was given some routing preference that reflected the attractiveness of AHS service. The re-flowing process re-computed a new best O-D route for each shipment. This produced traffic density data for the new AHS network, and the remaining conventional network. Also computed was the total ton-miles on each evolving AHS network. In flowing the traffic, it was assumed that all trips could use the AHS, if it were reasonable for a portion of the trip. This provided an upper bound on the market potential of each evolutionary AHS network to serve each of the traffic classes, TL, LTL, and rail-truck intermodal. In terms of the RSCs, what is modeled here is reflective of RSCs 8-12 with the additional stipulation that either all vehicles are equipped with the needed on-vehicle AHS hardware or that this an infrastructure-only AHS system. If all trucks are not so equipped, then the market potential has to be scaled back proportionally using the market penetration percentages reflecting the installation of on-board equipment.

B.2.2.1 Evolution to a Full AHS Interstate Network

In structuring the analysis that would select the evolutionary order in which corridors were to be converted to AHS, it was decided to begin with an ultimate interstate system AHS and then to work backwards to determine the evolutionary priority. The assignment of the flow of current shipper demands to the full interstate AHS system readily identifies the most intensely used corridors. These can then be progressively assembled to provide an evolutionary plan for network expansion.

As a first-cut, the full interstate AHS was taken as the union of the current interstate highway system, plus all toll roads. Critical links were added in places where the network was disconnected. All other roadways were retained as access roadways to the interstate AHS. This network was created by altering the link attributes of the PC*Miler network using the PTNM/Iris software. Figure B7 is a national map of that network with its access roads. The AHS portion represents 44,590 route miles . Mileages by state are given in table B1. Texas has the largest mileage followed by California, Illinois, Ohio, Pennsylvania, New York and Florida. Not surprisingly, the small northeastern states have the shortest route miles.

Table B1. State Mileages of the Interstate AHS Network

State	Mileage	State	Mileage	State	Mileage	State	Mileage
TX	3287.6	IN	1134.5	KS	859.2	WV	547.2
CA	2482.6	VA	1078.0	SC	799.0	AR	544.5
IL	2021.1	TN	1064.9	KY	796.9	NV	530.9
OH	1607.8	NM	1013.8	IA	790.4	MD	486.0
PA	1604.4	NC	997.5	WA	763.0	NE	483.1
NY	1502.8	CO	956.2	OR	719.9	NJ	462.6
FL	1461.3	UT	933.6	SD	681.4	ME	366.8
MI	1241.7	OK	928.3	MS	680.1	CT	340.5
GA	1238.3	WY	913.3	WI	640.0	VT	330.3
MT	1196.0	AL	903.8	ID	598.6	NH	218.5
AZ	1168.0	MN	902.6	ND	572.2	RI	74.4
MO	1160.7	LA	896.0	MA	559.9	DE	40.7
						DC	10.5

B.2.2.2 Traffic Flow Analyses

The traffic flow analysis used the shortest path traffic assignment software of the PTNM/Iris to assign each O-D pair to the network. The objective of the shortest path is a "best-route" objective that tends to favor the AHS segments while minimizing total travel time.

The routing model used in assigning traffic to the highway network is based on a simple driver route choice behavior model. It finds the route from origin to destination that minimizes the sum of the weighted distance, (D), times the link service quality, (LSQ)), where the sum is taken over the links that make up the path from origin to

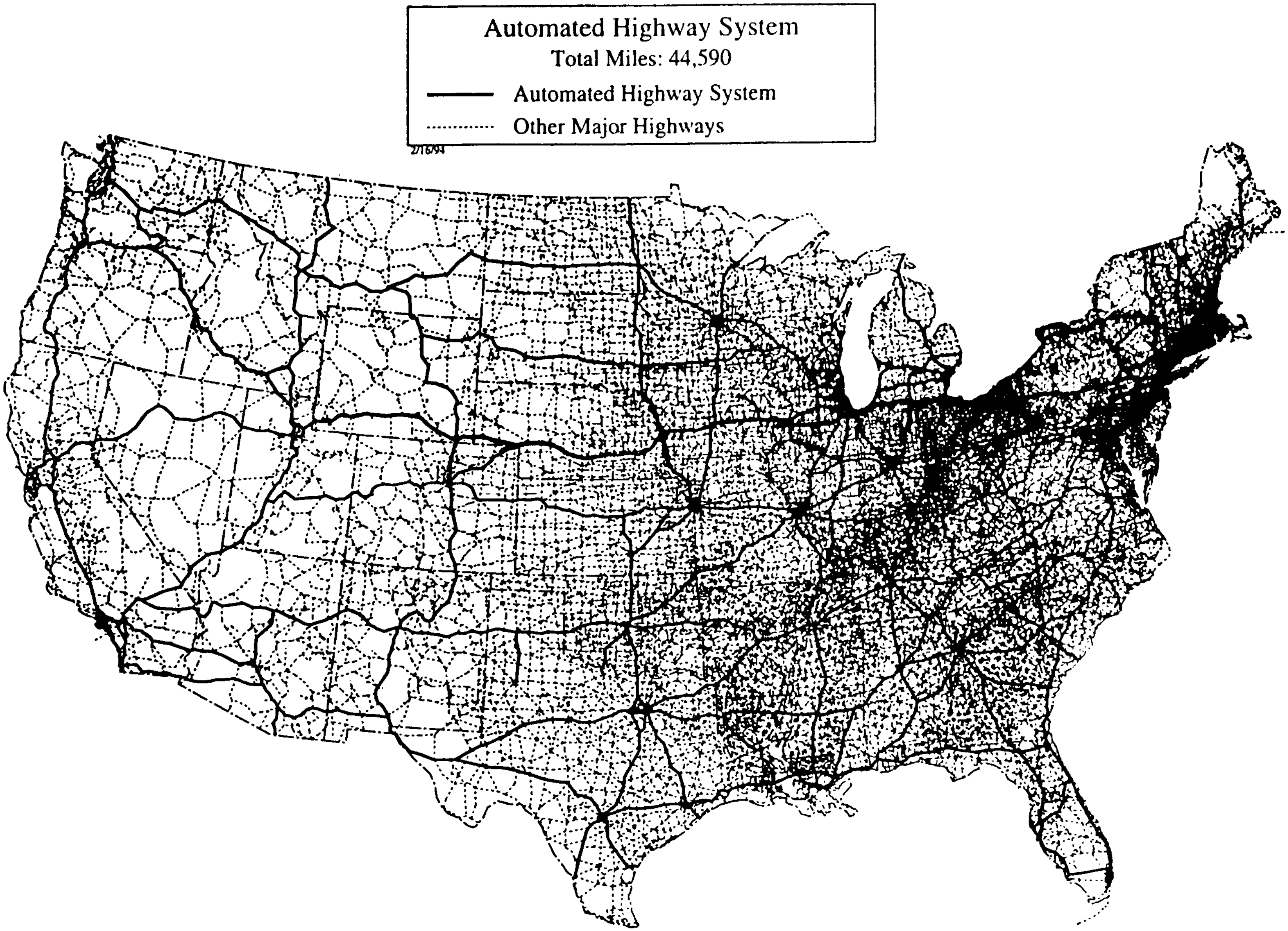

Figure B7. Map Showing the Interstate AHS Network (44,590 miles) Plus its Major Access Highways

B22

destination. The link service quality, LSQ, is a relative measure of the speed and quality of a road segment. Implicitly included in the measure are tolls, speed limit, type of road, type of traffic control devices and road geometry. Explicit values of LSQ are assigned to homogeneous groupings of road segments. For example, Interstate highways have an LSQ=1.0, Toll roads have LSQ=1.1, divided highways have an LSQ=1.3. No formal calibration procedure has been used to assign these values. They have simply evolved to be values that consistently generate the route that truck drivers tend to use between any given O-D pair. These values tend to properly tradeoff distance and differential route quality between different road types.
Presented with the opportunity to use an AHS infrastructure, one needs to anticipate how drivers will perceive the benefits of an AHS roadway relative to the conventional highway system. Such a roadway would probably be a tolled facility and thus the LSQ should be close to 1.1; however, the AHS facility will provide enhanced safety and comfort. It's use may also increase the driver's hours-of-service limit and thus provide substantial productivity opportunities that easily outweigh the negative implications of tolls. After much consternation, an LSQ of 0.9 was selected for the AHS facilities. This implies that a motor carrier would be willing to travel up to an additional mile for each 10 miles driven on the AHS facility. For many trips the AHS-best route is equivalent to the best route using the conventional parallel roadway segments. For other trips, this value of LSQ implies that a trucker would be willing to travel up to one mile farther for each 10 miles of travel on the AHS.

The fully allocated mileage costs for a class-8 truck is about $1.25 per mile. The LSQ measure of .9 for AHS segments implies that the AHS can deliver to the driver net benefits valued in excess of 12.5 cents per mile plus the cost of AHS tolls and the cost of amortizing any needed on-vehicle hardware. Otherwise the driver would choose a 10% shorter route on a conventional road, if it existed. This is a fairly large value of perceived benefit. Safety benefits are not expected to be sufficiently high to completely compensate for this extra cost; however, comfort benefits and possible extensions of hour of service limitations could yield sufficient value to allow LSQ=.9 to be a realistic value for an AHS.

The routing model assumes that all truck drivers have the same LSQ. This is a major simplification. In reality each driver has his own LSQ. Some would have LSQs greater than 1.0 which would mean that they would not use AHS. The AHS is assumed to be built near the right-of-way of existing conventional expressways. Thus, the equal distance conventional alternative would be chosen. Those drivers that had LSQs less than one would divert accordingly, given the opportunity. For those driver's whose value of LSQ is closer to 1.0, then the attractiveness of the AHS system based on an LSQ=.9 has been overestimated . For those with less, the AHS use has been underestimated, but it is unlikely that LSQ would be less than .9, unless there is some large perceived benefit of AHS that has been overlooked. In the end, the sum result is similar to that achieved from the much simpler approach of using one value of LSQ for all truck drivers.

Analyses were conducted using the following four freight traffic databases: the ICC rail intermodal traffic sample for year 1992, and both the less-than-truckload (LTL) and truck-load (TL) portions of the TRANSACT file that had been factored so that their total ton-mile levels matched 1992 totals reported by DOT. The ICC waybill data contains an expansion factor that reflects actual 1992 totals.

Three similar analyses were performed for each of the databases. The analyses began by assigning the entire database to the national AHS network using the PTNM/Iris. This analysis assumes that all of the traffic is technologically capable of using any portion of the AHS network. The origin and destination of each shipment is kept constant, but the traffic is routed on the best route on the AHS with its network of conventional access roads. The routes are computed by the shortest path module of the PTNM/Iris assignment process. Volumes on the links traversed by each shipment are accumulated to provide total volumes by direction on each link of the network.

The first analysis is a traffic flow analysis on the entire interstate AHS network. This provides estimates of the ultimate market potential of AHS and the geographic distribution of that market. This analysis produces traffic flows that are very similar to the geographic distributions that were discussed in section B.2.1.2.2. Since the whole interstate highway system is transformed into an AHS, routes change very little.

The second analysis, an AHS minimal-network analysis, focuses on those links of the AHS which serve the most traffic. Bi-directional link volumes are summed, sorted in descending order, multiplied by the link distance and then summed cumulatively. This provides a convenient way to identify the minimal AHS network that serves a desired percentage of the total traffic volume (in terms of unit-distance, e.g. trailer-miles). The results are presented in table B2 which lists the minimum AHS network length to serve 20%, 50%, and 80% of the traffic volume served by the complete interstate AHS network. Geographic network maps are also presented that depict the actual links that comprise each of those minimal networks. The results of these analyses identified a four phased evolution of a nationwide AHS highway infrastructure. The first stage is a 1,209 mile segment that serves the highest volumes in our analysis. The second is a 5,214 mile system. The third is an 11,255 mile system and the final is the complete 44,590 mile interstate AHS that serves all states.

The third analysis re-flowed each of the traffic data bases on each of the evolved network. Each link of the AHS network was given an attractive LSQ =.9 so that traffic tended to be attracted to the AHS corridors. This provides high-side estimates of the ultimate inter-city freight traffic potential of each of the evolutionary networks.

B.2.2.3 Results for Each of the Databases

B.2.2.3.1 Analysis of Rail Intermodal Traffic

The intermodal traffic shipments contained in the 1992 ICC Carload Waybill statistics were assigned, using the PTNM/Iris to the national highway network containing the interstate AHS. Results of that traffic assignment are presented in figure B4 in the form of a nationwide traffic density map. The geographic distribution of this traffic is discussed in section B.2.1.2.2 above.

AHS Minimal-Network Analysis

Even though a total of 44,500 miles of road were designated to contain the interstate AHS, only a relatively small portion of those miles would be needed to serve the bulk of the rail intermodal traffic, if that traffic were all to be diverted to the AHS system. Table B2 shows that only 6% of the AHS route miles are needed to serve the most dense 20% of the rail intermodal traffic . Figure B8 highlights those links of the network. It indicates that the I-80 corridor between Salt Lake City and Chicago is the principal long haul corridor, with dense corridors emerging from Los Angeles and in West Texas. 20.18% of the route miles are needed to serve 50% of the freight intermodal traffic. Figure B9 highlights these links which provide service between Chicago and San Francisco and Los Angeles and between Los Angeles and Houston. The only dense Eastern corridor is between Akron and Toledo. Only 20,845 miles or 46.7% of the national AHS system is needed to serve 80% of the rail intermodal traffic. Figure B10 highlights those links and shows clearly how the western portion of the AHS provides most of the service. Interconnected are each of the major western cities with each of the major midwestern gateways. Only the Chicago-Scranton corridor with a spur towards Washington, D.C. is needed in the eastern part of the of the US in order to capture 80% of the intermodal rail traffic.

Table B2. Minimum Miles of AHS Needed to Serve a Fixed Percentage of the Total Traffic Served by the Interstate AHS Network

% Capture	NMTDB Miles	NMTDB %of AHS	Rail Miles	Rail %of AHS	TL Miles	TL %of AHS	LTL Miles	LTL %of AHS
20%	1,180.4	2.65	2,648.9	5.94	2,273.6	5.10	2,368.1	5.31
50%	4,930.2	11.06	9,000.5	20.18	7,999.2	17.94	8,294.1	18.60
80%	15,481.4	34.72	20,845.1	46.75	17,959.4	40.28	19,106.5	42.84

B.2.2.3.2 Analysis of NMTDB Traffic

Traffic Flow Analysis
The 108,650 movement records contained in the National Motor Transport Data Base (NMTDB) were assigned to the AHS network using the PTNM/Iris. The geographic distribution of this traffic are similar to those discussed in section B.2.1.2.2 above.

AHS Minimal-Network Analysis
Table B3 shows that the top 20% of the traffic volume is served by 1,180 route miles or 2.65% of the interstate AHS. This is significantly smaller than that required to

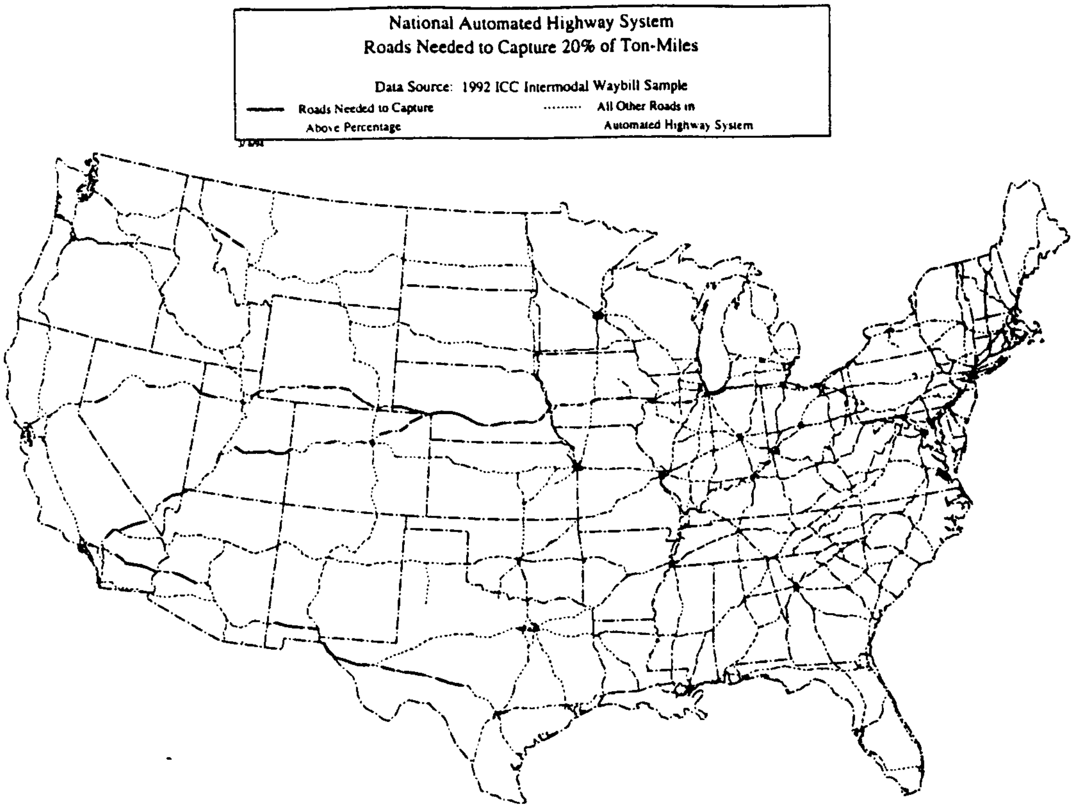

Figure B8. Map Showing the Minimum Network Segments Needed to Serve 20% of the Rail Intermodal Traffic

Figure B9. Map Showing the Minimum Network Segments Needed to Serve 50% of the Rail Intermodal Traffic

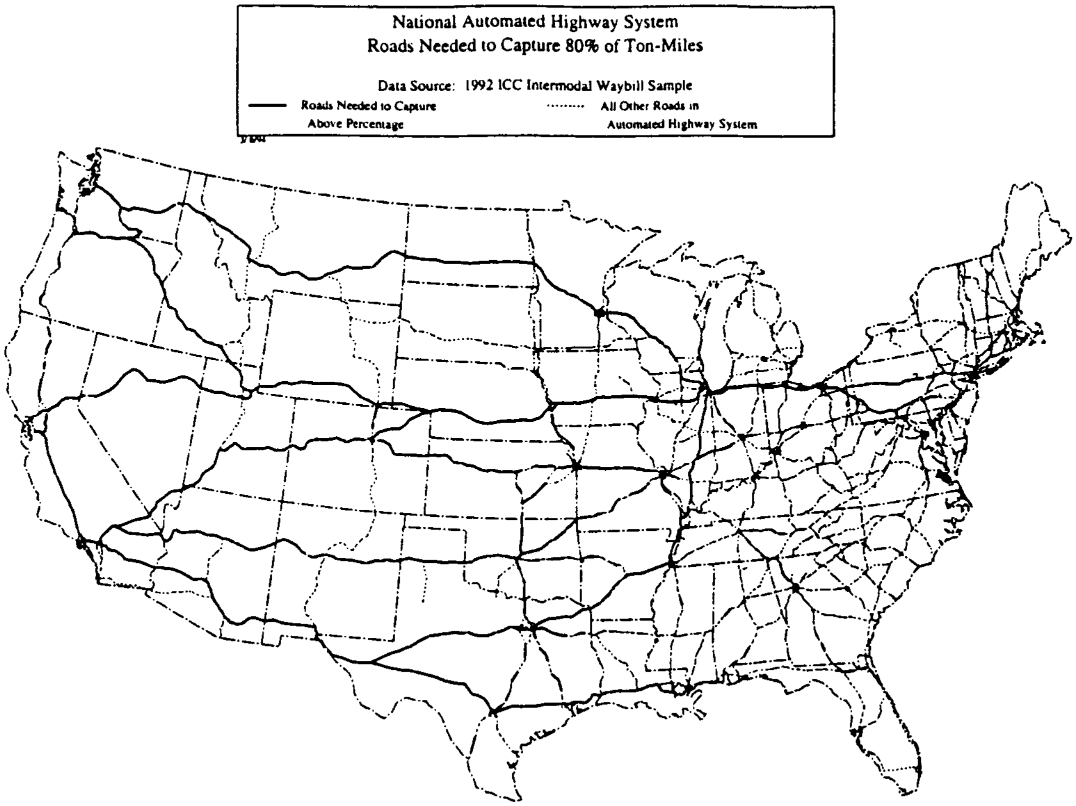

Figure B10. Map Showing the Minimum Network Segments Needed to Serve 80% of the Rail Intermodal Traffic

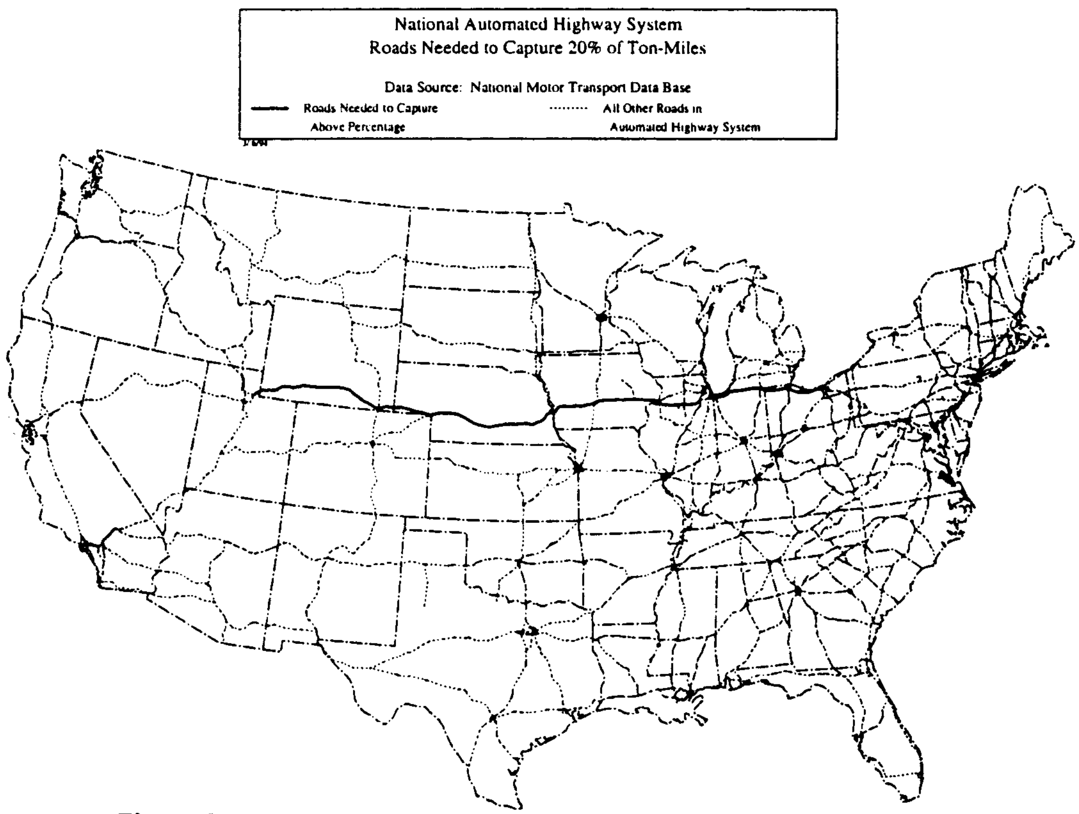

Figure B11. Map Showing the Minimum Network Segments Needed to Serve 20% of the NMTDB Traffic

serve the top 20% of the intermodal rail traffic. Figure B11, which highlights those major links is similar to that of the rail intermodal in the west, but replaces the west Texas segments with a corridor between Toledo and Cleveland and a short segment in northern Indiana. It must be remembered that the NMTDB is a biased subset focusing on extremely long-haul trucking that could be diverted to intermodal rail. This bias arises because the data came from surveys conducted at rest stops that are located on known long-haul corridors.
Fifty percent of the NMTDB traffic is served by a 4,930 mile network or 11.06% of the total. This is again lower than that of rail intermodal, indicating a more concentrated pattern of traffic for extremely long-haul truck traffic. Figure B12 highlights these corridors which are better developed in the east along I-80 and I-70 and in the west along I-80 and I-40. There is also a segment going from Chicago heading toward the Twin Cities.

Almost 15,500 miles of AHS are needed to serve 80% of the NMTDB traffic. These links are displayed in figure B13. They show east-west corridors that are contiguous through all but the most northern part of the west and extend to as far as Boston in the east. The Southeast is conspicuously absent from participation in the top 80% of the traffic flow.

B.2.2.3.3 Analysis of TRANZACT Truckload Traffic

AHS Minimal-Network Analysis
The TRANZACT database for shipments of greater than 10,000 pounds were flowed as truck-load shipments on the interstate AHS. As with the other data bases the flows were geographically distributed in a manner similar to those displayed in figure B5. These flows are substantially different than those of rail intermodal and the NMTDB. Significantly more traffic is moving over the network in the eastern part of the country. This is where lengths-of-haul are shorter and less attractive to rail intermodal services.

Table B3 presents the distribution of route miles as more of the traffic is captured by the AHS. Figure B14 displays the corridors that serve the top 50% of the truckload shipments. These represent 8,000 route miles or 17.9% of the total. The I-80 corridor is fully developed in the west. In the midwest, Chicago to Pittsburgh, Oklahoma City to Nashville, and Kansas City to Harrisburg are the primary east-west corridors. Atlanta, Memphis and St. Louis to Chicago are the north-south corridors.

It is not until one extends to the 80% level does New England begin to participate in the network as is shown in figure B15. There is still a great deal of concentration in the traffic on the network since a mere 40%, or 18,000 miles of interstate AHS is needed to serve 80% of the traffic. Most of the major cities are served except for those in the northwest, New England, southeastern seaboard and Florida.

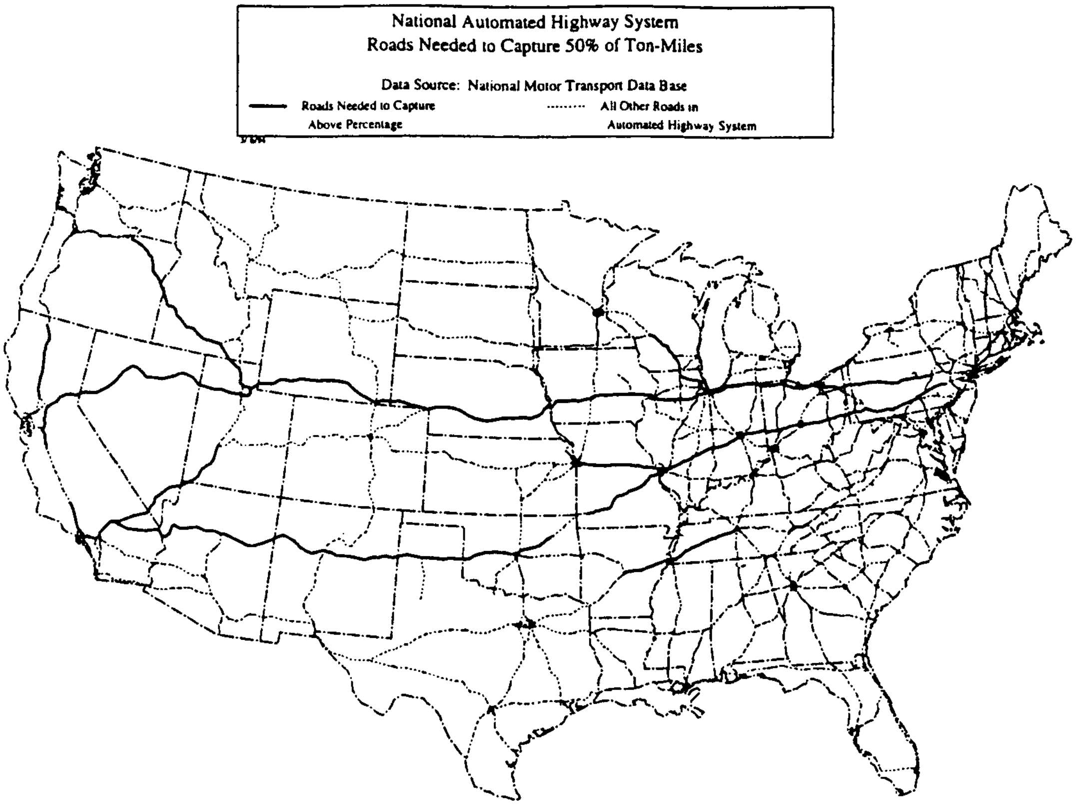

Figure B12. Map Showing the Minimum Network Segments Needed to Serve 50% of the NMTDB Traffic

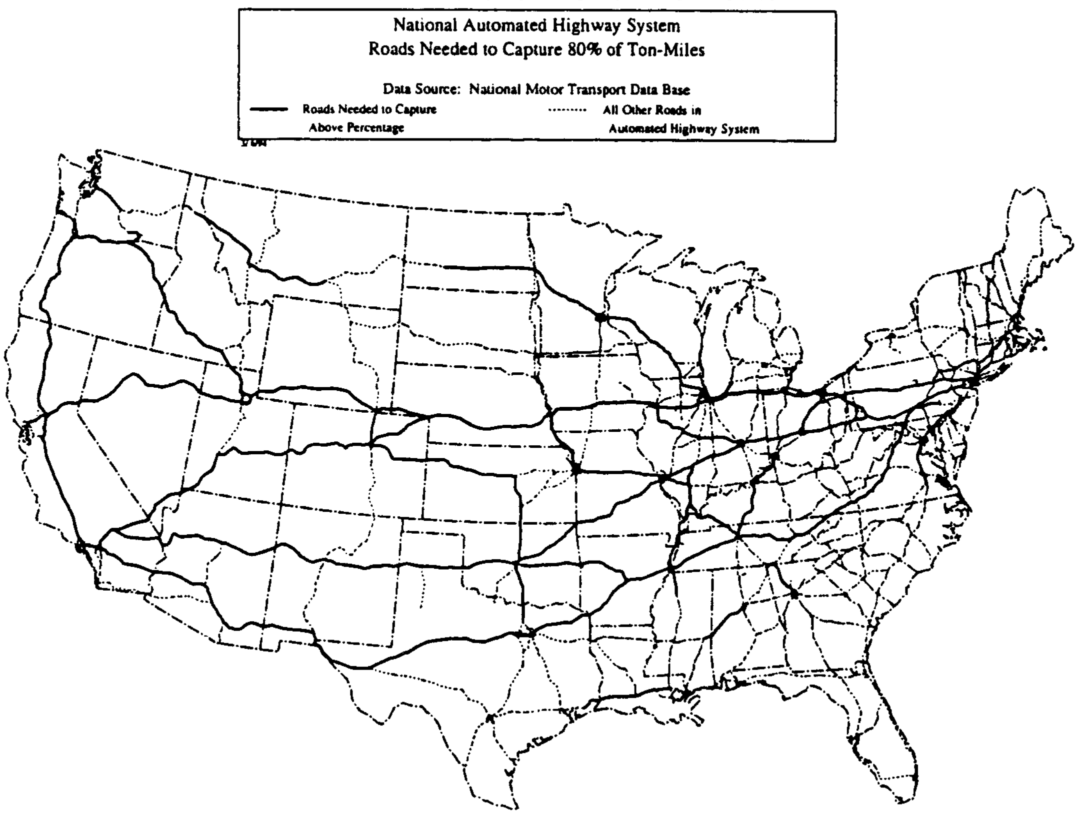

Figure B13. Map Showing the Minimum Network Segments Needed to Serve 80% of the NMTDB Traffic

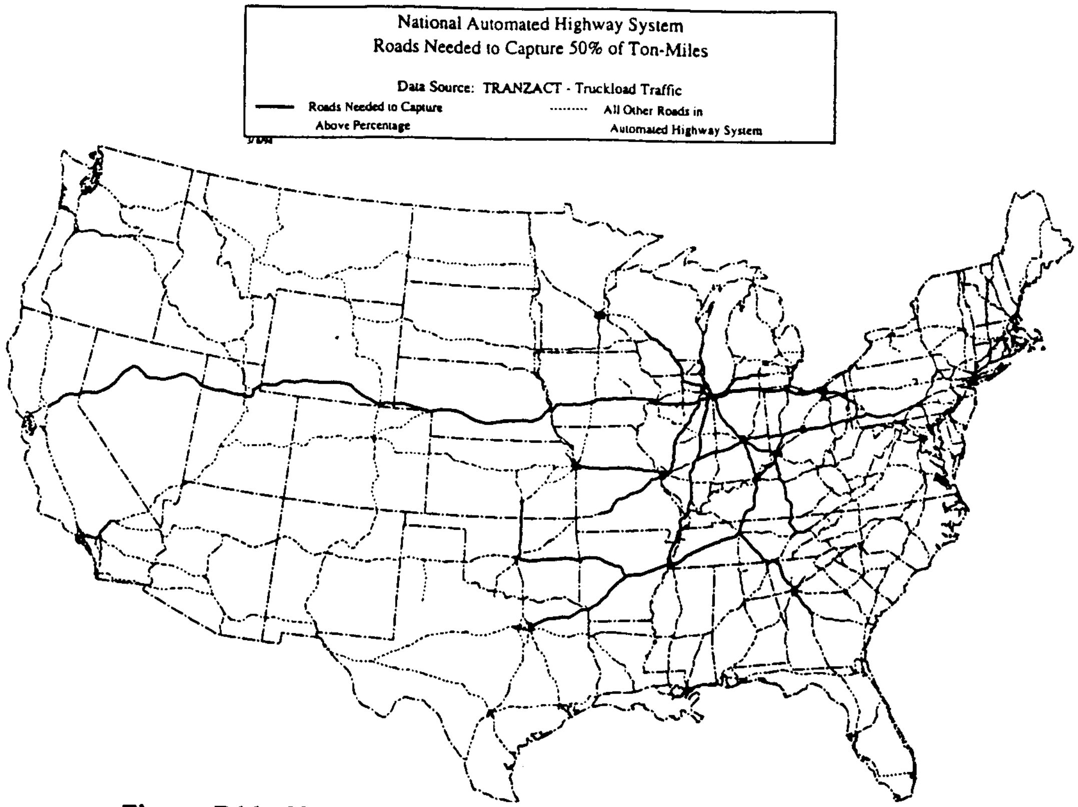

Figure B14. Map Showing the Minimum Network Segments Needed to Serve 50% of the Truck-Load Traffic

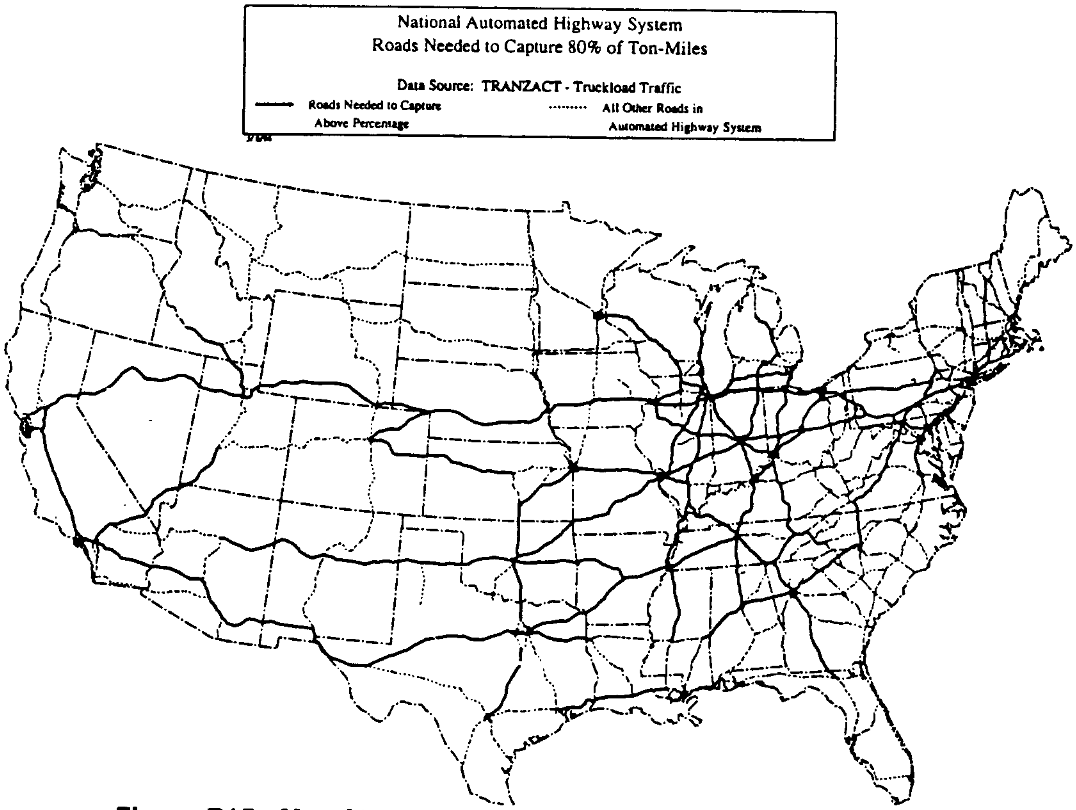

Figure B15. Map Showing the Minimum Network Segments Needed to Serve 80% of the Truck-Load Traffic

B.2.2.3.4 Analysis of Less-Than-Truckload Traffic

AHS Minimal-Network Analysis

The less-than-truckload traffic required 8,300 miles or 18.6% of the network to serve the top 50% of flow. This is almost 50% more than that required to serve 20% of the rail intermodal traffic. The corridors are displayed in figure B16. The network is more fully developed in the Northeast especially in the New York metropolitan region. It also has an I-75 segment between Northern Florida and Chicago.

To serve 80% of the less-than-truckload traffic, 19,100 route miles, or 42.8% of the total, are needed. Compared with TL traffic, the LTL traffic is more diffuse as would be expected from traffic that has, on average, shorter length of haul. Figure B17 displays the corridors that extend from Chicago all the way to Minneapolis, Jacksonville and Boston. In the west the I-5, I-80, I-40 and I-10 corridors are all developed. This map has the most developed I-95 corridor.

B.2.2.4 A Phased Evolution to an Interstate AHS

The 20%, 50% and 80% networks from the previous analyses were combined to define an evolving sequence of longer AHS networks consisting of roughly 1,200, 5,000 and 11,000 route miles. These networks were created by taking the common segments from the previous analysis.

Phase 0 is taken to be the nation's highways as they exist today. Phase 1 is a 1,209 mile corridor along I-80 between the outskirts of Salt Lake City, UT and to the Iowa - Illinois border west of Chicago. This corridor was selected as Phase 1 even though it isn't the most densely used corridor. It was selected because it was a very dense corridor that serves freight movements that have a particularly long length of haul. The corridor is also located in a more rural portion of the country. Its construction would probably face less opposition than what might confront some other corridors. The corridor serves significant amounts of the traffic contained in all four of the freight traffic data bases. This corridor is depicted in the map contained in figure B18.

Phase 2 extends the Phase 1 corridor across I-80 to the outskirts of San Francisco and Los Angeles to the west and to the New York metropolitan region to the east. It also branches south from Chicago along I-75 and west from Nashville to Ft. Worth along I-40. Figure B19 displays this network.

Phase 3 extends Phase 2 to corridors along I-90 and I-40 in the west and along I-81 and I-95 in the east. This is a very sparse network, yet it serves all but eight (8) of the lower-48 states. Figure B20 depicts the alignment of this network.

The TRANZACT TL and LTL traffic data bases were flowed over each of the Phased implementations of the AHS network. An LSQ of .9 was used to reflect the attractiveness of the AHS corridors. The attractiveness of the AHS corridors tended to attract traffic that would have otherwise traveled on neighboring corridors paralle l

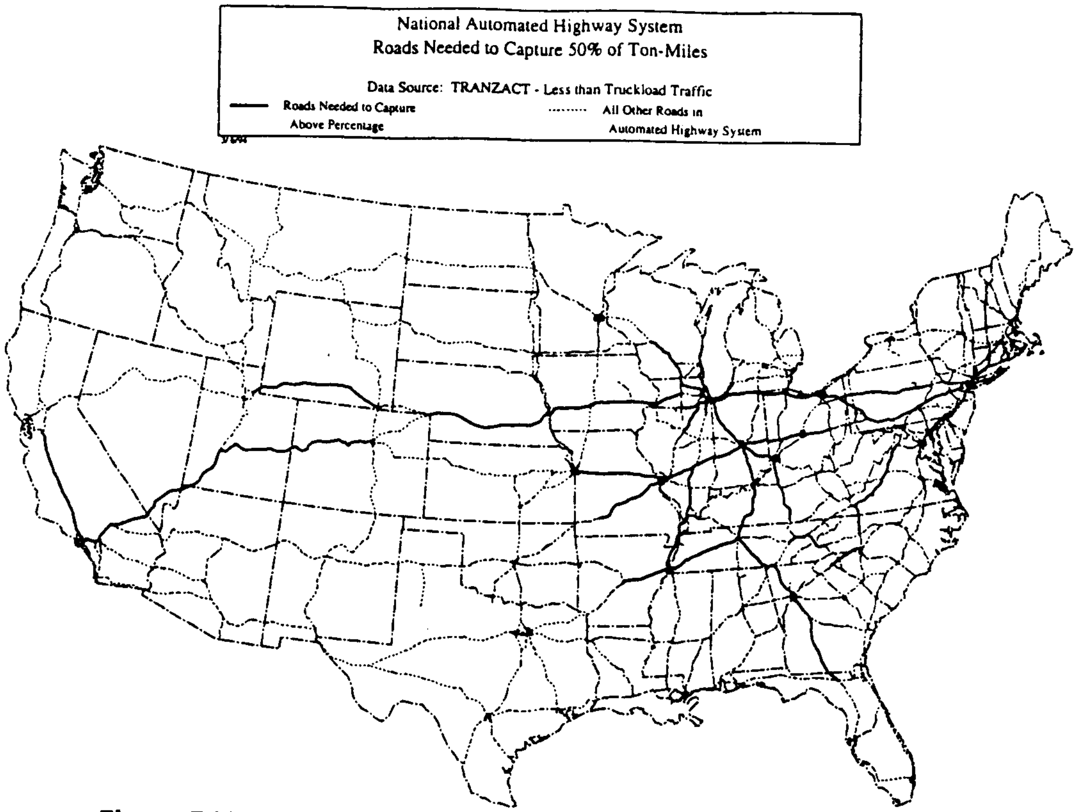

Figure B16. Map Showing the Minimum Network Segments Needed to Serve 50% of the LTL Traffic

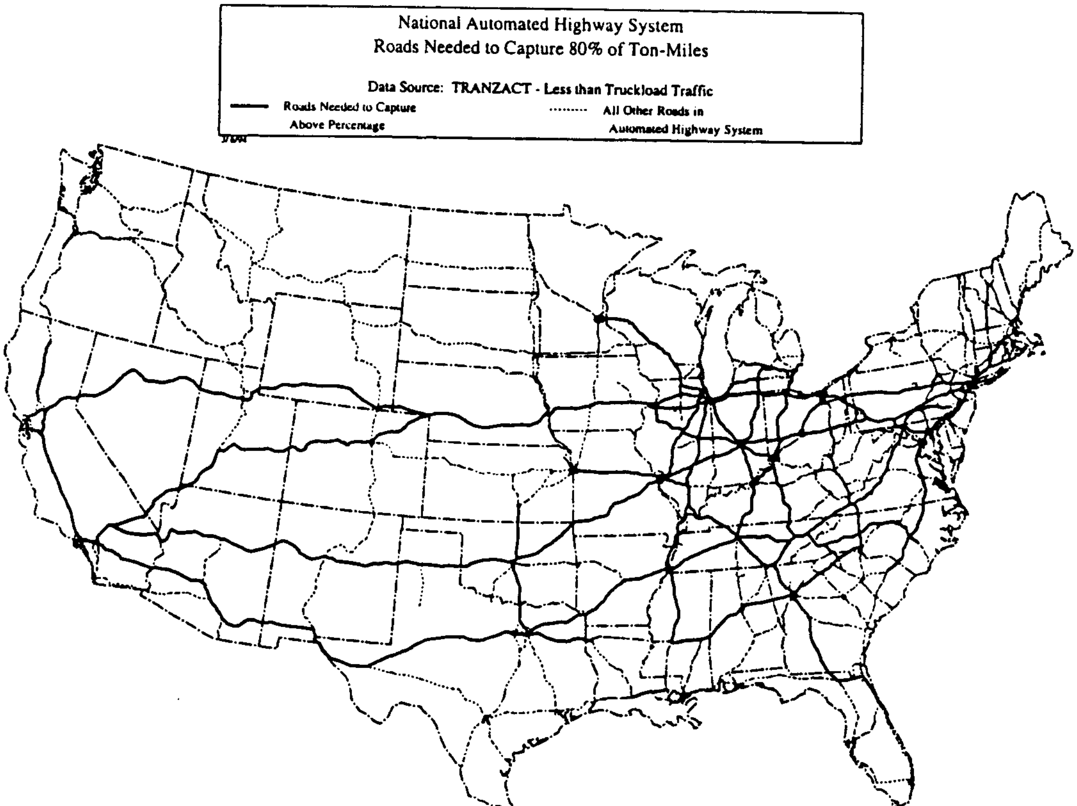

Figure B17. Map Showing the Minimum Network Segments Needed to Serve 80% of the LTL Traffic

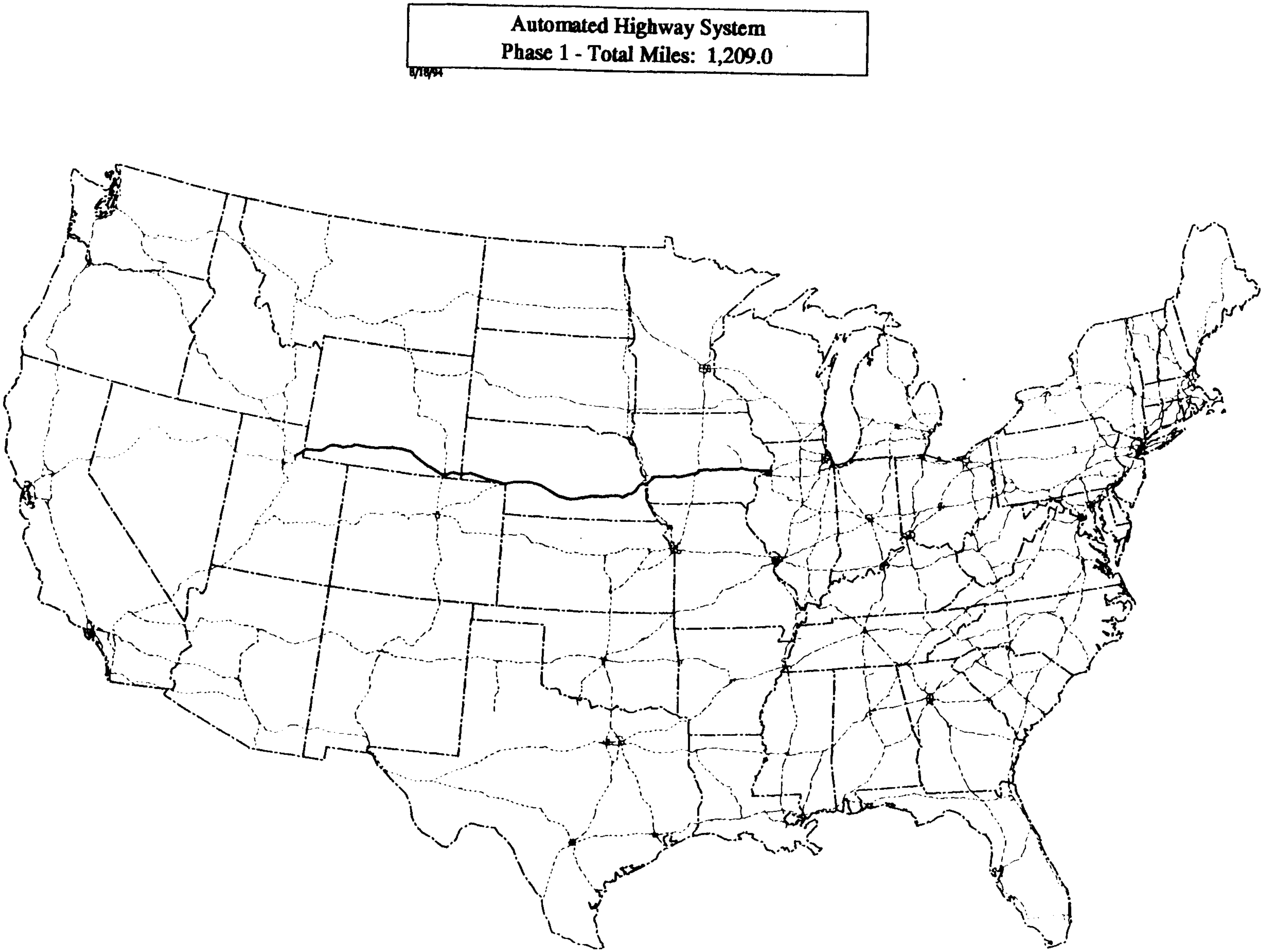

Figure B18. Map Showing the Phase 1, 1,200 Mile AHS Network

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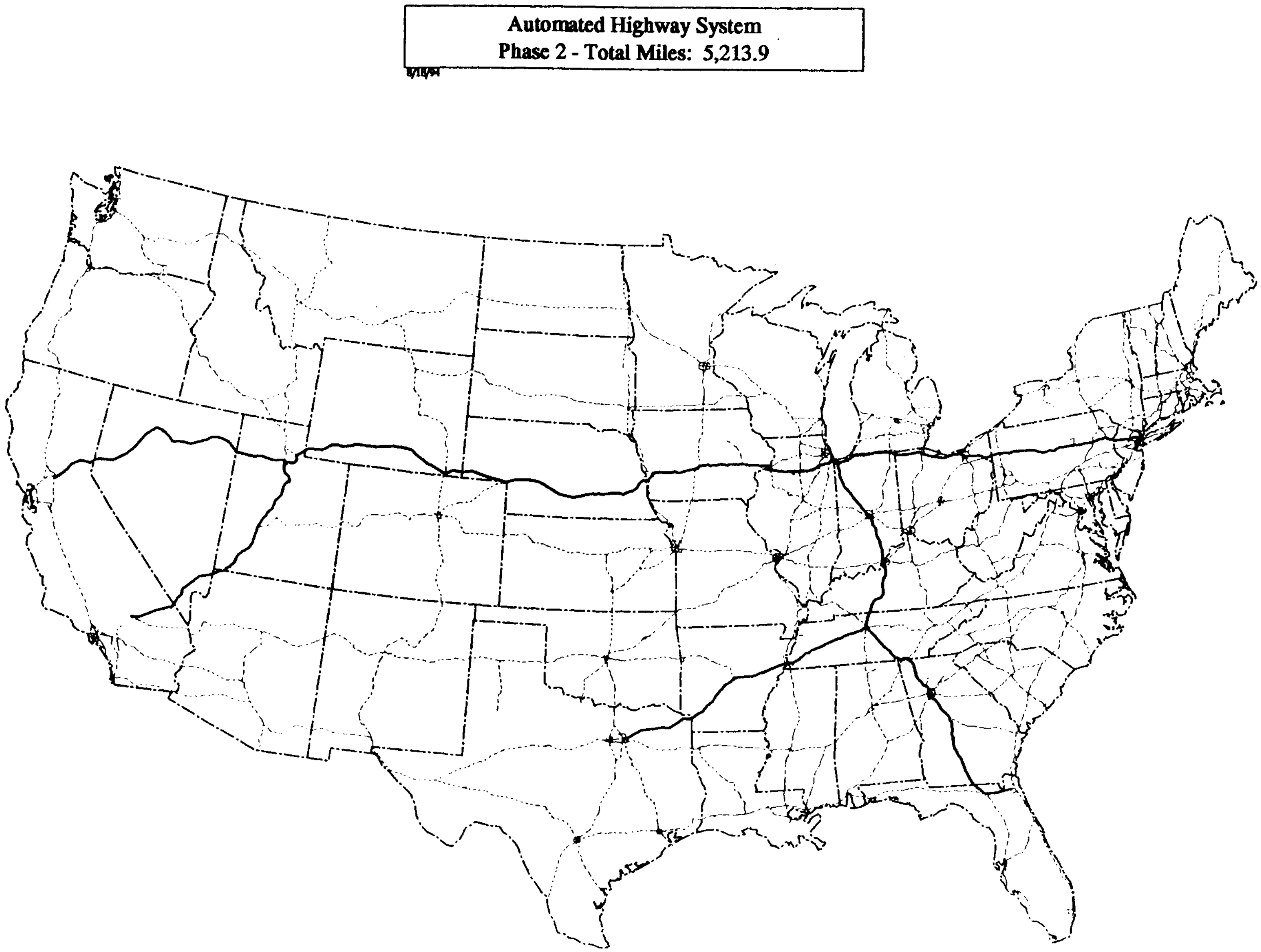


Figure B19. Map Showing the Phase 2, 5,200 Mile AHS Network

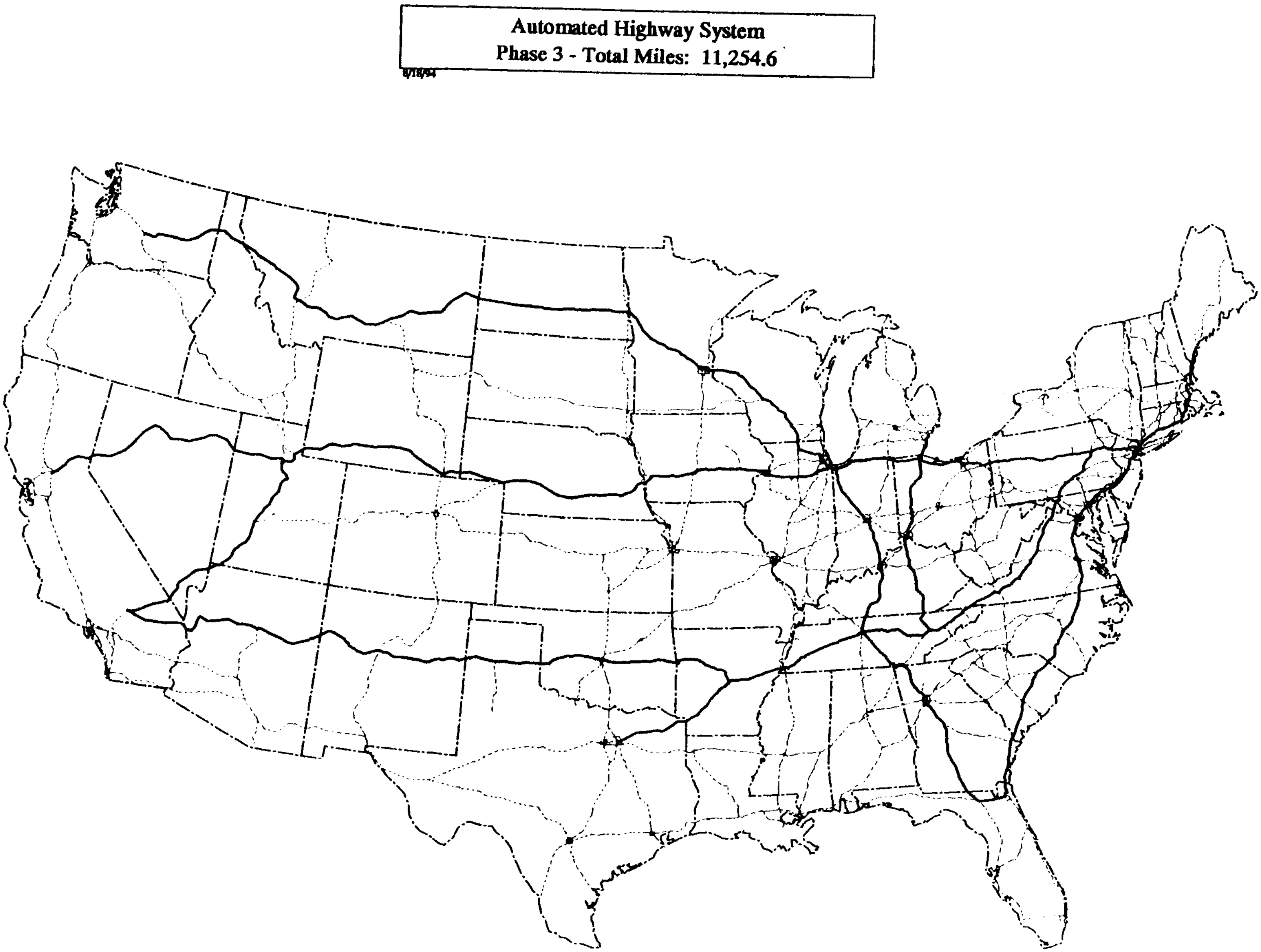


Figure B20. Map Showing the Phase 3, 11,250 Mile AHS Nework

conventional highways. This is particularly striking for the Phase 1 corridor. It attracted long haul traffic away from I-90 and I-70. In fact volumes along this corridor are 50% higher than they are with either no AHS or the full 44,000 mile interstate AHS. The distribution of TL and LTL traffic on the Phase 1 network as well as the rest of the conventional highway system are shown in figures B21 and 22. Figures B23 and 24 display the traffic volumes of TL and LTL traffic on the Phase 2 AHS networks. Figures B25 and 26 display the traffic volumes of TL and LTL traffic on the Phase 3 AHS networks. In comparing and contrasting these maps it is important to keep in mind that the scale for the TL maps is 5 times the scale of the LTL maps. It is interesting to note that when Phase 3 is built, the density on the Phase 1 I-80 corridor decreases substantially because traffic to/from the Pacific Northwest is diverted back to the shorter I-90 route. Thus, the network is already beginning to exhibit some characteristics of diminishing returns. The network may already be large enough to serve the real needs of interstate commercial movements.
A summary of the key statistics from the flow analysis are presented in table B3. The table clearly points out the following:

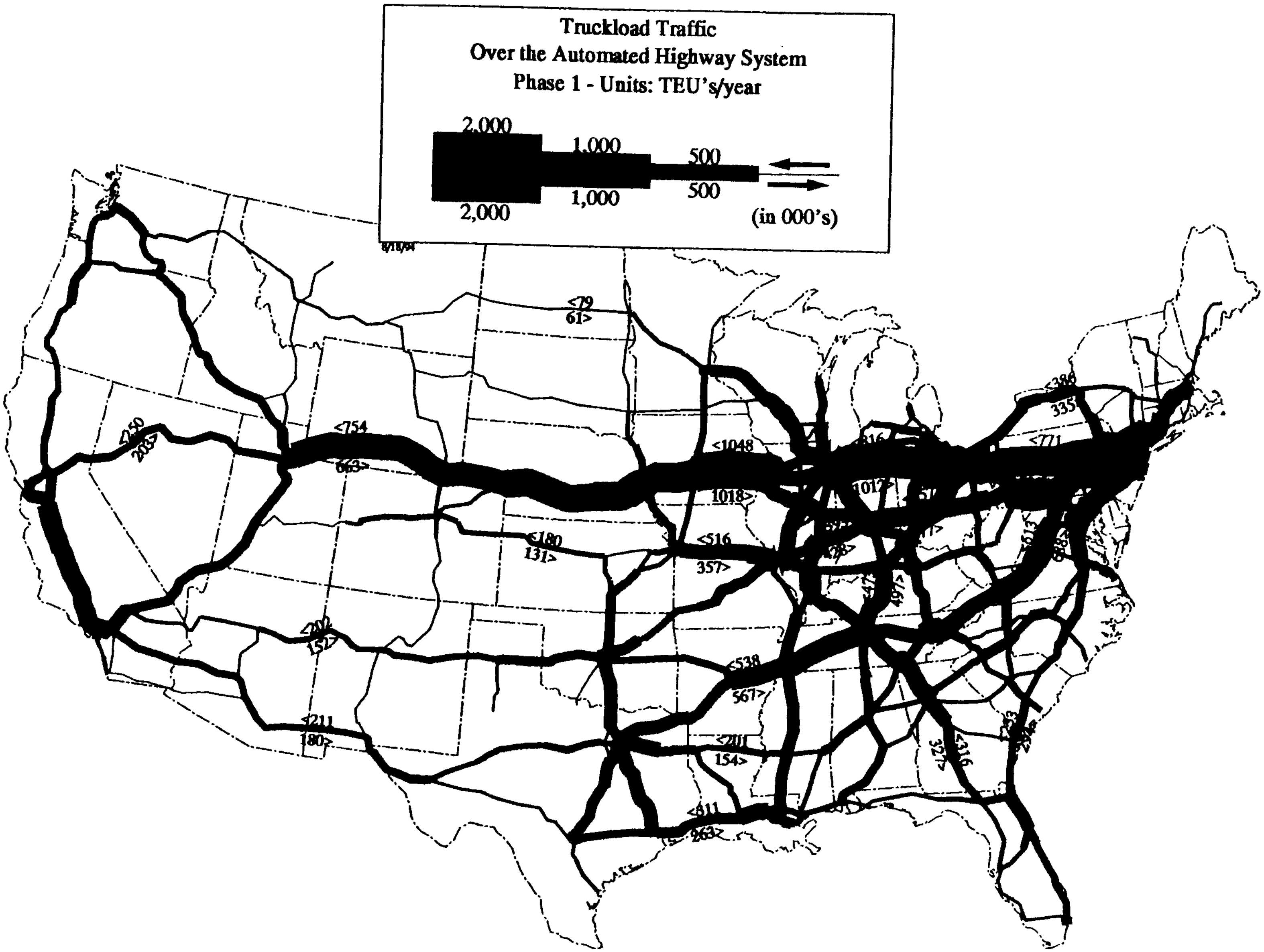
Even with an LSQ = .9, the traffic as a whole does not travel much farther. There is very little difference in total TEU-miles between the no-build alternative (Phase 0) and Phase 3.

The Phase 1 network is able to attract very high flows. On average, each segment of the AHS could be used by as many as 1.8 million trucks per year carrying intercity freight. (The combination of TL and LTL).

The Phase 3 network also has the potential to serve a large volume of trips. On average, 1.1 million trucks per year would be served by each segment of the network.

While the volumes are high, they may not be high enough to generate sufficient revenue to offset the cost of construction and maintenance. Assume that each truck pays tolls at a rate $.10 per mile driven on the AHS. If the traffic density reported in table B3 were achieved, those tolls would only generate $180,000 per mile per year. This level of revenue could support at most a capital expenditure of $2 million per mile. One cannot build much highway infrastructure with that amount of revenue. As the system gets larger, the average density of use becomes less, as is the ability to generate toll revenues that could repay the capital costs of the initial construction.

In conclusion, there are evolutionary paths that exist by which the nation could evolve to build an interstate AHS. There exist dense, relatively short corridors that could serve long-haul markets and help AHS score an important early success; however, the basic economics of an infrastructure-intensive system are very tenuous. The volume with trucks alone is large but not large enough to generate enough toll revenues to pay for the infrastructure needs of a RSC 10-11-type AHS.


Truckload Traffic
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Phase 1 - Units: TEU's/year
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500
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1,000
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(in 000's)
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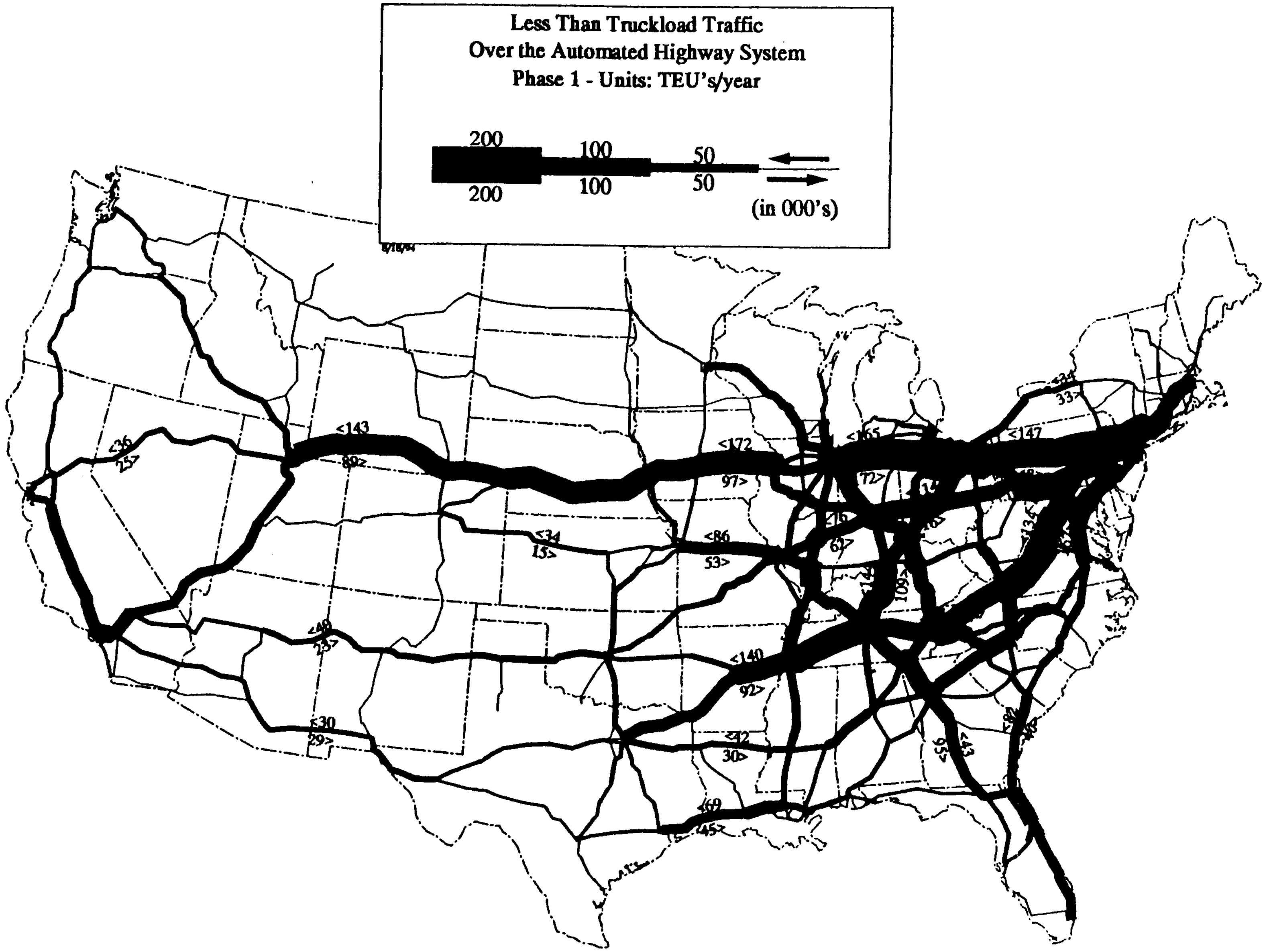
Figure B21.


Less Than Truckload Traffic
Over the Automated Highway System
Phase 1 - Units: TEU's/year
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100
50
200
100
50
(in 000's)
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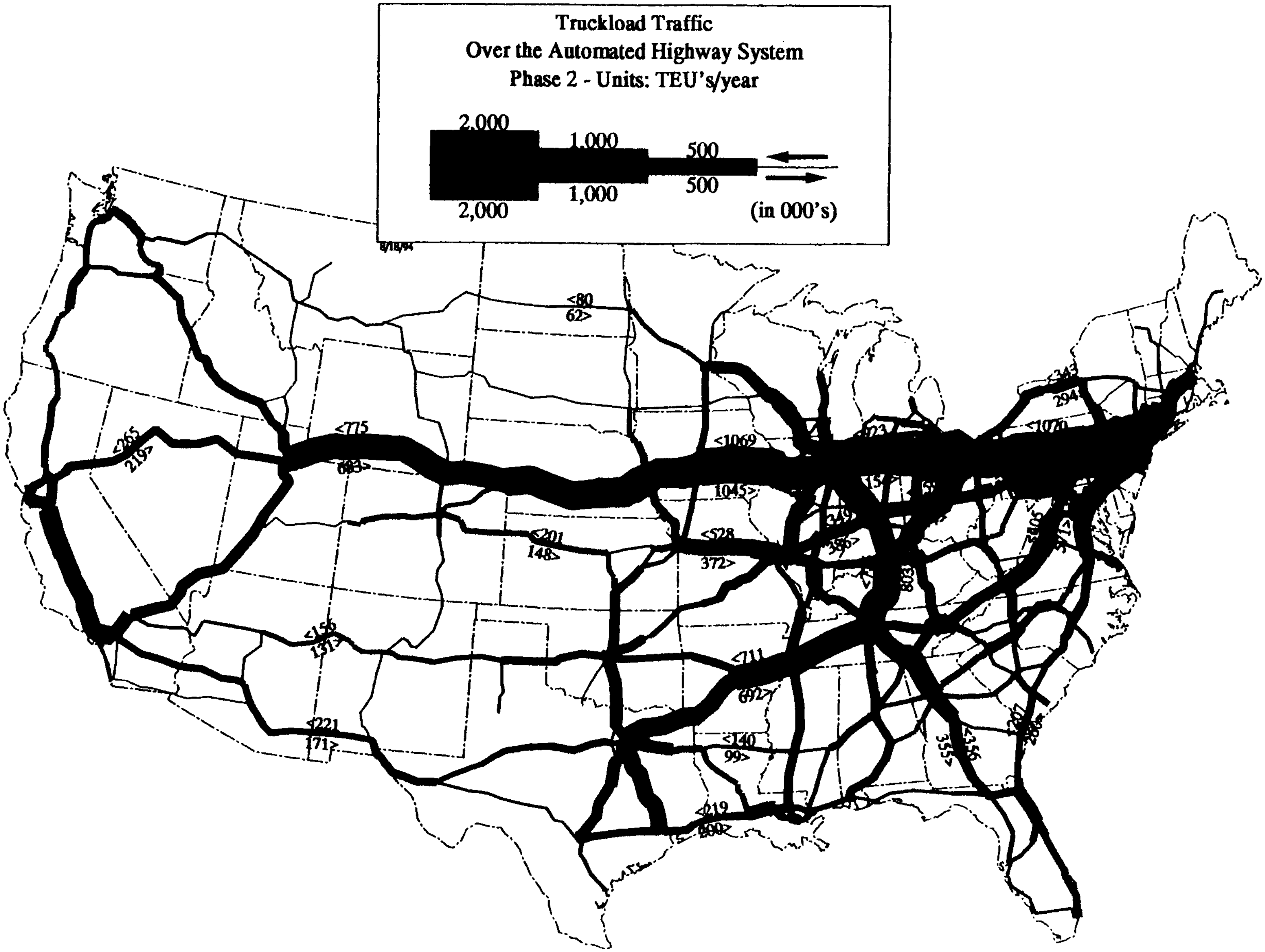
Truckload Traffic
Over the Automated Highway System
Phase 2 - Units: TEU's/year
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(in 000's)
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Figure B23.

B40

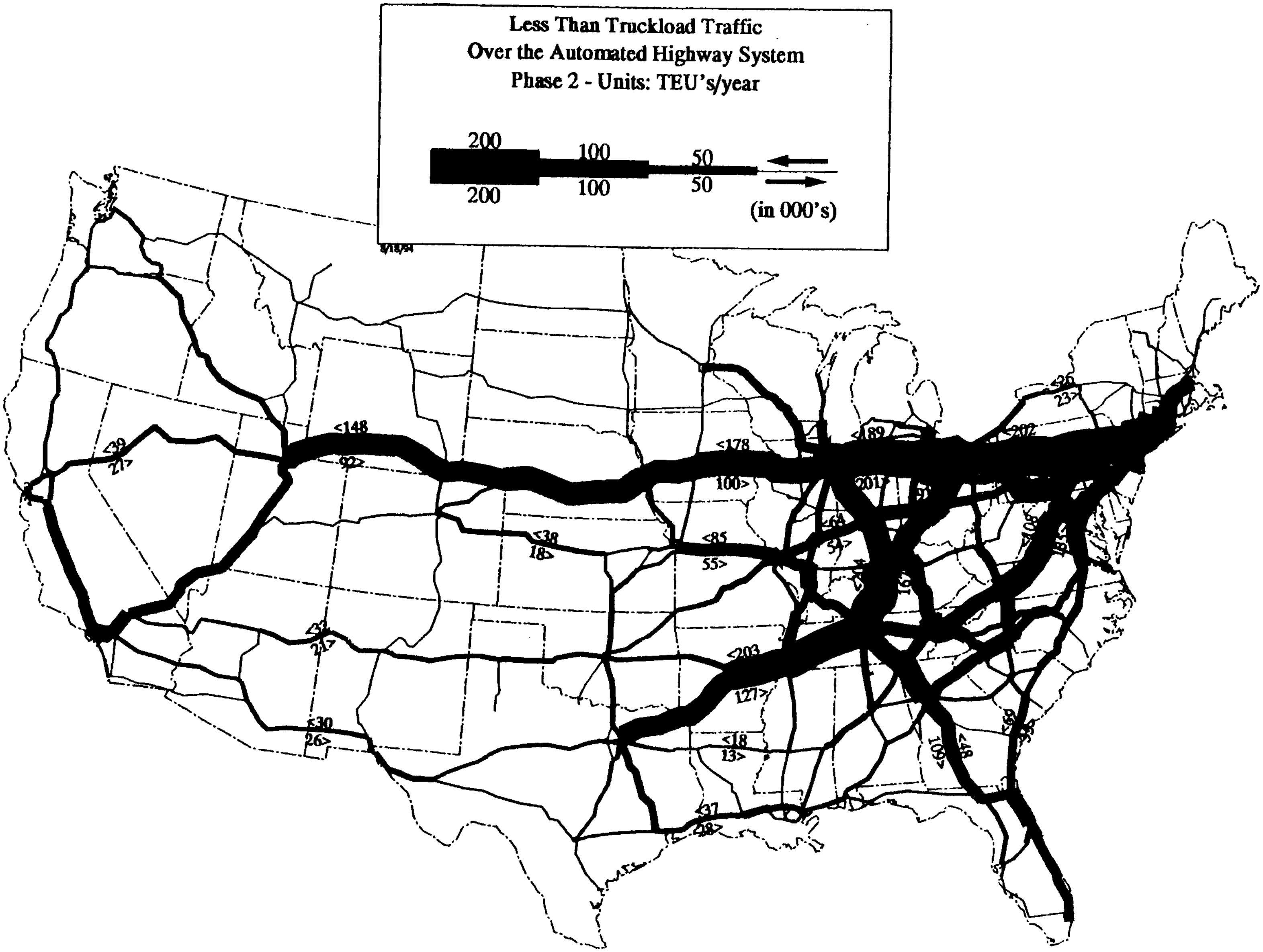
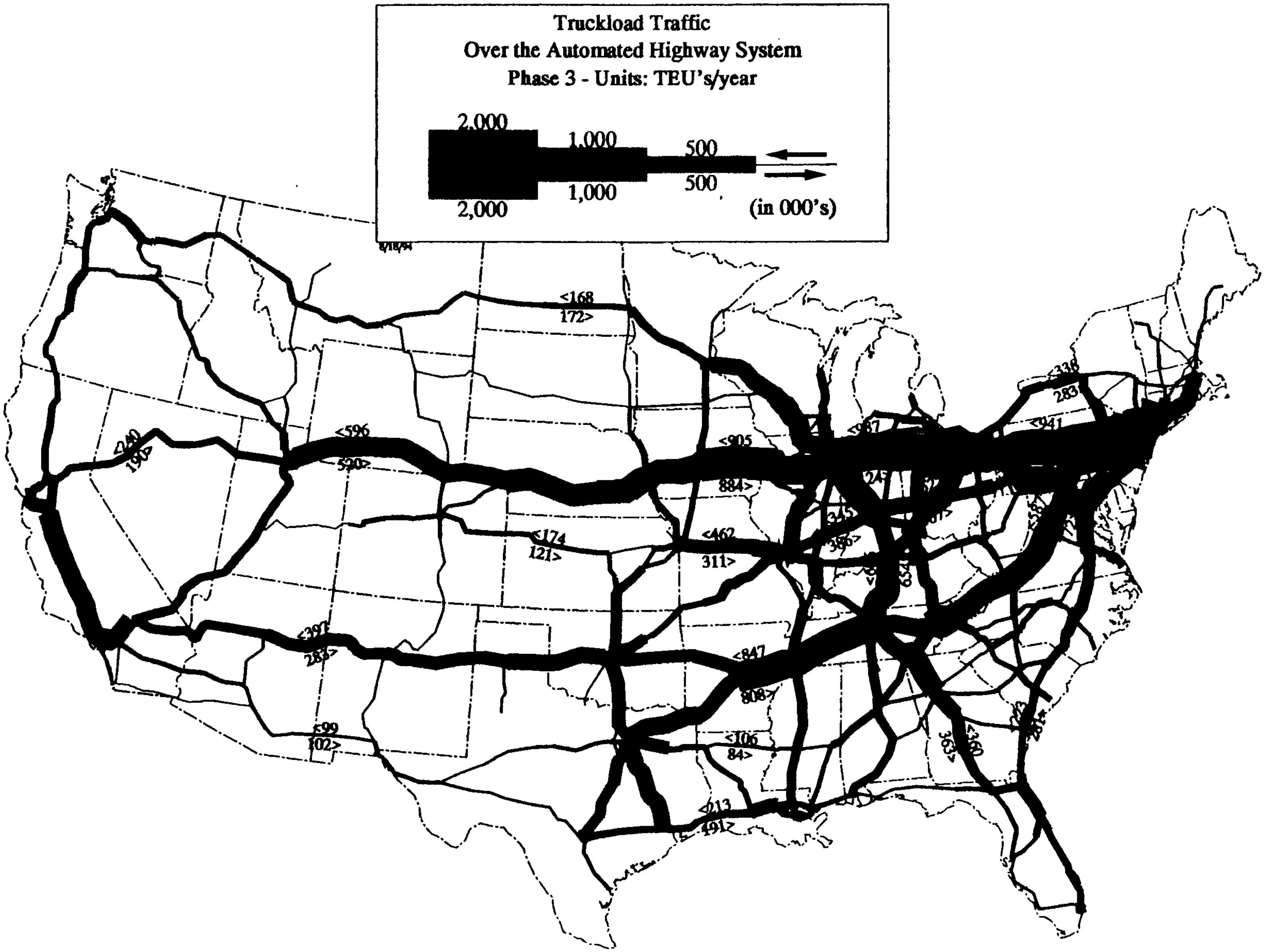


Figure B24.

B41



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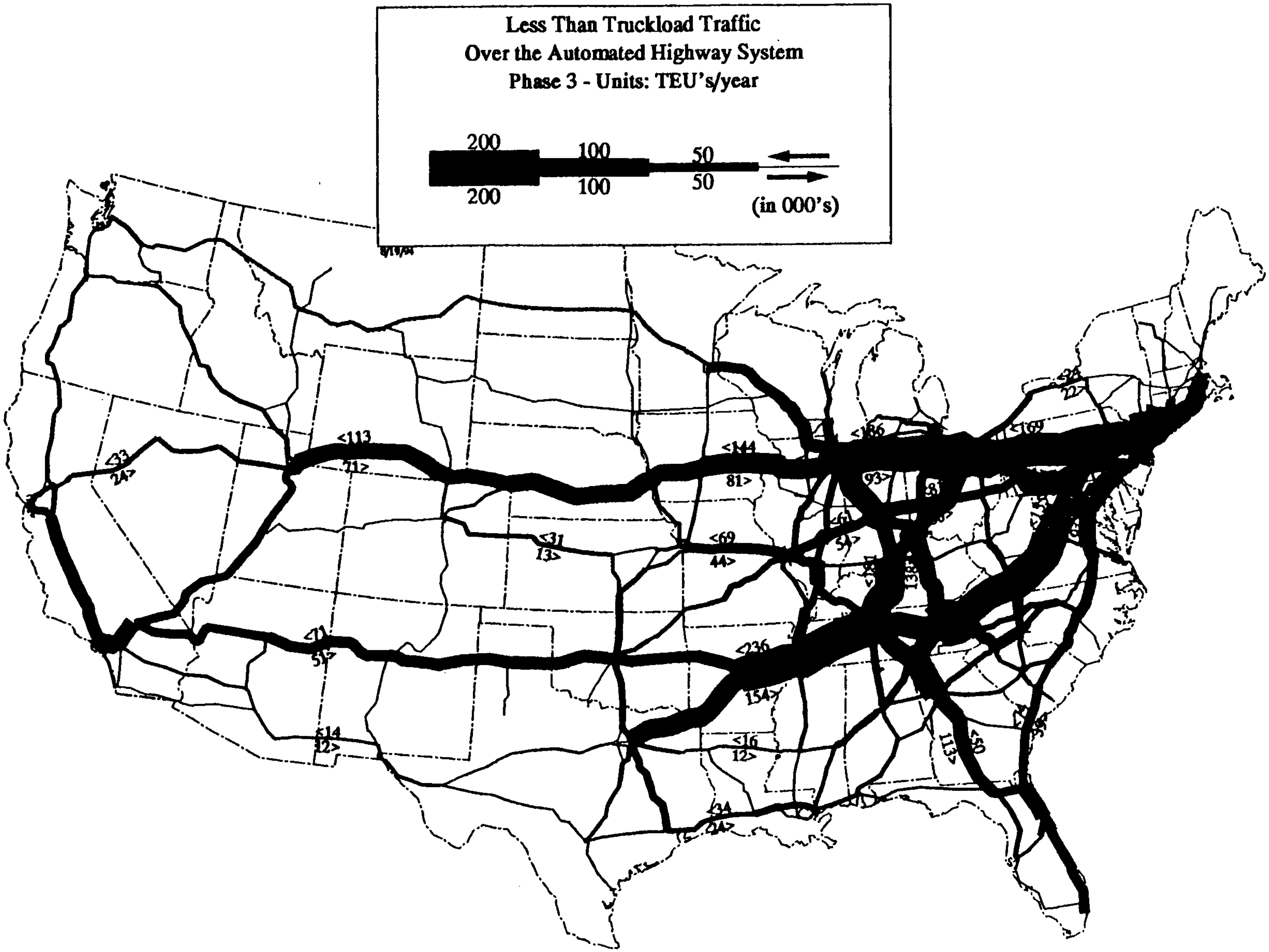
Less Than Truckload Traffic
Over the Automated Highway System
Phase 3 - Units: TEU's/year
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200
100
100
50
50
(in 000's)
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<50

Figure B26.

Table B3. Utilization Potential of the Evolving AHS Network for Truck-Load and Less-Than-Truck-Load Traffic

Phase & traffic base	Miles of AHS	Total TEU-Miles (000,000)	Off-AHS TEU-Miles (000,000)	On-AHS TEU -Miles (000,000)	Avr. TEU on AHS
Phase 0 - TL	0.0	20,531	20,531	0	0
Phase 0-LTL	0.0	3,222	3,222	0	0
Phase 1 - TL	1,209.0	20,589	18,671	1,918	1,587
Phase 1-LTL	1,209.0	3,233	2,942	291	240
Phase 2 - TL	5,213.9	20,655	13,891	6,764	1,298
Phase 2-LTL	5,213.9	3,245	2,004	1,241	238
Phase 3-TL	11,254.6	20,668	10,196	10,472	930
Phase 3 LTL	11,254.6	3,250	1,320	1,930	172

B.2.3 The Market for Vehicle-Borne, Infrastructure-Free RSC 2-Type AHS

B.2.3.1 Market Characteristics

The comfort, convenience and safety attributes of automated operation are significant motivators for truck drivers and their companies to invest in vehicle-borne AHS equipment that could be used ubiquitously over the rural segments of the conventional interstate highway system. Currently the motor carrier industry is investing significant amounts of capital in intelligent systems that improve safety, driver comfort and carrier operations. Investments in anti-lock brakes, cruise control and two-way satellite communication systems are common place. Anti-lock brakes deliver primarily a safety benefit, cruise control delivers primarily a driver comfort benefit and satellite communication systems deliver primarily an operational efficiency benefit. It is the direct benefits that these technologies have delivered that has fostered their market penetration.

The benefits are so compelling and available at such a reasonable cost that anti-lock brakes and cruise control are standard options that are included in almost every large (class 8) truck sold today. Qualcomm has sold over 85,000 OmniTRACKS two-way satellite communication units to more than 315 trucking companies. These units, which provide continuous and ubiquitous two-way communications, monitoring and tracking of trucks, cost about $4,000 per truck for the hardware. Actual communication charges are extra. At these prices these systems sell. These proven results suggest that there is a strong potential market for vehicle-borne AHS technologies that provide safety and driver comfort amenities over a wide expanse of the driving cycle.

The important common characteristic of each of these existing technologies is that each provides benefits over most of the driving cycle. Anti lock brakes provide a safety enhancement to the motor carrier at all times. Cruise control can be used on essentially all roads to deliver comfort and convenience benefits over short and long stretches of travel. The valuable element of the OmniTRACKS system is that, because it is satellite-based, it monitors and maintains communications across the country. Similarly, a pure vehicle-based RSC 2-type AHS system would be able to deliver comfort and safety benefits over most of the driving cycle. These benefits would be available to all trucks that purchased the on-board equipment; even the first truck. It is thus quite reasonable to surmise that the safety benefits will motivate the carriers, and the job enhancement aspects will motivate the drivers to invest in RSC 2-type vehicle borne technologies if they are affordable.

The beauty of RSC 2-type vehicle borne AHS technologies is that they are not dependent on investments in the infrastructure to deliver the safety, comfort, and convenience benefits. Thus, the costs are modular. They are incurred directly by the end user who gains the direct benefit. It would be difficult to imagine how an infrastructure-based cruise control system could have been successful, because incremental investments could not have delivered incremental benefits. In fact, Qualcomm was able to incrementally offer incremental communications by renting space on existing satellites rather than having to establish it's own satellite infrastructure prior to entering the market. Similarly, the safety and convenience aspects of a vehicle-borne RSC 2 are benefits that could easily motivate motor carriers and independent truck driver to invest. The big question remains as to whether the market size for an RSC 2-type system is sufficiently large that units can be affordably priced and enable the developer to recover his R&D costs as well as make a profit.

The market opportunities for such equipment are favorable simply because the productivity of the equipment is so large for motor carriers and for inter-city commercial bus operations. Drivers for these firms spend a lot of time and travel many miles on our nation's interstate highway system. Most of that mileage is driven on highways that are not in urban areas. These freeways are not normally congested. They are rural in nature. These drivers use the highway system ubiquitously, almost as a random process rather than a repetitive driving back-and-forth over the same pavement. Thus, a system that is oriented to the infrastructure is burdened with the need to invest in much of that wide expanse of infrastructure before users can begin to capture much of the benefit. Such a system cannot require much capital investment by the truck or inter-city bus owner because this cost cannot be distributed over much of the driving cycle. A system that is vehicle-based delivers to its driver benefits that accrue continuously from the beginning for each mile traveled over suitable highways. Since the total cost of the technology is primarily capital cost with little operating and maintenance costs, the higher the utilization, the lower the per-mile costs. Truck drivers, inter-city bus drivers, and traveling salesmen have enormous benefit opportunities.

Assuming that this technology requires only investment in on-board sensors and actuators, one can readily justify investment in the technology. An RSC 2-type system could deliver benefits over much of the driving cycle that are greater than that of cruise control. Thus, on inter-city hauls one could expect that these systems could be used more than 80% of the time. Given that a class-8 truck logs roughly 125,000 miles per year, this system could deliver benefits to an owner-operator during over 100,000 miles of travel per year A carrier who uses team or relay drivers may have even more to gain. He may be able to double the annual utilization of this equipment without incurring additional capital costs.

Assume that the on-board RSC 2-type AHS equipment has a 5 year life and requires annual maintenance of 10% of its capital cost. At a 12% cost of capital, a $5,000 system would add only one, (1), cent per mile to the operating costs of an owner-operator that logs 125,000 miles per year. That driver would capture about 100,000 miles of safety and comfort benefits. Demonstrated safety improvements could reduce insurance premiums sufficiently that the incremental cost of such equipment would be essentially zero.

As postulated, the relationship between capital costs and per-mile incremental costs is linear. A $10,000 system would add about two (2) cents per mile to the operating cost. For fleet owners that use tandem or relay drivers the cost per mile is proportionally less for trucks that are used more intensely. For a truck that logs 200,000 miles per year, a $5,000 system would add only about 0.6 cents per mile to the trucks operating costs. Thus, one could expect that those first to invest in such a technology will be commercial operators that make the highest annual use of the nations interstate highways.

B.2.3.2 Market Size Estimate

The current market for inter-city trucks is approximately 100,000 units per year. With a 50% market penetration at a unit price of $5,000, this provides an annual market size of $250 million per year in the domestic class 8 truck market. Class 6 and 7 are also active in the inter-city motor carrier market. Their average domestic sales for the past 5 years have been 17,500 and 66,000, respectively.

B.2.4 Driverless Automated Freight System: Opportunities to Serve Smaller Shipment Size

RSC 8-12 provide the opportunity for driverless operation. These RSCs are particularly attractive to the commercial and transit sector because of their potential for major reduction in driver labor costs derived from driverless operation. Each of these RSCs has an exclusive roadway and its associated entrance and exit facilities that interface with the conventional road system. These facilities could be expanded by connecting the entrances and exits to /from off-line terminals where captive vehicles could be loaded and unloaded. Additional off-line terminals could be constructed at strategic locations to facilitate interfaces with inter-modal operations. These off-line terminals could interface with conventional trucking or rail operation in a cross-dock type of operation or they could be facilities that could integrate directly into the shipping facility of a major sourcing location for raw materials, a manufacturer, or a distributor.

The significant advantages that such an operation delivers are the elimination of driver labor cost and its associates hours-of-service constraints. Thus ultra long-haul shipments could be dispatched from a terminal and travel non-stop, except for refueling, to its destination. For shipments having trip length greater than 500 miles, this would substantially reduce the transit time because the 10-hours of service limitation on drivers would not be applicable. For extremely time-sensitive shipments that would normally have used team drivers, a comparable level of service would be provided at a savings of two units of labor costs. With labor costs running at $0.40-$0.50 per-mile, this can be seen as a significant benefit. If the on-board hardware costs could be kept low, say below about 5 cents per mile, this would still leave substantial benefits that could justify tolls of upwards of 25 cents per mile for class 8-type large combination vehicles operating in an RSC-10/11-type system. A benefit spread of greater than $0.10 per mile combined with the travel time, reliability and safety benefits can be significant motivators for high volume shippers like UPS and other LTL operators to construct the necessary facilities to connect their terminals to an RSC 10/11-type of interstate AHS.

There may also be a significant latent market for such driverless operation if the per unit cost of the on-vehicle AHS system is low enough. In these situations market forces may be such that smaller shipments do not need to be consolidated and then dispersed but instead can be dispatched directly from origin to destination in smaller RSC 8/9 single vehicle equivalent (SVE- type system. If it costs little more to ship direct rather than consolidate, ship, and disperse, then the market will ship direct. This is in concert with the basic trends of shippers to desire smaller, more frequent shipments rather than large infrequent shipments. The tangible benefits of just-in-time shipments to reduce inventories and improve manufacturing efficiency would benefit from this driverless small vehicle freight concept.

The opportunities of such a concept were investigated using the LTL shipment data. It was found that indeed a large percentage of LTL shipments are small enough to fit in SVEs. The average shipment size for the 139 million LTL shipments in 1992 was found to be 926 pounds, (Eno, 1992). This is a substantial market. In converting the TRANZACT data to TEUs it was assumed the an average LTL TEU was 20,000 pounds. By further assuming that half of the TEUs could be disassembled back to their original size before consolidation, consisting of an average of ten (10), 1,000 pound shipments transportable in SVEs, them. Assume that 50% of these are diverted to the driverless system; then, each mile, of the more extensive Phase 3 AHS network described in table B3, could serve an average of 850,000 SVE LTL shipments per year. This is a sizable volume from which one might be able to extract a toll that is on the order of $.10 per mile. At this level these SVEs would contribute to the capital and operating costs of such a system but only on the margin. Even by using all of the optimistic assumptions above, a driverless SVE concept could generate tolls that could service no more than a $850,000 per mile capital debt. At that, this concept could only evolve as the network grew to provide service to much of the country. Operationally, the shipments would still need to be collected and distributed using conventional means. Pick-up and delivery terminals would need to be located in a cross-dock fashion with the off-line terminals connecting the RSC 8 AHS. This concept needs for many such terminals to be constructed so as to minimize the collection and distribution distances. Thus, it begins to make sense only after the AHS has grown to provide service over a sizable region.

In freight transportation, one has to be careful not to "cube-out" as well as not to exceed weight limits. The volumetric constraint is not as important a constraints to the LTL shippers because their shipments are already severely restricted in size. The kinds of commodities served by the LTL industry are not of the type that typically cube-out before they weigh-out. The cube-out traffic could not be effectively served because of the size limitations of the RSC 8-type systems.

LTL freight rates vary widely; however, their average in 1992 was 24.82 cents per ton-mile whereas truck load carrier collected only 9.96 cents, (Eno, 1993). This demonstrates that small volume shippers are willing to pay a substantial premium to keep shipments small. Within LTL, smaller shipments pay higher prices than larger shipment. We can gain some idea about what shipment sizes could be could be economically served by a driverless AHS. If we assume that LTL shippers are willing to pay roughly $.25 per ton-mile, then at what point does the LTL operator have sufficient revenue to route shipments on the driverless AHS. It can be assumed that the operation and vehicle capital costs of a driverless, RSC 8-type, SVE-sized vehicle could be as little as 50 cents per mile, not including any toll charges for the use of the AHS system. These freight rates imply that only shipment sizes greater than three tons, or 6,000 pounds, could take advantage of the direct driverless operation. This would provide revenues of $.75 per mile, leaving $.25 per ton mile for tolls, profit, and other expenses, after paying the vehicle costs of $.50 per mile. The flow of LTL traffic on the Phase 3 network reported in table B4 indicates an average annual utilization of each mile of the network by roughly 600,000 LTL shipments averaging 6,000 pounds. If one could capture 50% of that market and be able to charge tolls of $.10 per vehicle mile, this would generate $30,000 per route mile of annual toll revenue for the RSC 8-type AHS. By considering the freight rates that shippers might be willing to pay and the vehicle costs, the amount of infrastructure capital costs that such a system could defray may be at most $300,000 per route mile. This is hardly enough to finance even a 10% share of the capital costs of building such a system. Note that consideration of freight rates and operating costs, suggests that this type of system will not be able to serve very small shipments weighing 1,000 pounds, but will instead require consolidation of shipments to 6,000 pounds. This increased size is dangerous to the concept because a 6,000 pound payload is at or above the design limit of an SVE.

In summary, existing freight traffic demand in the LTL sector suggest that shipment sizes and freight rates are such that a driverless SVE RSC-8/9-type AHS concept could serve this demand. However, such a concept only begins to make sense when the geographic size of the AHS network becomes large. Further more, if toll charges are limited to approximately $.10 per vehicle mile, then, even using optimistic estimates, the market size is not large enough to pay for more than a small portion of the capital costs of such a network. If one considers what shippers currently pay for LTL service, each mile of the Phase 3 AHS would serve an on average 300,000 driverless vehicles a year that could be expected to contribute toll revenues of about $30,000 per route-mile per year.

B.2.5 Major Conclusions for AHS Service of Inter-City Freight

B.2.5.1 Conclusion for Commercial Freight Transportation

- The commercial freight inter-city market has most of its driving cycle on rural, uncongested interstate highways.
- Class 8 trucks, on average, log more than 125,000 miles per year of travel, of which 100,000 is on the interstate highway system.
- The market for class 8 trucks (over 33,000 pounds) is approximately 20,00 per year.
- Motor carriers have aggressively bought new technology that provides improved safety, comfort and convenience for the driver and advanced communication systems that improve the management of the truck fleet.
- A vehicle-borne, infrastructure-free RSC 2-type system that would be usable on much of the nations interstate and expressway highway system without any infrastructure improvement would be extremely attractive to motor carriers (and the inter-city bus industry). A good price point for these systems would be a capital outlay of about $5,000 , and a maintenance cost of less than $500 per year. At this level this adds about one cent per mile to a truck's operating costs.
- At a 50% market penetration of new sales, there is a $250 million annual market for a $5,000 vehicle-borne RSC-2 type system that is installed as optional equipment on new class-8 trucks. Conversions of existing trucks increases proportionately the size of this market.
- An infrastructure-based, RSC 8-12-type AHS has a clear evolutionary path starting with dense 1,200 mile corridor along I-80 between Chicago and Salt Lake City. Each mile of such a system could serve as many as 1.8 million truck movements per year if the economics are right. Because such a system would serve only a small portion of the driving cycle of most trucks using the system, the on-vehicle hardware costs can't be amortized over as many miles as an RSC 2, infrastructure-free system. It will be paramount to keep the on-vehicle costs extremely low so as not to stifle market entry by those trucks that could otherwise use the system.
- Future evolutions of an RSC 10-11-type AHS could grow to an 11,000 mile system that could serve roughly 50% of the current truck-served, inter-city freight market.
- Even by assuming a 100% market penetration, the 11,000 mile RSC 8-12-type AHS would only generate toll revenues of $110,000 per route mile at toll rates of

$.10 per mile. This level of tolls can service the capital debt of about $1 million per mile. It is unlikely that motor carriers would be willing to pay AHS tolls that are much greater than $.10 per mile

- A driverless, SVE, RSC-8/9-type, Phase 3 AHS concept could serve a substantial amount of LTL demand. If toll charges are limited to approximately $.10 per vehicle mile, then, LTL demand patterns, shipment size, vehicle costs and existing freight rates suggest that each mile of such a system could serve as many as 600,000 of these shipments per year. Assuming a 50% market penetration, traffic densities on a Phase 3 network could generate toll revenues of about $30,000 per route-mile per year.

- Comparing the basic economics of the market for a driverless, RSC-2-type AHS with an infrastructure-intensive RSC 10-11-type AHS suggests that an RSC 2-type system is much more attractive to the inter-city freight industry. It's on-board costs can deliver benefits over much more of the driving cycle, the system has a much lower cost of entry (infrastructure does not have to be built), and even a mature RSC 10-11-type AHS does not serve enough volume, even at a large toll ($.10/mile) to service the cost of the infrastructure. This finding suggests that R&D investment focused on reducing the cost of reliable vehicle-borne, infrastructure-free RSC-2 type systems is the best way to have AHS successfully serve the inter-city freight market.

B.3 OPPORTUNITIES FOR AHS-BASED INTRA-CITY COMMERCIAL FREIGHT

B.3.1 Characteristics of Intra-City Commercial Freight Traffic

The intra-city commercial freight market, often called urban goods movement, is made up of two major segments, the distribution of goods from warehouses and consolidation centers to commercial establishments and the collection of refuse. They involve either delivery or pick-up functions that are facilitated by the driver. Routes have one trip end as a terminal. Distribution or pick-up points are dispersed along "traveling salesman"-type routes. Individual shipments tend to be small. Vehicle capacities need to be able to accommodate many individual shipments. These are distributed along a route. The routes taken by existing intra-city freight traffic tends to be on local streets and arterials. Cumulative volumes are very large, but they are widely distributed geographically across each metropolitan area. Driving is done throughout the day, not just in congested periods. The market is not controlled by a major corporate entity. It is a collection of many small players. The trucks that serve this market, class 2-7, accumulate annual mileages that are in the 20,000 - 50,000 mile range, much less than half that of inter-city trucks. The reason for the low mileage is that the driving speeds of intra-city trucks are substantially less than inter-city trucks and a significant amount of the driver's time is spent in performing pick-up and delivery functions.

There is a real lack of hard data on intra-city freight transportation that can be used to provide quantitative support for the qualitative findings made above. There exists no national database for local truck movements. Companies involved in intra-city distribution have their own proprietary data bases. We were unable to locate a database that contained an ensemble of data for intra-city freight movement for any metropolitan area.

B.3.2 Implications on AHS Service of Intra-City Goods Movement

It is difficult to envision the kind of AHS that could serve a significant portion of the intra-city freight market. Its geographic diffusivity and its many stop pick-up/delivery operation makes each of the RSCs not particularly attractive to this market. Vehicle-borne RSC 2-type AHS is not envisioned to operate on arterials and local streets. Thus very little of a truck's driving cycle could benefit from such a system. Combined with the fact that these trucks don't travel nearly as far as their inter-city counterparts, an intra-city truck could legitimately distribute the cost of such a system on an order-of-magnitude less miles, roughly 10,000 miles. This makes an RSC 2 type system at least 10 times more expensive to an intra-city truck driver. For an RSC 8-13 type system to be useful to this market it would need to have an extensive network of intra-city freeways so equipped. Small pockets of this market could be found to be properly concentrated and have narrowly defined repetitive movement; however, these sub markets are the exception.

Thus, AHS, at least in its early stages, is not particularly attractive to, or well suited to serve, the intra-city freight market. At best, this market would be served by AHS only in its later stages of development.

B.3.3 Conclusions for Intra-City Freight Movement

- Intra-city freight and the collection and distribution of inter-city freight are extremely difficult to serve with automation. The small shipment size and the multiple stop character of the operation are not conducive to automation.

- As with inter-city commercial bus operation, the driver performs more functi ons than simply driving the truck. The driver is the service interface with the customer.

- The geographic diffusivity of this traffic is such that much of the intra-city goods movement driving cycle takes place on road segments that are not compatible with an RSC-2 type AHS. Because each vehicle logs relative low annual mileage vehicle-borne AHS hardware can be amortized only over those few miles. An infrastructure-intensive RSC 8-12-type AHS serve even less of the driving cycle.

- AHS does not seem to be particularly attractive to this market.

B.4 OPPORTUNITIES FOR AHS-BASED COMMERCIAL FOR-HIRE INTER-CITY PASSENGER TRANSPORTATION

B.4.1 Characteristics of the Current Inter-City Passenger Market

The commercial, for-hire, inter-city transportation market is but a small portion of the total inter-city passenger-mile market. In 1991, the private automobile served 80.7% of the 2 trillion inter-city passenger-mile market. The commercial, for-hire inter-city passenger carriers served only 18.6% of that market. Air transportation is the dominant technology. Its 16.8% share of the total market was 90% of the commercial market. The other commercial modes, rail and bus, have an infinitesimal share of the market. Commercial rail's share of the market, which is served almost entirely by Amtrak, is only slightly larger than that of private air (as opposed to commercial air). Commercial rail served only 13.7 billion passenger-miles, while private air served 13.1 billion. Each had about 0.7% of the total inter-city passenger market. In 1991 there was a total of 4,204 inter-city bus operating companies . Most of them are small charter operators. There were 31 class 1 inter-city bus operating companies that offer scheduled service. Of these, most are small. The industry is dominated by a single national carrier, Greyhound. In total, these companies operated 20,855 buses and served 23.5 billion passenger-miles, or 1.2% of the inter-city people travel market. The replacement rate is approximately 2,000 buses per year. At its current levels, this is not a very large market. Each bus is an extremely productive entity. They log over 100,000 miles per year, most of which is traveled on the Interstate highway system. Consequently, a vehicle-borne, infrastructure-free

RSC 2-type AHS system, that can operate throughout the Interstate highway system, can deliver benefits during 100,000 miles of bus use per year. Even a relative expensive system could have attractive per mile costs.

In addressing the commercial market for AHS in the service of inter-city passenger demand, two approaches can be considered. One is to investigate how a commercial, public carrier using AHS technology could better serve the current inter-city bus patrons and to determine what AHS technological nuances would give such a technology a service advantage. The second is to study how AHS could penetrate each of the existing inter-city commercial carrier sub-markets individually. This second approach will be pursued first and will be combined with an analysis of the private car market to build a picture of the suitability of AHS in the total inter-city passenger market. Once completed, a separate investigation will be made as to how, in terms of a mix of public and private mechanisms, AHS can deliver inter-city passenger service.

In focusing on existing commercial inter-city passenger sub-markets, neither the bus or the rail market provide much of an opportunity, by themselves, for a nation-wide AHS. The inter-city bus mode is extremely diffuse with very low volume. Only through the provision of substantial public subsidy is the rail mode able to maintain a national network for which significant concentration exists only on the Boston - Washington corridor. It is only in that market for which it may be worthwhile to search for a significant AHS market, although it may be contrary to good public policy to divert traffic from rail.

The long-haul air market provides no opportunity for AHS patronage. Its travel time advantages are simply too overwhelming. The short-haul portion of existing air service; however, may be a source of some modest commercial inter-city passenger traffic for AHS on an incremental basis. If the inter-city linkages of AHS were economically justified by other markets, then diversion of short-haul air passengers may deliver incremental users to an inter-city AHS.

With the infrastructure in place, one can envision that the door-to-door service capabilities of AHS could erode the under 250 mile portion of the air transportation market; however, this market is not very large. Only 10% of the inter-city air passenger trips are 250 miles or less, much of which is in the Northeast corridor. These passengers are extremely sensitive to travel time, otherwise they would have not taken a plane for such a short distance. They have plenty of competitive choices including Metroliner services in the Northeast. It would be the additional comfort, convenience and door-to-door service offered by the private vehicle segment of AHS that could capture some part of this market. More of it would be captured outside the Northeast corridor where short-haul air transport does not have good rail service competition.

B.4.2 The Inter-City Passenger Market for Vehicle-Borne, Infrastructure-Free RSC 2-Type AHS

In total, the existing commercial inter-city passenger market is not expected to contribute more than a small amount on incremental demand for an inter-city AHS. What demand is served will not have sufficient substance to impart any significant special technological needs. Even if we assume that an RSC 2-type AHS has a 50% penetration of the sales of new inter-city buses, this amounts to the sale of only 1,000 units per year. This is certainly too small of a market on which to build an RSC 2-type AHS; however, it can complement the inter-city freight market. The technology that is needed for an RSC 2-type AHS for inter-city passenger transport is the same as that needed by a freight-oriented RSC 2-type AHS. Thus, the inter-city market is an incremental market that contributes to the total market for RSC 2 type systems. As is presented above in section B.2, the annual market for RSC 2-type AHS for inter-city freight transportation is an order-of-magnitude larger, approximately 10,000 units per year at the 50% market penetration rate.

Of course, the largest potential market for RSC 1/2-type AHS is the private automobile. The good news is that there is an enormous amount of inter-city travel served by the private automobile, 1.8 trillion passenger-miles. Most of that travel is on the interstate highway system. The bad news is that any one vehicle's annual mileage in inter-city travel is small. Average vehicle occupancy for the majority of those trips is high, greater than 2.0. Trips tend to be short however, there are some very long vacation trips. The average inter-city mileage for a private automobile is roughly 5,000 miles per year. Even for an RSC 1/2-type system that could serve much of those 5,000 miles, for the average car, this is a very low annual mileage over which to distribute the on-vehicle capital costs of an RSC 1/2-type system. Quantifiable benefits of $.10 per mile would only substantiate a capital investment of about $2,000 This assumes a five year life, a 10% interest rate and modest annual maintenance costs. Only for special users such as "traveling salesmen" and others who log a lot of miles on the interstate system, could the cost be distributed over sufficient use to be easily justified. While even a small penetration of this extremely large market provides some significant volume of potential users, the economics for the private automobile are substantially worse than that of the inter-city bus and class 8 motor carrier.

B.4.3 Market Growth

Market growth in the commercial inter-city passenger area is expected to be slightly larger than growth in the economy in general. Most of the growth can be expected in the airline sector. The airline sector has been growing at an annual rate that is about one percentage point greater than the economy as a whole. The trends in inter-city rail continue to increase, but at a rate slower than airlines. Inter-city bus has been decreasing (Eno, 1992).

B.4.4 Latent Demand

It has been difficult to identify some possible sources for latent demand in commercial inter-city passenger transportation. While one can envision AHS causing a significant increase in inter-city travel in private, personal AHS vehicles, it is more difficult to conceptualize a commercial inter-city passenger operation that could be spawned by AHS.

If the public could become accustomed to the provision of remote customer services, as they have done for short trips in elevators, then, driverless operation could create a market for a more moderate-sized AHS "bus" that could provide a higher frequency, more demand-responsive service over that of existing buses and trains. Such a service would, if anything, draw its traffic from existing auto users as opposed to creating a brand new transportation market. One might be able to provide more inter-city mobility to the very young and the very old; however, their fundamental inter-city travel demands are modest, at best.

A fundamental problem is that in the commercial inter-city passenger market, the driver serves a greater purpose than simply driving the vehicle. The driver provides general oversight, customer service, a significant element of security and is available to respond to emergency and unexpected situations. Each of these is very difficult, if not impossible, to deliver through remote means. Consequently, it seems very unlikely that a corporate entity would dispatch a group of passengers on a long journey without a human representative on board. Without the labor savings benefits of driverless operations, an AHS inter-city bus operation has essentially the same cost and service characteristics of existing operations; thus, there is little to motivate the creation of latent demand. This suggests that driverless AHS buses are not practical commercially for customer service reasons.

In summary, we simply have not been able to envision a latent inter-city travel market that could be created by an AHS inter-city bus operation; although, one is rarely a sufficient visionary to see these markets in advance.

B.4.5 Conclusions for the Commercial Inter-City Passenger Market

Table B4 summarizes some of the major characteristics facing the commercial inter-city market.

Table B4. Major Characteristics of the Commercial Inter-City Passenger Market

Existing Mode	1992 Market Size (billion p-m)	Opportunities for AHS	Notes
Inter-city bus	24	An RSC 2 system would be very attractive to this market	Major portion of bus fleet could covert to AHS operation
Inter-city rail	14	Little shift to private AHS vehicle, some markets could convert to inter-city AHS bus operation	AHS incursion into this market causes some public policy problems
Air passenger	340	Small opportunities for private vehicle AHS in short haul non- Northeast corridor markets	
Private air	13	No real competitive opportunity for AHS	

The major conclusions are:

- The commercial inter-city market is small in comparison with the inter-city passenger market served by the private automobile.
- The only likely short term commercial inter-city passenger market for AHS is that of inter-city bus. This is a very small market. Only 1,000 new inter-city buses are sold each year. However, the driving cycle of an inter-city bus is similar to that of an inter-city truck. Thus, it could provide a good secondary market for an RSC 2-type AHS that was designed to serve the inter-city freight market.
- The bus market is less conducive to a driverless AHS because the driver provides substantial benefits other than driving.
- An infrastructure intensive AHS has better opportunities than commercial freight to serve geographically contained sub-markets, because commercial buses can be managed to operate in constrained corridors. Such a system could better serve geographic segments of the automobile market because the driving cycle of a particular automobile is much more geographically constrained than that of an inter-city truck.

- The large inter-city market is served by the private automobile. Unfortunately, on average, the private automobile travels too few miles on inter-city expressways to justify spending even a modest amount for an RSC 1/2 type system. However, there may exist some significant sub-markets, such as traveling salesmen, that could easily justify investment in an RSC 1/2 type system. Such systems also become more attractive if they could be used for the daily commute portion of the automobile's driving cycle.

B.5 OPPORTUNITIES FOR AHS-BASED TRANSIT

B.5.1 Characteristics of the For-Hire, Intra-City Passenger Market

Urban transit, that is, for-hire, intra-city passenger transportation is only a small fraction of intra-city person transportation which is dominated by the private automobile. Nationally, transit serves only 3% of intra-city person trips. These trips can be broadly classified into three sub-markets. The first market is composed of the transit trips that take place in the New York metropolitan region. This market serves roughly half of all US transit trips. It stands alone. The second market serves those trips that do not have access to the private automobile. These trips are predominantly short, less than 10 miles and are made by the poor, young, and/or elderly. The third is composed of longer distance commuter trips in dense corridors. These trips are typically served by express buses or rail rapid transit, have patrons that have higher income levels and are typically work-related.

Of these existing markets, only the express bus sub-market is conducive to the early stages of AHS where only one or a few corridors may be automated. A particularly attractive example of such a system is the exclusive counter-flow bus lane leading to the Lincoln Tunnel. This example will be discussed more thoroughly, below.

In the future, it may be that a more dense network of AHS could provide services that could entice automobile drivers to leave their private cars at home. To this end an analysis of the service potential of a dual-mode AHS operating on a dense metropolitan network is also presented.

B.5.2 Conventional Mass Transit- Automation of the Lincoln Tunnel - I-495 Exclusive Bus Lane

B.5.2.1 Description of the Current Operation

The Port Authority of New York and New Jersey, in conjunction with the New Jersey Department of Transportation, operate an east-bound counter-flow exclusive bus lane, (XBL), along a 2.5 mile stretch of I-495 leading from the New Jersey Turnpike through the Lincoln Tunnel to the Port Authority bus terminal located on 8th Avenue in Manhattan. Used is the left most west-bound lane. It is separated from on-coming west-bound traffic by temporary cones that are deployed every morning. The permanent concrete New Jersey-type barrier separates the XBL from the three east-bound lanes. The lane leads to an exclusive, bus-only lane in the Lincoln Tunnel. Tolls are collected electronically, requiring no stopping at the toll plaza. .

The XBL is in operation from 6:30 am to 10:00 am on weekday mornings. It serves an average of 1600 buses per morning at a peak rate of approximately 700 buses per hour. This one lane serves about 65,000 riders every morning, about 30,000 during the peak hour. It saves riders an average of about 20-25 minutes of delay in accessing and traveling through the Lincoln Tunnel. This facility is the most productive bus-only lane in the US. It performs the people moving capacity of 10 lanes of automobiles.

At present the facility is at capacity for two reasons. Wide variations in the spacing of buses caused in part by varying driver responses to speed variations along the XBL limit its capacity to 700-800 buses per hour. Speed variations exist at the downward helix, passing through the toll plaza, at the entrance to the tunnel and on the upgrade leading to the exit on the Manhattan side of the tunnel. The most severe capacity constraint exists in the bus terminal on the Manhattan side of the tunnel. Here the bottleneck is caused by buses maneuvering for docking space. This causes backups. It is a classic entry/exit problem. Neither bottleneck has had a simple solution. Drivers need to be more consistent and responsive and better real time communications, management and control are needed to route buses through the bus terminal.

B.5.2.2 AHS Opportunities for the Lincoln Tunnel

AHS could contribute to the alleviation of both bottle necks. An AHS system could maintain better spacing of buses even with speed variations and a real-time information system could better guide the buses to and from their loading docks in the terminal.

From a market perspective this application of AHS has a number of fortunate characteristics. The buses that use the facility tend to use it on a daily basis. Thus on-board AHS equipment of the RSC 2-type can get high utilization. Since the entire corridor is less than 3 miles long, any infrastructure-based AHS equipment need be deployed only along a short corridor. Benefits accrue to an extremely large number of users because of the high patronage of the buses. A 25% increase in capacity of the XBL would serve an equivalent number of travelers as are served currently by all 3 of the conventional east-bound lanes. The travelers who would benefit from the system are more representative of the whole population than those that currently drive automobiles through the tunnel.

There are several fundamental characteristics that make the Lincoln Tunnel XBL a particularly good application for AHS. First, there is a monumental problem on the horizon if a substantial capacity improvement is need in this facility. There is no place to put another access lane and the cost of boring another tube is enormous. Thus, capacity through automation would surely be the most cost effective solution. Even without need for capacity improvement, automation would smooth out the flow of buses and improve the travel time reliability of the buses. The application is on a very short corridor, less than five (5) miles, and the same busses use the facilities repeatedly. Less than 1500 buses would need to be AHS-equipped The institutional challenges are probably as limited as possible. All buses are the property of NJDOT and were purchased with PANYNJ money. NJDOT and PANYNJ have authority over all operations and construction in the corridor. For these major reasons, this is an excellent candidate "early winner" for AHS

B.5.2.3 Simulation of AHS Bus Operation on the Lincoln Tunnel XBL

In order to better understand the capacity issues on the XBL and to demonstrate that higher capacity could be achieved, we developed a simulation of the XBL's operation. The simulation consists of a 3-dimensional model of the XBL's roadway system. A driver simulation model that controls the throttle and brakes of each bus "drives" along the XBL. A vehicle-follower mode has been implemented that determines if the bus should operate in a leader mode or a follower mode. Under the leader mode the control system regulates speed according to a desired speed profile. In the vehicle-follower mode, the vehicle maintains spacing and regulates its speed relative to the vehicle directly ahead.

B.5.2.4 Simulation Results

The simulations indicate that even with randomly arriving buses at the New Jersey Turnpike end, the XBL can easily accommodate an increase in demand to as much as 1600 vehicles per hour by controlling the bus speed to a minimum of 20 miles per hour along the tightest part of the helix.

B.5.3 Analysis of a Dual-Mode "Mini-Bus" System for New Jersey

B.5.3.1 Characteristics of Dual-Mode Transit

Dual-mode is a concept that has a history of more than 20 years. The term "Dual-mode" refers to a transit system whose vehicles are capable of both computer controlled automatic operation on a fixed guideway and manual operation (with driver) on the regular street network [3]. It has the advantage of the automated operation's improved safety, travel time reliability and, in driverless operation, the potential to lower labor costs while simultaneously keeping the flexibility of door-to-door service. The operation of a dual-mode system is depicted in figure B27.

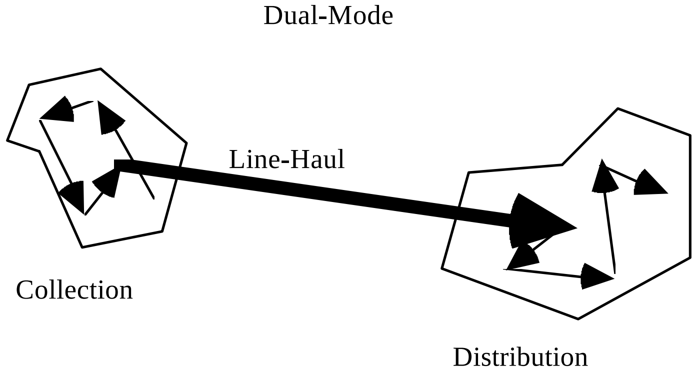


Figure B27. Dual-Mode Service Concept

It is assumed in this report that single-vehicle-equivalent (SVE) sized, low-capacity, 6 - 12 passenger vehicles perform the neighborhood pickup of passengers with a common destination, use the Automated Highway System (AHS) for line-haul operation to the vicinity of destination, and distributes passengers to destination by conventional operation on the local street network. Drivers do not need to accompany vehicles on the automated portion.

With such an operational concept, it is possible to provide the door-to-door service which have service characteristics that are comparable to the private auto. Applications in Santa Clara, California and Milwaukee, Wisconsin were studied extensively in the middle 1970s. The conclusions of those studies indicated promise for the concept; however, technological development of the automated portion of the concept was not pursued.

We chose to re-evaluate the concept, this time within the context of a region-wide implementation throughout the state of New Jersey. New Jersey, being the most densely populated state has travel patterns that are common to most metropolitan areas. It has dense major corridors as well as a wide expanse of diffuse suburban-to-suburban travel patterns that are dispersed over a large area. We also chose New Jersey because we had a comprehensive journey-to-work trip file that exhibited both the spatial and temporal characteristics of auto-based trips to work. A basic question that was not answered by the early dual-mode studies was: is there in fact demand for dual-mode's service capabilities? Dual-mode requires that at least a few people wish to travel from about the same location to about the same location at about the same time. Without this commonality in trip demand, dual-mode has no trips to serve irrespective of its technological capabilities. This question can only be addressed using a demand data base that reflects both spatial and temporal characteristics.

B.5.3.2 Analysis Procedure and Results

The analysis procedure involves three separate steps to examine the applicability of dual-mode system and to inspect the market potential. These is the work-trip demand file generation, the dual-mode demand aggregation model, and the graphical user interface (PTNM/Iris). Following are the description of each of these three steps.

B.5.3.2.1 The Work-Trip Demand File Generation

A dual-mode system would operate throughout the day; however, its peak service will be provided in serving trips to and from work. Our focus is thus on dual-mode's service to the journey to and from work. Detailed data precisely describing both the geographic (origin-destination) and the temporal (departure time) of work trips in any region are not available. However, such a demand file can be generated synthetically by assigning individual trips to randomly selected arrival-at-work times from distributions that reflect the actual times at which workers of a certain time arrive at work. These times can be projected backwards using expected travel times to yield specific departure times for each trip. This produces individual work-trip data which has a precise origin and destination, an exact (to the second) departure time. Taken over all trips this procedure yields a reasonable representation of journey-to-work trip activity in a region, (Velussi, 1992).

This procedure was used to generate a work-trip data file for New Jersey as follows: first, the 1990 journey-to-work census file for New Jersey was used to the source of specific origin and destination for each work trip. Only the auto-based trips were selected. It was felt that long distant transit trips that are currently served by commuter bus and rail would not be diverted to a dual-mode operation. Second, an employment type was assigned to each trip based on the trip's destination and that destination's distribution of employment by type as defined by employment location file of NJ's Department of Commerce. Employment types were aggregated into three sectors of employment, professional, manufacturing, and service. Origins and destinations were aggregated to 1020 demand points that corresponded to the PC-Miler version 7 link-node network representation of NJ's highway system. Finally, an arrival time for each trip was selected using a random drawing from desired arrival time distributions for each trip type. A trip departure time was appended to each trip in the file by computing the nominal travel time between origin and destination and subtracting it from the desired arrival time. Trips destined to New York City were removed from the file. It was deemed that these trips should be taking the train to New York.

The final product is a file of trips with each record containing origin node, departure time, and destination node. Such a file is created for the morning commute to work in NJ. It contains individual records on some 1.8 million intra-NJ trips. Only the trips that were greater than 5 miles in length were retained for possible service by a state-wide NJ dual-mode system. This reduced the size of the trip file to 1.1 million individual trips. If these trips are flowed over the NJ highway network , assuming uncongested road conditions, they generate 15,200,000 car-miles of travel every morning. The geographic distribution of these trips is shown as a traffic density chart in figure B28. Only the high volume links are displayed. Note that segments of the Garden State Parkway serve over 25,000 trips in the north-bound direction every morning.

B.5.3.2.2 Analysis of Dual-Mode Network Flows

The Princeton Transportation Network Model, (PTNM/Iris) was used to view and analyze the flows of dual-mode vehicles over the NJ dual-mode AHS network. The PTNM network used in the dual-mode analysis consisted of 3,360 directed links and 1,020 nodes. As a first step, it was assumed that all major highways in NJ were part of a dual-mode AHS. Dual-mode trips were assigned to the NJ network. Based on the traffic volumes, a more limited RSC 9-type dual-mode AHS network was designed. RSC 9 has new dedicated AHS lane(s) with limited access and is exclusive to Single Vehicle Equivalents (SVE). These vehicles that are commensurate with the 6-12 passenger capacity of the dual-mode vehicles used in the analysis. Dual-mode trips were reassigned to the combined dual-mode and remaining NJ highway network.

The dual-mode network had 538 2-lane route miles plus segments along the NJ Turnpike and Garden State Parkway (GSP) which extended its length to 754 2-lane route miles . This dual-mode AHS network could serve each weekday morning 1.3 million vehicle-miles with an average occupancy of 4.48 passengers. Figure B29 shows the dual-mode network of NJ without NJ Turnpike and GSP extensions. Figure B30 shows the dual-mode network of NJ with NJ Turnpike and GSP extensions.

B.5.3.2.3 The Dual-Mode Service Model

The dual-mode service model searches trip file to find trips which have the same origin and destination node and depart at about the same time. The search for trips that have the same origin and destination is synonymous with searching for trips that have similar geographic origins and destinations, because trips have been assigned to modes. In urbanized areas these modes represent roughly a four square mile area.

The detailed steps of the model are as follows.

Step 1. Delete non-divertable trips which are shorter than a pre-specified trip length.

Step 2. Sort trip file by O/D and departure time.

Step 3. Choose minimum group size (n), departure time window size (t), and dual-mode vehicle loading capacity (c).

Step 4. Aggregate individual trips into dual-mode trips based on n, t, and c.

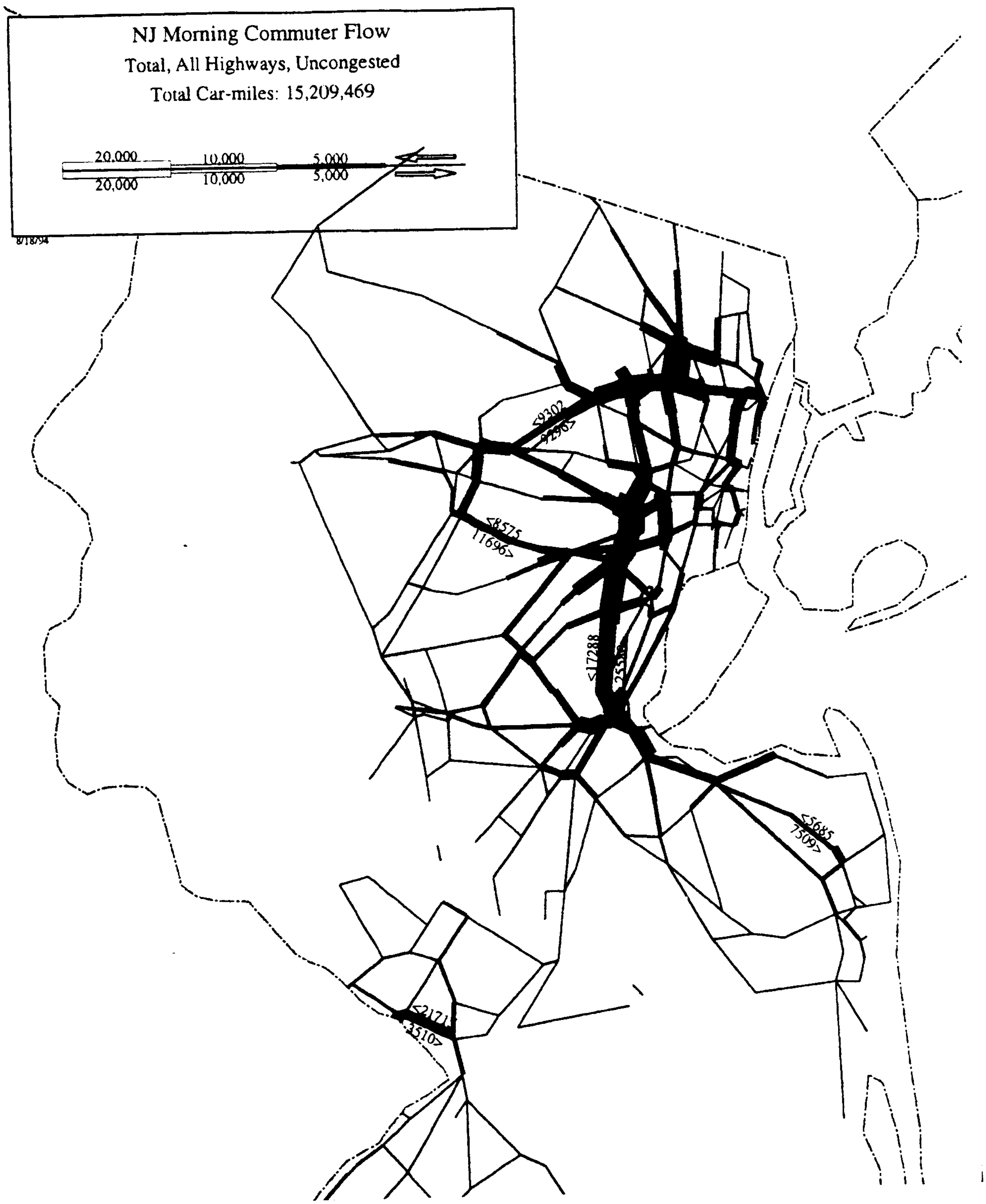


Figure B28. Major Flows of New Jersey Morning Auto-Based Work Trips

B62

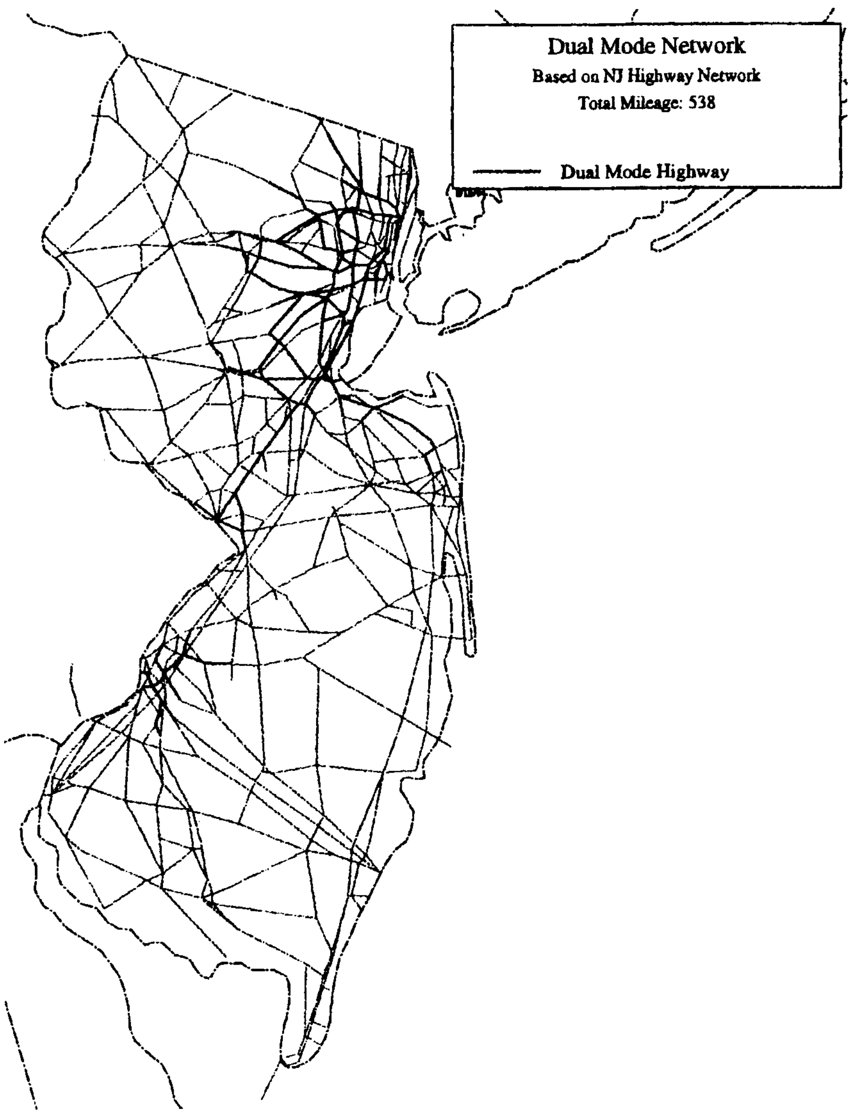


Figure B29. New Jersey Dual-Mode Network Without the NJP and GSP, 538 Route Miles

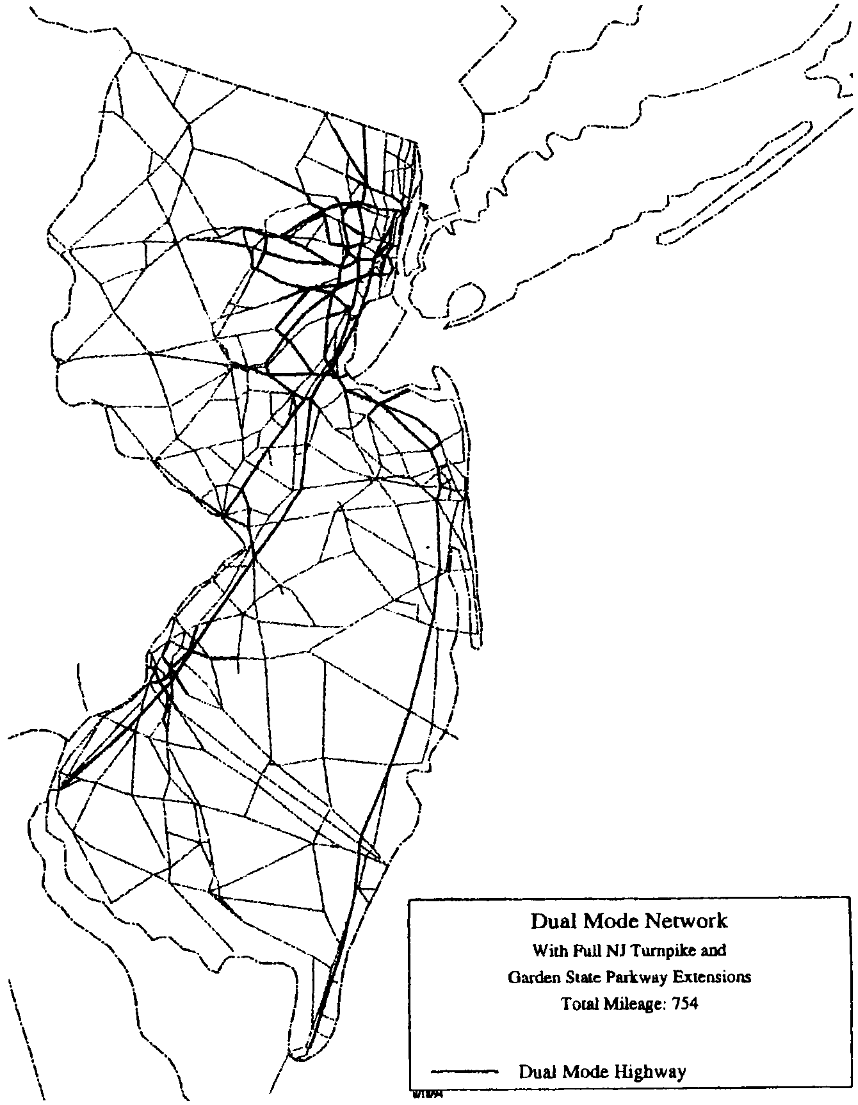


Figure B30. New Jersey Dual-Mode Network With the NJP and GSP, 754 Route Miles

In Step 1, 5 miles was used as a minimum trip length. As a result, trip file has reduced to 1.1 million records. For Step 3, we tested values of 3, 5, 7 passengers for n, and 1, 3, 5 minutes for maximum collection time, t, and 6, 12, for vehicle passenger capacity, c.

Tables B5 through B7 summarize the result of demand model implementation with various combinations of n, t and c. As measures of effectiveness, sum of passengers served, sum of passenger-miles traveled, average dual-mode trip length in miles, sum of dual-mode vehicle trips, and average occupancy rate as passengers per dual-mode vehicle are tabulated for each combination of variables.

The tables reveal that as t increases, all measures of effectiveness increase consequently. As n increases, all measures of effectiveness except average occupancy rate decrease. As c increases, sum of passengers served, sum of passenger-miles traveled, and average occupancy rate increase also, but sum of dual-mode vehicle trips decreases. One interesting result is that regardless of the value of c, average dual-mode trip length remains constant as long as n and t keep the same value. The other noteworthy fact is that the marginal benefit is very small even if c increases from 12 passengers to unlimited passengers. This fact suggests that there is little need for vehicles that have passenger capacities greater than c = 12 passengers.

The model with minimum occupancy of 3 passengers, (n=3), maximum collection time of 3 minutes, (t=3), and maximum vehicle capacity of 6 passengers, (c=6) was chosen the prototype dual-mode operation for the New Jersey dual-mode network. The prototype can serve 780,759 passengers (71 %) out of NJ's 1,116,985 daily auto-based work trips that are greater than 5 miles in length. The sum of passenger-miles traveled is 8,241,496 passenger-miles and accordingly the average dual-mode trip length is 10.6 miles.

If each passenger paid fares of $.10 per mile, the dual mode system could generate revenues of $800,000 per morning. assuming that total daily ridership is a little over three (3) times morning ridership and that there are an equivalent of 300 transit days per year, a $.10 per passenger mile fare would generate annual revenues of about $800 million. The fare would probably need to be more than $.10 per mile before the farebox revenue could pay for all operating costs and begin to contribute to the debt service on the capital cost of the AHSway. Since the morning average occupancy is high, but only 4.48 then a $.10 per mile fare only generates an average of $.45 per vehicle mile in the morning period. One can expect slightly lower results in the evening period and substantially poorer results in the off-peak period. Also, no account has been made for the empty repositioning of vehicles. Thus total daily average occupancies can be expected to be substantially poorer, possibly as low as 3.0. at this level, each vehicle is generating only $.30 per mile of revenue. Fully allocated costs of operations, plus vehicle cost, minus driver costs are at least this amount. It may well be that fares would need to be more like $.20 -$.25 per mile for such a system to begin to contribute to the debt service payments for the AHSway.

Table B5 Summary of Result with Vehicle Capacity = 6

1) Sum of Passengers 2) Sum of Passenger-Miles 3) Average Trip Length (miles) 4) Sum of Dual-mode Vehicle Trips 5) Av. Occupancy (pass./veh)		**Departure Time Window Size (t)**		
		1 Minute	**3 Minute**	**5 Minute**
Minimum Group Size (n)	**3**	1) 517,990 2) 4,998,143 3) 9.6 4) 125,212 5) 4.14	1) 780,759 2) 8,241,495 3) 10.6 4) 166,859 5) 4.68	1) 880,748 2) 9,688,551 3) 11.0 4) 178,862 5) 4.92
	5	1) 275,559 2) 2,400,014 3) 8.7 4) 48,934 5) 5.63	1) 557,426 2) 5,336,308 3) 9.6 4) 96,658 5) 5.77	1) 687,493 2) 6,895,023 3) 10.0 4) 118,120 5) 5.82
	7	NA	NA	NA

Table B6 Summary of Result with Vehicle Capacity = 12

1) Sum of Passengers 2) Sum of Passenger-Miles 3) Average Trip Length (miles) 4) Sum of Dual-mode Vehicle Trips 5) Av. Occupancy (pass./veh)		**Departure Time Window Size (t)**		
		1 Minute	**3 Minute**	**5 Minute**
Minimum Group Size (n)	**3**	1) 518,506 2) 5,003,077 3) 9.6 4) 116,145 5) 4.46	1) 781,763 2) 8,251,896 3) 10.6 4) 139,985 5) 5.58	1) 881,584 2) 9,698,351 3) 11.0 4) 140,914 5) 6.26
	5	1) 279,275 2) 2,433,431 3) 8.7 4) 40,961 5) 6.82	1) 563,254 2) 5,396,186 3) 9.6 4) 71,527 5) 7.87	1) 693,412 2) 6,961,879. 3) 10.0 4) 82,014 5) 8.45
	7	1) 167,677 2) 1,380,780 3) 8.2 4) 18,796 5) 8.92	1) 425,847 2) 3,868,794 3) 9.1 4) 44,091 5) 9.66	1) 564,798 2) 5,379,442 3) 9.5 4) 56,223 5) 10.05

Table B7. Summary of Result with Unlimited Loading Capacity

1) Sum of Passengers 2) Sum of Passenger-Miles 3) Average Trip Length (miles) 4) Sum of Dual-mode Vehicle Trips 5) Av. Occupancy (pass./veh)		Departure Time Window Size (t)		
		1 Minute	**3 Minute**	**5 Minute**
Minimum Group Size (n)	**3**	1) 518,525 2) 5,003,246 3) 9.6 4) 114,401 5) 4.53	1) 781,781 2) 8,251,965 3) 10.6 4) 132,781 5) 5.89	1) 881,639 2) 9,698,779 3) 11.0 4) 128,345 5) 6.87
	5	1) 279,325 2) 2,433,838 3) 8.7 4) 39,231 5) 7.12	1) 563,348 2) 5,397,084 3) 9.6 4) 64,350 5) 8.75	1) 693,524 2) 6,962,977 3) 10.0 4) 69,475 5) 9.98
	7	1) 167,867 2) 1,382,198 3) 8.2 4) 17,106 5) 9.81	1) 426,278 2) 3,873,464 3) 9.1 4) 37,041 5) 11.51	1) 565,433 2) 5,385,931 3) 9.5 4) 43,860 5) 12.89

The sum of dual-mode vehicle trips is 166,859 trips log ging 1,875,151 vehicle miles. The flow volumes on the dual -mode guideway as well as on the major conventional roads is shown in figures B31 and 32. Figure B30 shows the total morning volumes in units of dual-mode vehicles per link. Figure B31 shows the peak period volumes. For the entire morning period, the most heavily use segment of the dual-mode roadway has a volume of only 4.982 vehicles. This compares to the 28,000 peak flow rate that exists now with automobiles. Figure B32 shows that the peak-hour flow is only 2320 dual-mode vehicles. This could be accommodated on an automated roadway that had capacities equivalent to today's conventional highway lane.

The dual-mode network is really not very congested. It would not need to be any more than one lane in each direction and still be able to serve these 780,000 passengers every morning. In fact, figure B33 shows the distribution of link volumes in units of dual-mode vehicles per hour for the most heavily used link as well as the median link. Values are given in 15-minute increments during the morning travel period. Note the buildup and dissipation of link throughput as the morning progresses.

This enormous efficiency in moving people in New Jersey is accomplished by dual-mode's simulated ability to attain a high average vehicle occupancy. Among the, 49,467 trips (30 %) are occupied by 3 passengers, 27,359 trips (16 %) by 4 passengers, 17,276 trips (10 %) by 5 passengers, and 72,757 trips (44 %) by full of 6 passengers. Figures B34 through B37 display the dual mode vehicle flows for vehicles occupied by 3,4,5, and 6 passenger, respectively.

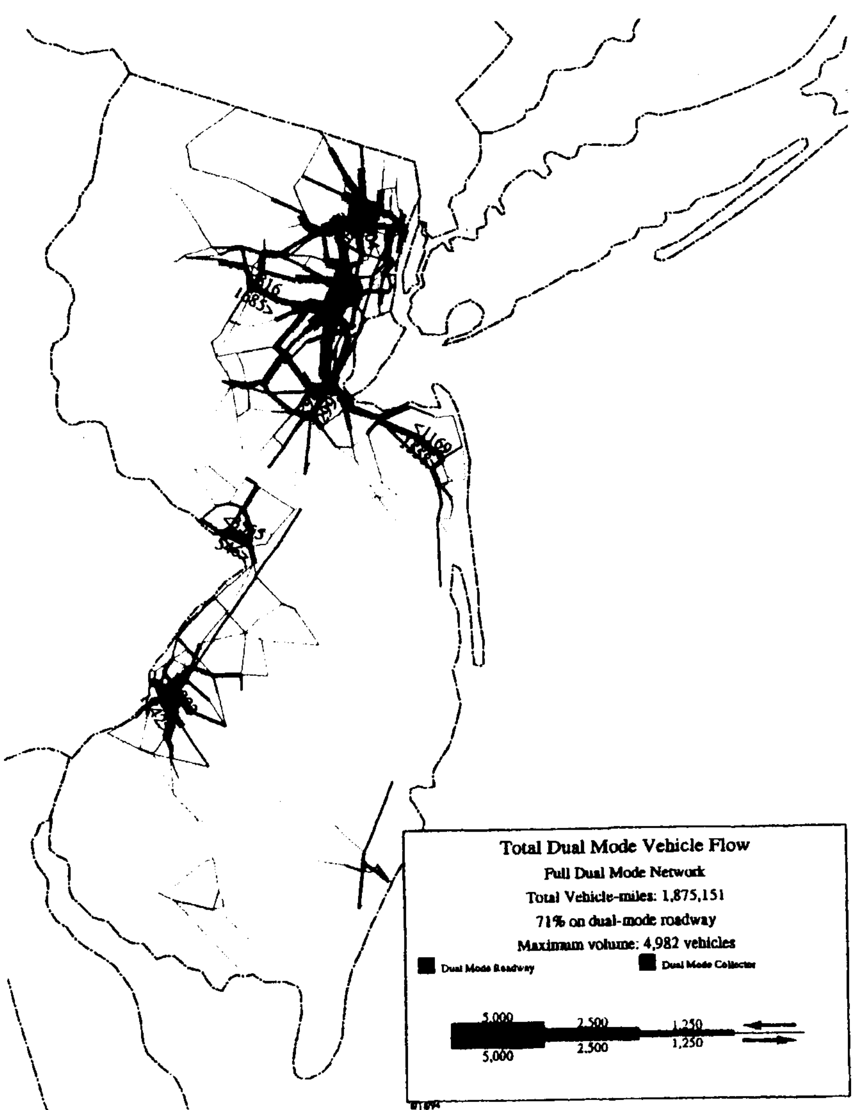


Figure B31. Total Morning Commute Dual-Mode Vehicle Flow for n=3, t=3, c=6

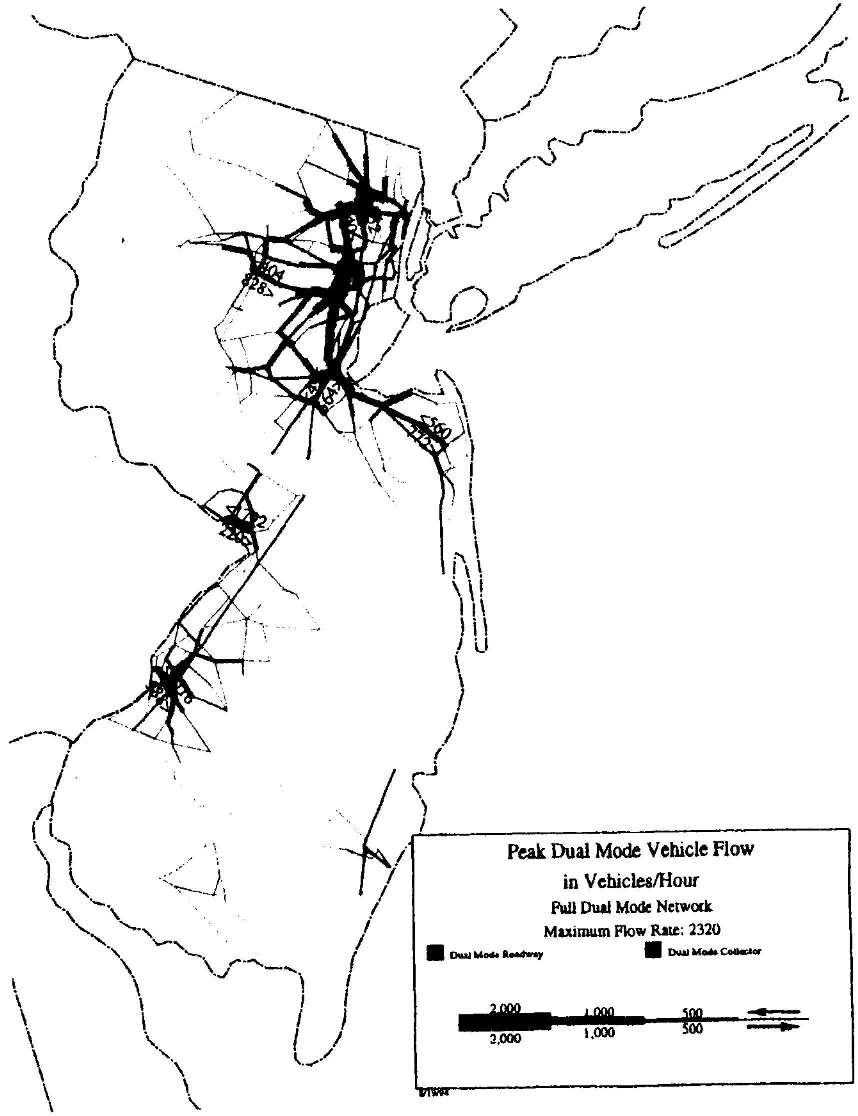
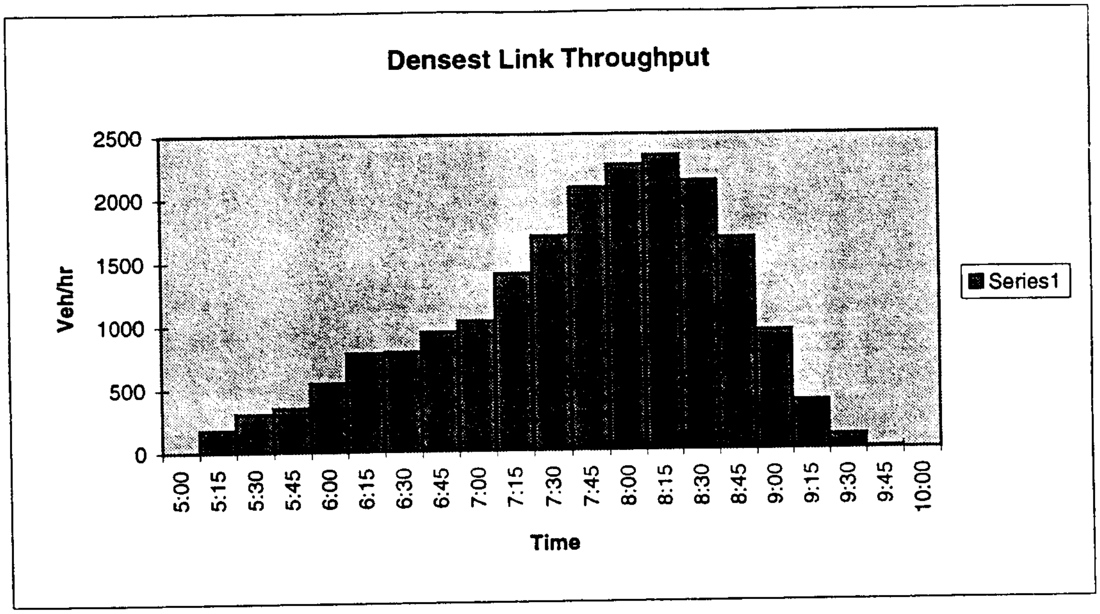


Figure B32. Peak Period Dual-Mode Vehicle Flows for n=3, t=3, c=6

Based on Full Dual-Mode Network



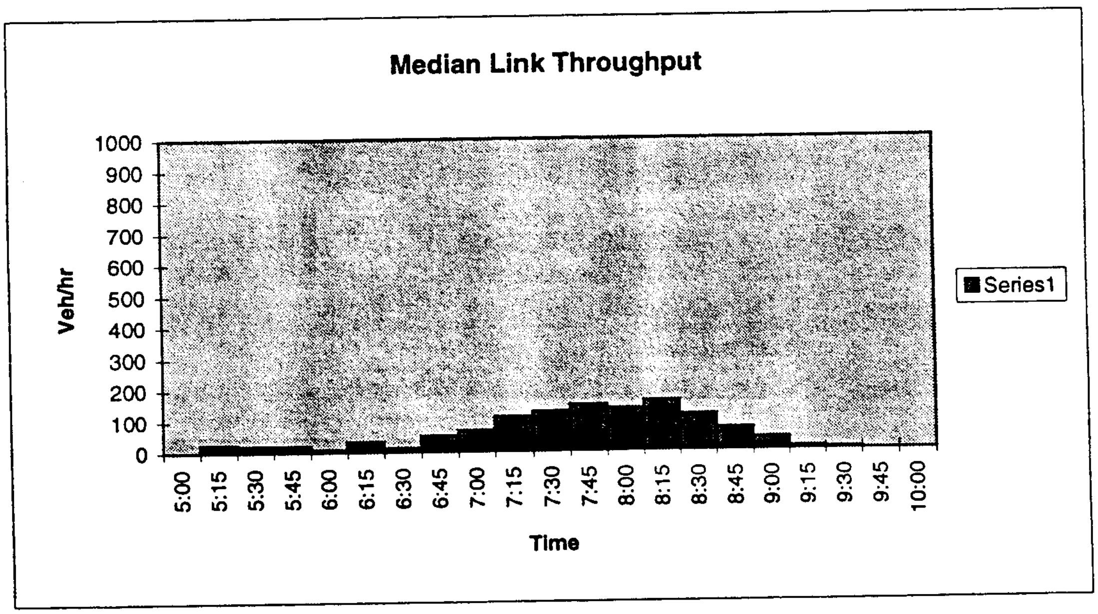


Figure B33. Road Segment Traffic Densities of Dual-Mode Vehicles for n=3, t=3, c=6

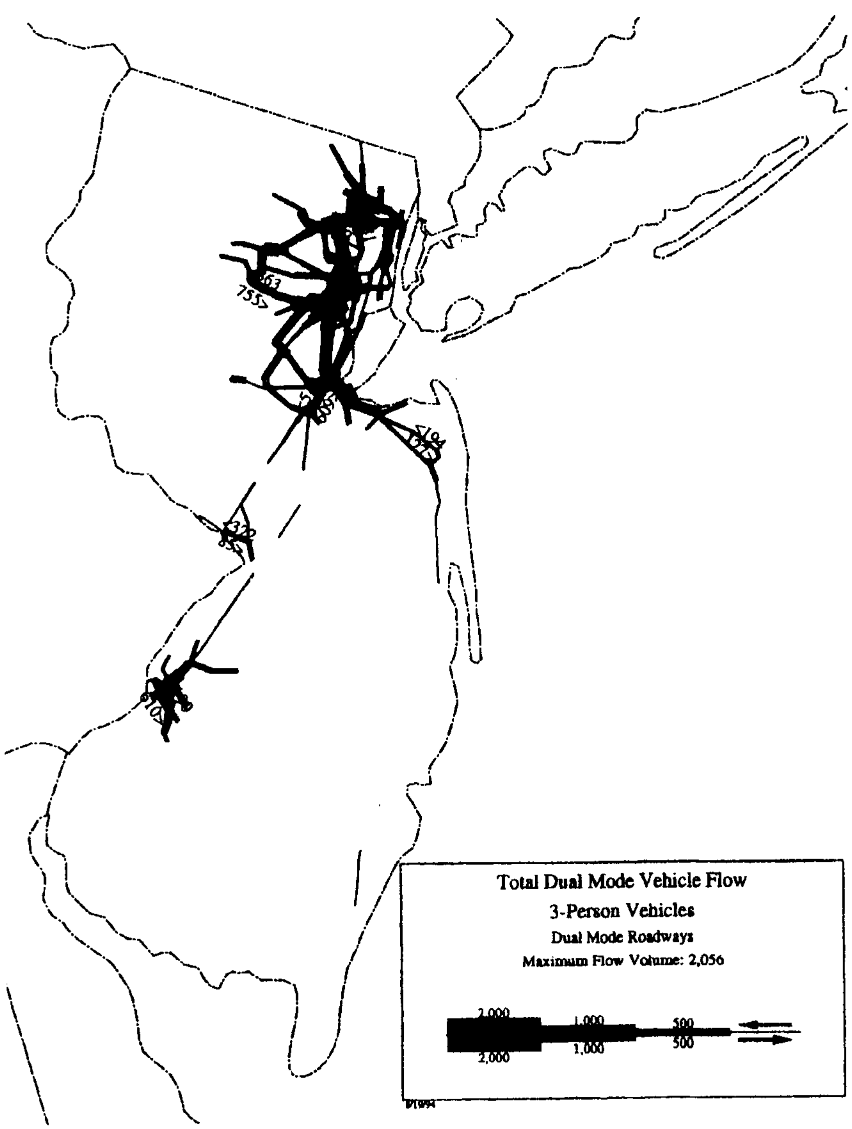


Figure B34. Total Morning Commute, Flows of Dual-Mode Vehicles Occupied by 3 Passengers for n=3, t=3, c=6

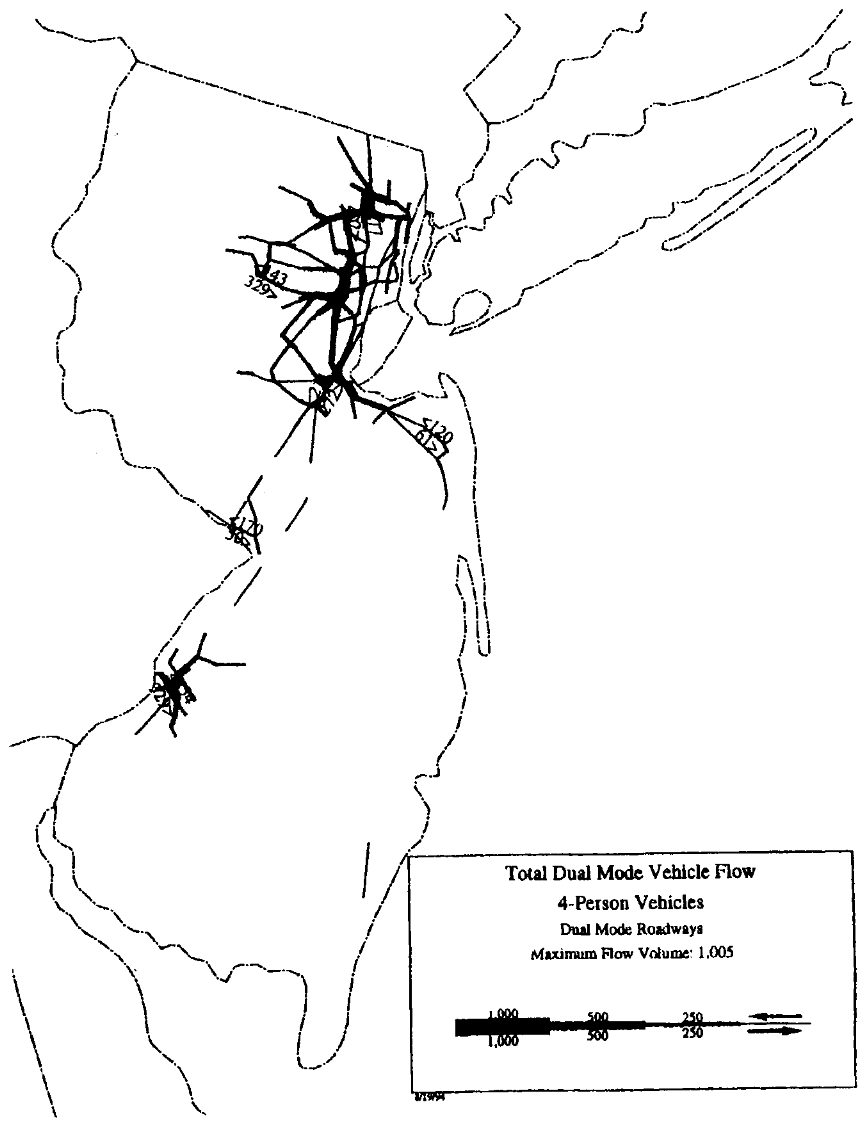


Figure B35. Total Morning Commute, Flows of Dual-Mode Vehicles Occupied by 4 Passengers for n=3, t=3, c=6

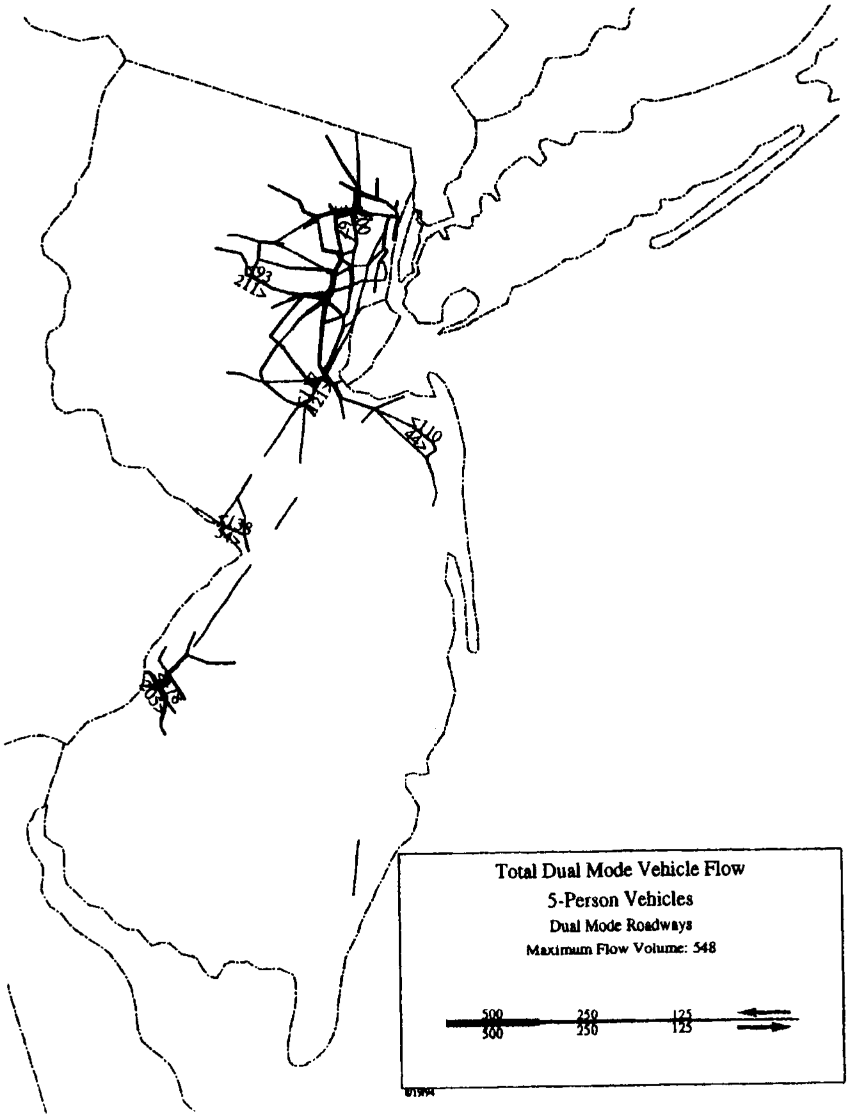


Figure B36. Total Morning Commute, Flows of Dual-Mode Vehicles Occupied by 5 Passengers for n=3, t=3, c=6

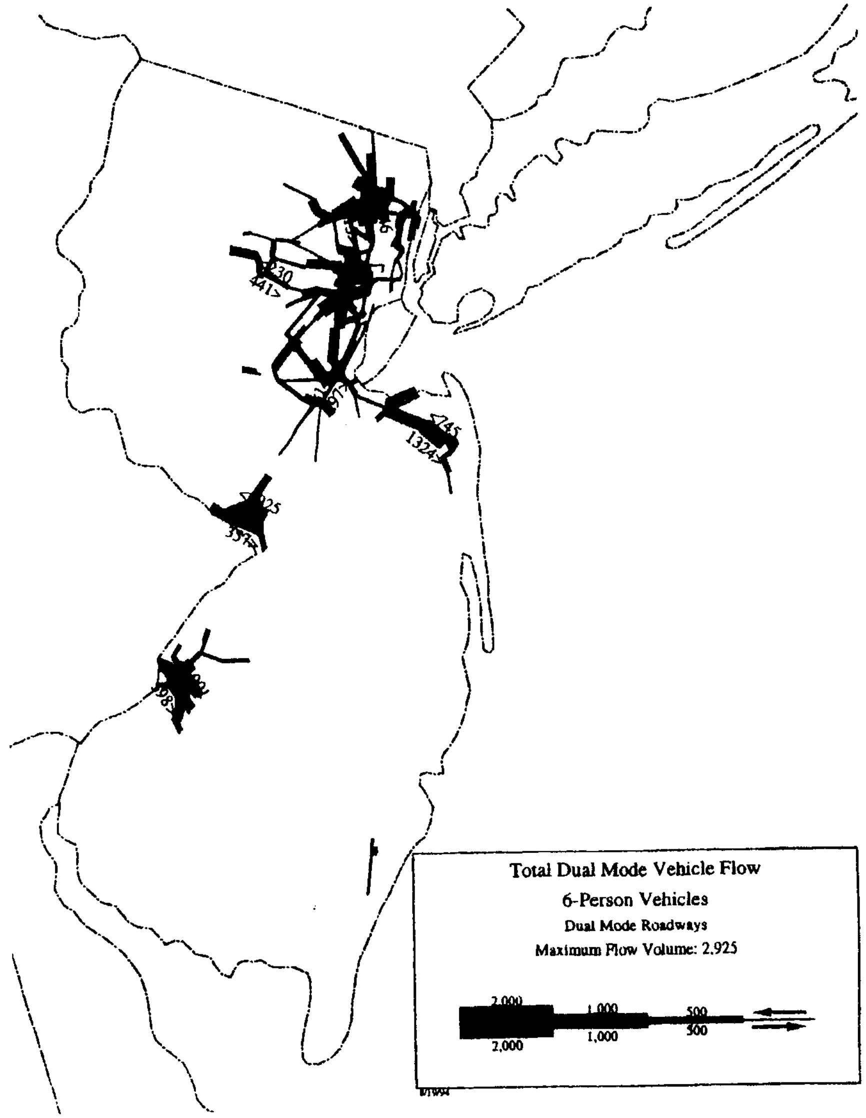


Figure B37. Total Morning Commute, Flows of Dual-Mode Vehicles Occupied by 6 Passengers for n=3, t=3, c=6

When the occupancy of all of these variously-occupied vehicles is averaged, the average vehicle occupancy is 4.68 passengers per dual-mode vehicle. This is an enormous average vehicle occupancy, especially when compared with that of the current automobile's value of 1.1 for work trips.

This analysis concludes that the spatial and temporal patterns of NJ's current auto-served work trips are compatible with dual-mode's service concept. In fact, the potential average occupancy is so large that a single lane, each direction, AHS, with a conventional lane capacity of 2,000 vehicles per hour, serving dual mode vehicles, could serve 70% of NJ's work trips of greater than 5 miles in length. This could become an enormously efficient means of serving much of New Jersey's journey to work needs, as well as that of other similar metropolitan areas. It has been shown that fare levels of about $.20-$.25 per mile may be able to pay operating costs as well as begin to contribute to pay for the AHSway's capital costs. Our analysis has only showed that NJ's auto-based, work trip demand has spatial and temporal patterns that could be served effectively, (travel times comparable to auto trips), by a dual-mode system. It has not demonstrated that any auto driver would indeed use the dual-mode system.

B.5.3.2.4 Conclusions About a Dual-Mode AHS

- This analysis shows that a relatively small 538 mile dual-mode AHS network could serve more than 70% of NJ's work trips that are currently taken by auto and are greater than 5 miles in length. This is a very strong finding. It needs to be moderated somewhat because we only analyzed ability to serve. We did not attempt to determine how many of those trips would likely divert to a dual-mode system if such a system were to be built and the service offered.

- This analysis does highlight the fact that many work trips are close by in origin, destination and time. A service that would easily enable dynamic ride-sharing through the use of automation has a large market potential. It can attain enormously high average occupancy levels that can reach 4.5 passengers per vehicle in the peak period.

- Because NJ's work trip patterns are thought to be similar to those that exist in many metropolitan areas, the dual-mode concept may have wide applicability.

B.5.4 Analysis of Driverless AHS Transit Opportunities

The dual-mode analysis performed above suggests that many of the trips served by the dual-mode system could also be served by a driverless SVE, RSC 8-10-type AHS. Vehicles would remain captive to the AHS. Off-line stations are where passengers board and alight vehicles. Access to the stations would be by walking, convention mini-bus collection and distribution services, kiss-ride and automobile park 'n ride. Because riders collect and distribute themselves to/from the stations, this concept has few of the trip coordination problems that would plague a dual-mode system. Vehicles with announced destinations would be waiting at station platforms. Passengers assemble themselves into vehicles much as they do when selecting elevators on the ground floor of very tall buildings; find the correct elevator bank, find the elevator with the open door, get in, dial your destination. After a predetermined wait an the platform, or as soon as the vehicle is at capacity, it is dispatched to its destination. Your trip may be non-stop or may involve a few intermediate stops. Get out at the right stop. This concept make more sense as the size of the network of AHSways grows, thus, reducing the access problem.

There would be no need for any drivers. What is needed is a large number of stations so as to minimize the access problem. Vehicles capacities similar to those investigated in the dual-mode analysis should be appropriate. Such a system is compatible with RSC 9-10 type SVE systems. RSC 8-type AHS probably does not have enough supervisory management to be appropriate for this driverless transit concept.

In urban areas, trips are short and the passenger needs less personal service. Security and oversight may be provided more efficiently using remote sensing means, such as, surveillance video, direct voice communications and emergency routing features that divert a vehicle directly to an enforcement center or hospital. Thus, an urban transit operation using driverless SVEs , captive to an exclusive urban AHSway, could provide direct, on-demand, non-stop, point-to-point passenger service without high labor costs. From a user perspective this substantial improvement in the quality of service could be truly competitive with the private automobile; thus, attracting high ridership. Because of the high AHS vehicle utilization rates and the shared ride opportunities that a transit operation could achieve, the cost per ride of a transit operation can be substantially less than that of a private AHS vehicle. Neither has driver labor costs. They both have the same direct operating costs. Because the capital cost that can be spread over many more users that give the driverless AHS transit operation a substantial cost advantage. From the service side, it is identical, point-to-point on the AHSway. Transit still has a service shortfall in getting to and from the AHSway. If the AHSway is extensive with many transit stops, then walk access to the system may be acceptable; otherwise, a more conventional mass transit or park-and-ride operation will be needed for collection and distribution.

Such systems have been studied extensively over the past 25 years. Unfortunately, transit interests have not been able to advance the technology. What is interesting today is that the concept is entirely compatible with any of the RSCs that involve exclusive AHSways in urban areas. Driverless AHS transit could be an incremental investment on any such systems requiring only the construction of the off-line stations. Otherwise, the same private vehicles could be purchased by a private or public operator and put into revenue service once the stations were built. Thus this application could piggy-back onto the economies of scale associated with private vehicle development and the AHSway construction.

In summary, driverless AHS systems would require an exclusive AHSway as envisioned in RSC 9-12. The driverless feature is not attractive to providers of inter-city passenger transportation and intra city freight transportation because the driver provides substantial services beyond those of "driving" that can not otherwise be automated. On the other hand, inter city freight and intra-city passengers can do without a driver, if the difficulties of access can be dealt with. In these situations, a driverless AHS may gain a significant cost advantage while providing comparable user service.

B.5.5 Conclusions for the Transit Market

- Urban transit, that is, for-hire, intra-city passenger transportation is only a small fraction of intra-city person transportation which is dominated by the private automobile. Nationally, transit serves only 3% of intra-city person trips.

- Only the express bus sub-market of transit is conducive to the early stage s of AHS. A particularly attractive example of such a system is the exclusive counter-flow bus lane leading to the Lincoln Tunnel. This is the busiest bus corridor in the US

- There are several fundamental characteristics that make the Lincoln Tunnel XBL a particularly good application for AHS. First, there is a monumental problem on the horizon if a substantial capacity improvement is need in this facility. There is no place to put another access lane and the cost of boring another tube is enormous. Thus, capacity through automation would surely be the most cost effective solution. Even without need for capacity improvement, automation would smooth out the flow of buses and improve the travel time reliability of the buses. The application is on a very short corridor, less than five (5) miles, and the same busses use the facilities repeatedly. The institutional challenges are "minimal". All buses are the property of NJDOT and were purchased with PANYNJ money. NJDOT and PANYNJ have authority over all operations and construction in the corridor. For these major reasons, this is an excellent candidate "early winner" for AHS

- A Dual-mode service over a 750 mile NJ AHS network could provide auto-like service 780,759 passengers (71 %) out of NJ's 1,116,985 daily auto-based work trips that are greater than 5 miles in length. A $.10 per passenger mile fare would generate annual revenues of about $800 million. It may well be that fares would need to be more like $.20 -$.25 per mile for such a system to begin to contribute to the debt service payments for the AHSway.

- The average vehicle occupancy is 4.68 passengers per dual-mode vehicle. This is an enormous average vehicle occupancy, especially when compared with that of the current automobile's value of 1.1 for work trips. Because of this high average vehicle occupancy, the densest link on the network needs to serve a maximum of only 2,000 vehicles per hour.

- Dual-mode is an interesting transit concept for a mature AHS. It needs to have access to an rather extensive network of AHSways in order to serve a significant portion of urban/suburban travel demand.

- A driverless AHS transit application could piggy-back onto the economies of scale associated with private vehicle development and the AHSway construction.

- A driverless AHS transit system could serve metropolitan trip demand nearly as well as dual-mode without the need of drivers and with less confusion in the collection and distribution. This concept make more sense as the size of the network of AHSways grows, thus, reducing the access problem.

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