U.S. Department
of Transportation

Implications of Intermodal Freight Movements for Infrastructure Access, Capacity, and Productivity

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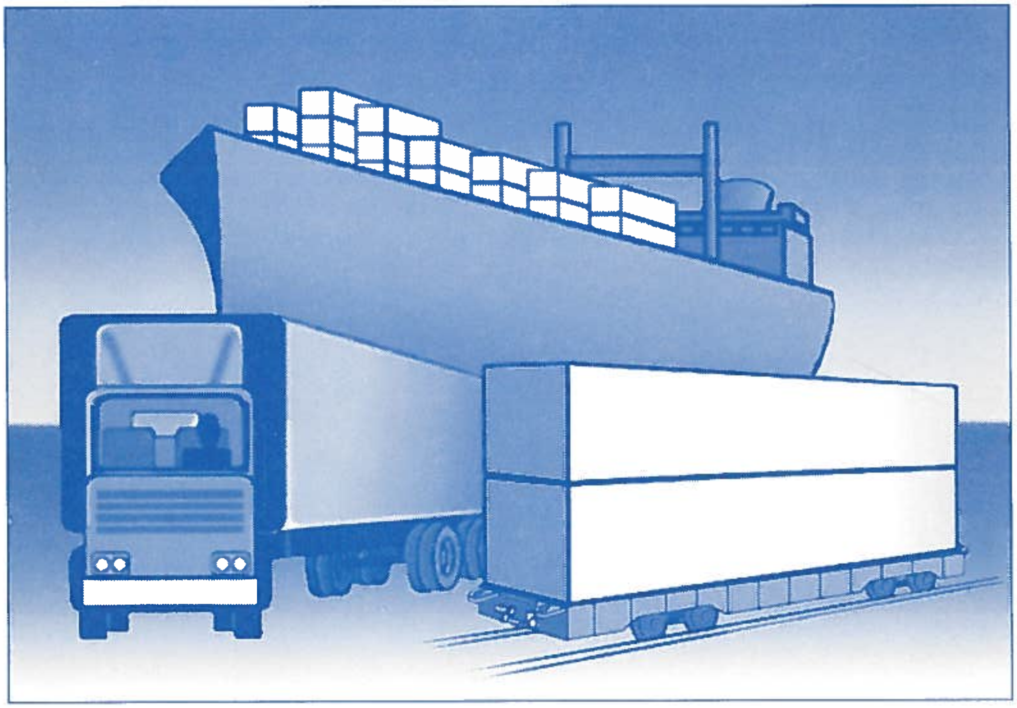

Prepared by:
John A. Volpe National Transportation Systems Center
Cambridge, MA 02142-1093

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Bahar B. Norris, PhD, Marsha J. Haines

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13. ABSTRACT (Maximum 200 words)

This report evaluates the status of intermodal freight in the U.S. with reference to infrastructure access problems such as inadequate highway connectors and facility clearance, and terminal capacity constraints affecting levels of service. Though the overall performance of the intermodal freight system is impacted negatively by access and capacity impediments, the study findings point to a significant congestion mitigation benefit from intermodal operations. Compared to the all-highway alternative, the study shows that intermodal operations produce only about one fifth of the VMT that would be generated by the trucking alternative. An array of solutions focusing on infrastructure improvement, institutional and deregulatory streamlining, and technological innovations are proposed to improve the performance of the intermodal freight system.

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectare (ha) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gm)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x - 32)(5/9)]°F = y°C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

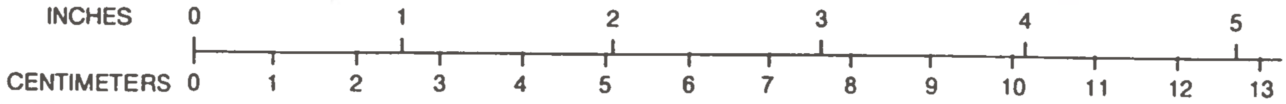
VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5)(y + 32)]°C = x°F

QUICK INCH-CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

Updated 9/29/95

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EXECUTIVE SUMMARY

This Executive Summary provides a synopsis of a final report prepared in partial fulfillment of contractual obligations to complete a research project for the Federal Highway Administration (FHWA). The multi-year study was sponsored by the Office of Policy Development, the Industry and Economic Analysis Branch, for the purpose of enhancing our understanding of the intermodal freight industry. Contributors to the study include A&L Associates, Cambridge, MA, and Mercer Management Consulting, San Francisco, CA.

1.0 INTRODUCTION AND BACKGROUND

1.1 PURPOSE AND OBJECTIVES

The purpose of this study is to explore the issues relating to intermodal interfaces, freight mode choice, and the performance of the intermodal transportation system. The overall mission is to examine the implications of the adequacy of infrastructure access and terminal facilities for the overall performance of the intermodal transportation system. To achieve this mission, the study reviews the latest research in industry dynamics; conducts a focused analysis of the Mid-Atlantic intermodal corridor; conducts a study of operations and best practices in terminal facilities; identifies the unmet needs in transportation infrastructure; assesses the potential impact of the system's operational strengths on the greater efficiency and performance of the transportation system; and recommends policy options available to enhance the performance of the intermodal freight system.

The scope of this report is threefold:

- Infrastructure access, connectivity, and network linkages
- Intermodal terminal facilities
- Modal operations, competitiveness, and performance

To achieve the above mission within the outlined scope, the report pursues three broad objectives:

1. **Identify Infrastructure Access Impediments.** Conduct a corridor analysis to estimate the adequacy of infrastructure and connectors on intermodal viability and

market share, and shipper mode choice, construct an intermodal cost model, and estimate how truck-rail tradeoffs influence highway congestion.

2. **Identify Terminal Facility Issues.** Conduct an in-depth terminal analysis to identify the extent to which terminal location, capacity constraints, gate practices, drayage and train interchange operations, container handling practices, and yard equipment and technologies, affect the performance of the intermodal system.

3. **Identify Modal Performance Parameters.** Conduct an industry scan to estimate the impact of intermodal carrier capabilities, linehaul competitiveness, advanced information systems and technologies, and efficient resource utilization on the overall performance of the freight movement system (see Figure ES-1).

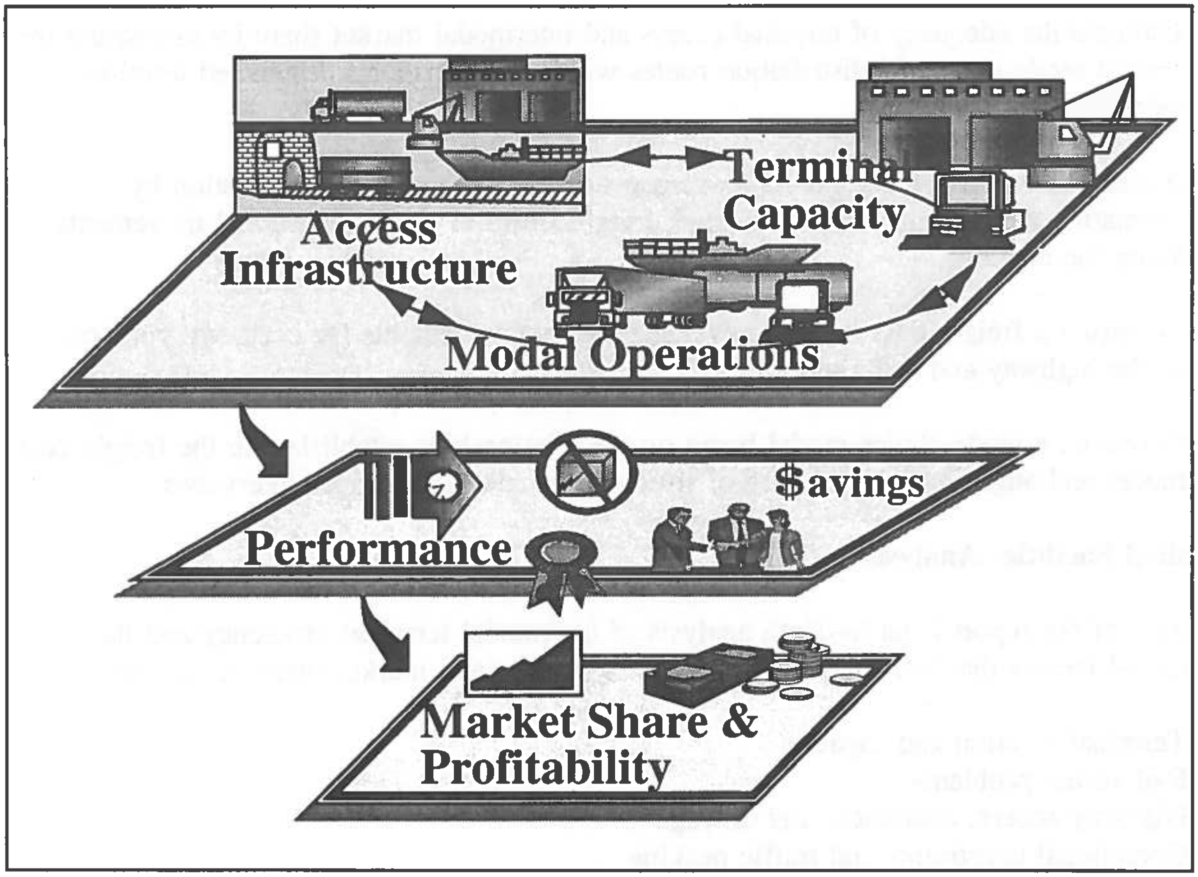


Figure ES-1. Transportation Performance: Interplay of Access, Terminal Capacity & Mode Share

1.2 APPROACH

The study adopted a three-pronged approach to achieving the above objectives:

Corridor Analysis

As detailed in section 4 of the report, the Mid-Atlantic intermodal freight corridor was selected to conduct a focused analysis of highway-rail costs and mode choice. The corridor extends from the northern New Jersey region to two end-points in Atlanta, GA, and Jacksonville, FL, allowing a focused analysis of a medium-length freight corridor. The objectives of the analysis were to:

- Estimate the adequacy of terminal access and intermodal market share by estimating the freight mode share and distribution routes within the corridor's designated terminal catchment areas.

- Assess the impact of intermodal movements on highway network congestion by estimating the tradeoffs of the all-truck freight flows vis-à-vis intermodal movements along the corridor.

- Construct a freight cost model to evaluate the relative weights for each cost component of the highway and rail alternatives.

- Construct a mode-choice model based on the relationships established in the freight cost model and augmented by a series of structured carrier and shipper interviews.

Terminal Facilities Analysis

Section 5 of the report is an in-depth analysis of intermodal terminal efficiency and the operational factors that influence intermodal performance and market share, including:

- Terminal location and capacity
- Rail access problems
- Highway access, clearance, and drayage
- Operational constraints and traffic peaking
- Terminal best practices

Industry Scan and Policy Implications

Sections 2, 3, and 6 of the report further augment the findings of the corridor analysis and terminal focus, and attempt to provide an overview of the opportunities and challenges facing the industry by:

- Identifying the industry characteristics and the emerging industry trends through a literature review (section 2).
- Identifying the determinants of carrier performance by describing how production efficiency, productivity, and service quality relate to shipper mode choice and carrier performance (section 3).
- Reviewing the findings of the National Commission on Intermodal Transportation (NCIT), and the issues related to the National Transportation System (NTS) and the National Highway System (NHS) (section 2).
- Making policy and strategic recommendations for alleviating access impediments and operational inefficiencies and improving performance (section 6).

1.3 INDUSTRY SCAN

Background

Definition. Intermodal freight is defined in this study to mean the coordinated and sequential use of two or more modes of transportation where the responsibility for the completion of the trip is assumed by a single party. The most common form of intermodal freight moves in containers or trailers on rail flatcars for the line-haul portion of the shipment, and on truck for the door-to-door pickup and delivery at origin and destination, with a possible marine link. This is the definition adopted in this study. In its fully multimodal form, however, the journey may involve an air or pipeline segment, midway or at either end, and possibly transloading of non-containerized cargo (see Figure ES-2).

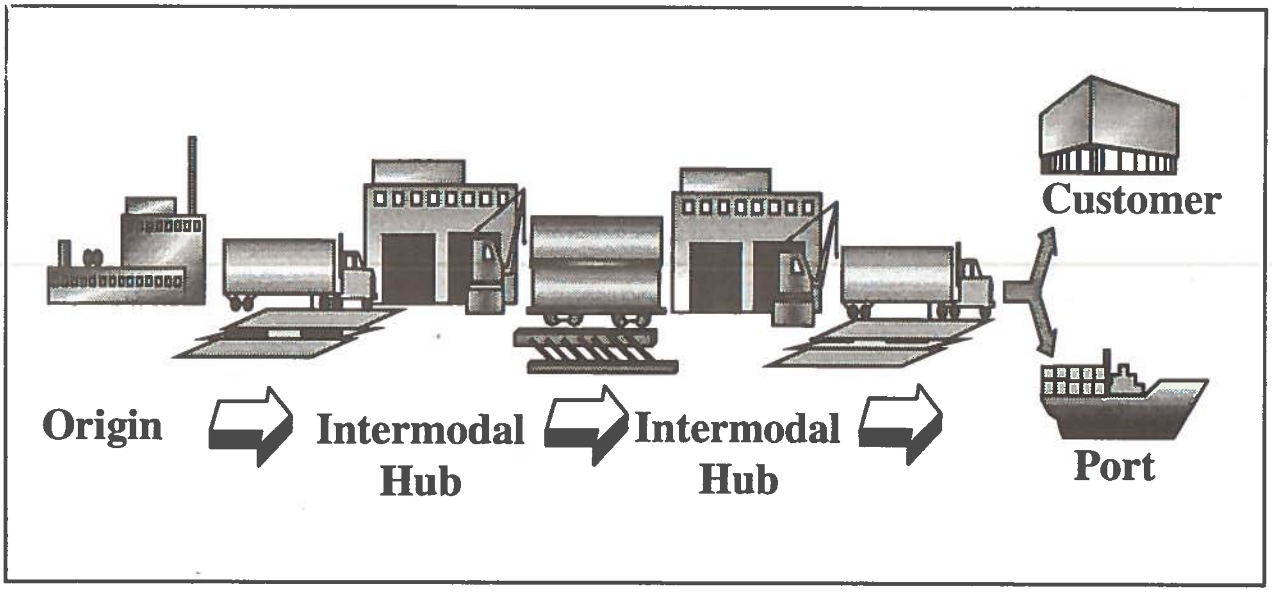
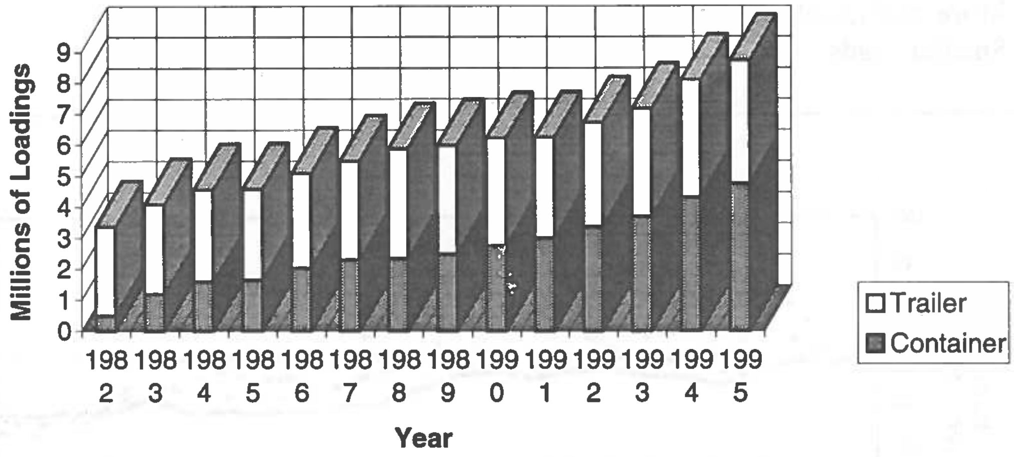


Figure ES-2. The Truck-Rail Intermodal System

Volumes. The intermodal industry could be defined as the segment of the domestic interstate freight operators that derives its revenues from moving cargo in containers or trailers on multiple modes. The industry has estimated annual revenues of $8 billion, and moves more than 8 million loads of containers and trailers each year. The rate of the growth in loadings in past years has been approximately 6-7 percent, with the most rapid growth occurring since 1984 in double-stack lanes. In the last few years the growth in the number of container loadings has been at a more rapid pace than trailers. (see Figure ES-3).

Customers. Customers of the rail intermodal line-haul service include the domestic subsidiaries of steamship lines (50 percent), third-party shipper agents (30 percent), United Parcel Service (UPS) (10 percent), the U.S. Postal Service (4 percent), less-than-truckload carriers (4 percent), with the other 2 percent accounted for by truckload carriers and a few direct shippers including major retailers and manufacturers.

Commodities. Commodities that are most commonly containerized are general cargo "break-bulk" goods in finished packages and include steel, chemicals, plastics, and processed and canned food products and beverages. Increasingly, intermodal carriers have begun carrying refrigerated products and "neo-bulk" cargo such as auto parts, lumber, and paper and pulp products in containers.



Source: TTX, 1995

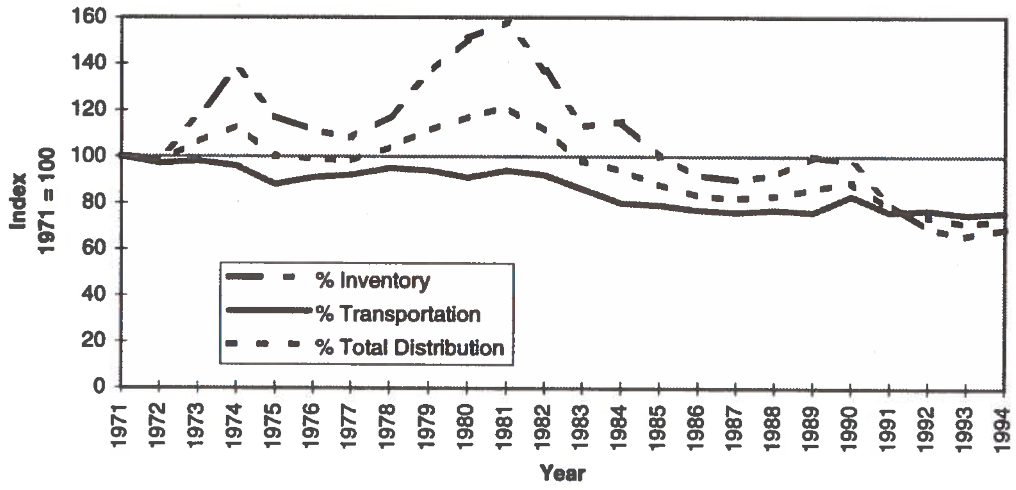
Figure ES-3. Intermodal Trailer and Container Loadings

Logistics and the Transportation System

Logistics Costs. Logistics costs in the U.S. total $730 billion and consist of inventory carrying (29 percent), warehousing (9 percent), transportation (57.5 percent), and logistics administration (4.5 percent). Total logistics costs have declined from a high of 18 percent of the Gross Domestic Product (GDP) in 1981 to 10.8 percent in 1994. Transportation declined from 8.3 percent of the GDP in 1971 to 6.3 percent in 1994. Deregulation, greater productivity due to application of advanced transportation and information technologies, and improved logistics supply-chain practices are among the factors contributing to the declining costs. This means that while the GDP has grown, U.S. businesses have been spending a steadily declining portion of their revenues on moving inventories or holding them idle (Figure ES-4).

Influence of the JIT Requirements. One challenge before intermodal carriers is to meet shippers' just-in-time (JIT) delivery schedules. Service providers have to respond to new delivery requirements by adjusting the frequency of shipment, schedule reliability, linehaul speed, and in-transit times, by offering:

- More frequent deliveries
- Faster linehaul speed
- More predictable transit times
- Smaller loads



Source: Robert Delaney, "Is Logistics Productivity at a Crossroad," Sixth Annual Press Conference - Cass Logistics, June 1995.

Figure ES-4. Index of Inventory Carrying, Transportation, and Total Logistics Costs as a Percentage of GDP

Service Quality and System Performance

Performance can be defined as the extent to which operations performed by a given mode or transportation system produce the desired results. Implied in the use of the term is that in every industry segment there are *accepted standards* to which participants should conform.

These standards can be quantitative financial performance standards such as costs and profitability or more qualitative customer satisfaction standards.

Efficiency. Efficiency is closely related to productivity as it relates a system's output to the total input costs incurred. An efficient operation maximizes the output produced per unit of cost, or minimizes the costs, so that the given inputs generate the greatest quantity of output. It is essentially construed as "getting more for less": producing more output from fewer or the same inputs.

Productivity. Productivity is the ratio of real output produced to the real input consumed in the process of producing the good or service. An example of partial factor productivity is labor productivity. Labor factor productivity in the U.S. among Class I railroads has steadily increased from $58,000 in revenues per employee in 1980, to $140,000 per employee in 1992 (see Figure ES-5).

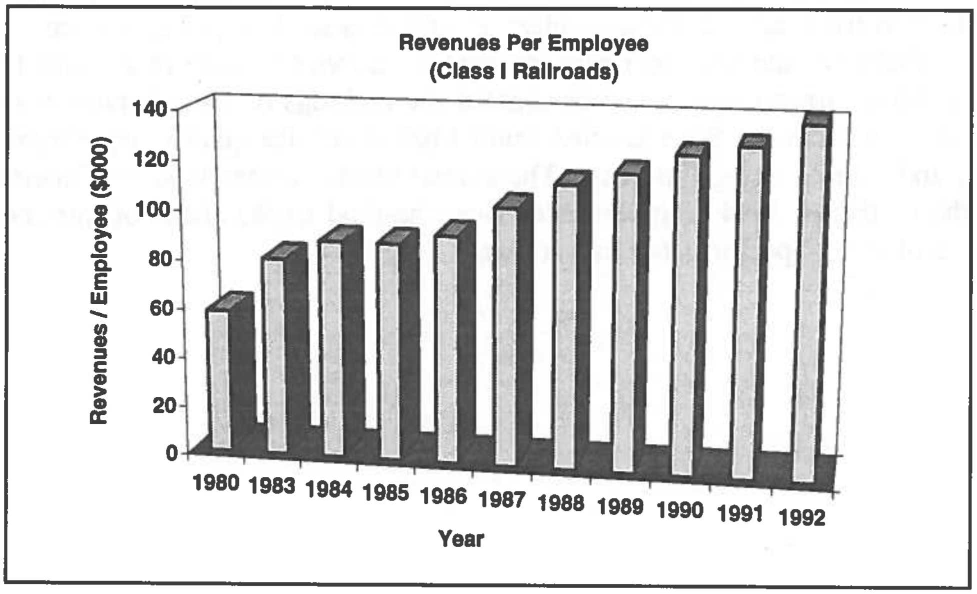


Figure ES-5. Rail Labor Productivity

Utilization. Utilization is defined as the extent to which resources used match the intended capacity, and includes concepts such as facility throughput, equipment turn-around time, and cycle time. A facility's throughput determines the efficiency with which a piece of equipment is used, and is estimated by the number of loads cleared at the facility or handled by a mechanized lift per unit of time. An overhaul of terminal container handling and inspection practices at Union Pacific Railroad, for instance, reduced driver waiting time at the terminal by 1 hour and 40 minutes, allowing a driver to make another trip per day in addition to the usual five drayage trips.

Equipment utilization impacts modal competitiveness: average load-to-load cycle time for rail equipment is roughly 17 days, compared to a truck trailer that turns around every 6 days. In other words, a truck trailer turns around about 58 times each year, while a similar rail container is likely to turn around only about 21 times per year.

Service Quality. Service quality is often used in reference to how well an industry satisfies the customer demands, and has a strong element of customer perception. In Total Quality Management vernacular, quality means "meeting or exceeding customer's expectations by doing the right thing right the first time."

Performance. Modal performance has been measured by comparing the customer ratings of intermodal and truck service for a number of attributes such as price, service, equipment availability, and customer responsiveness. Service criteria (e.g., quality of delivery, reliability, transit time) have dominated the rankings of most important factors in carrier and mode selection. Price is often ranked below service quality, equipment availability, and ease of doing business. The annual market research survey Intermodal Index has shown that in 1994, shippers rated over-the-road trucks ahead of intermodal carriers in 15 of the 17 performance categories.

2.0 WHAT ARE THE BENEFITS OF INTERMODAL FREIGHT?

The genesis of the efforts to articulate the benefits of intermodal freight could be traced to the statement of mission and policy position adopted in Title V of the Intermodal Surface Transportation Efficiency Act (ISTEA). Section 5001(e) amendment to Section 302 of Title 49 USC:

> *It is the policy of the United States transportation system in the United States to move people and goods in an energy-efficient manner, provide the foundation of improved productivity growth, strengthen the Nation's ability to compete in the global economy, and obtain the optimum yield from the Nation's transportation resources.*

There have been some efforts since the ISTEA went into effect to quantify the current and potential benefits from intermodal freight operations, though most benefits remain to be estimated. The following benefits are estimated by comparing the performance of rail and truck, and include:

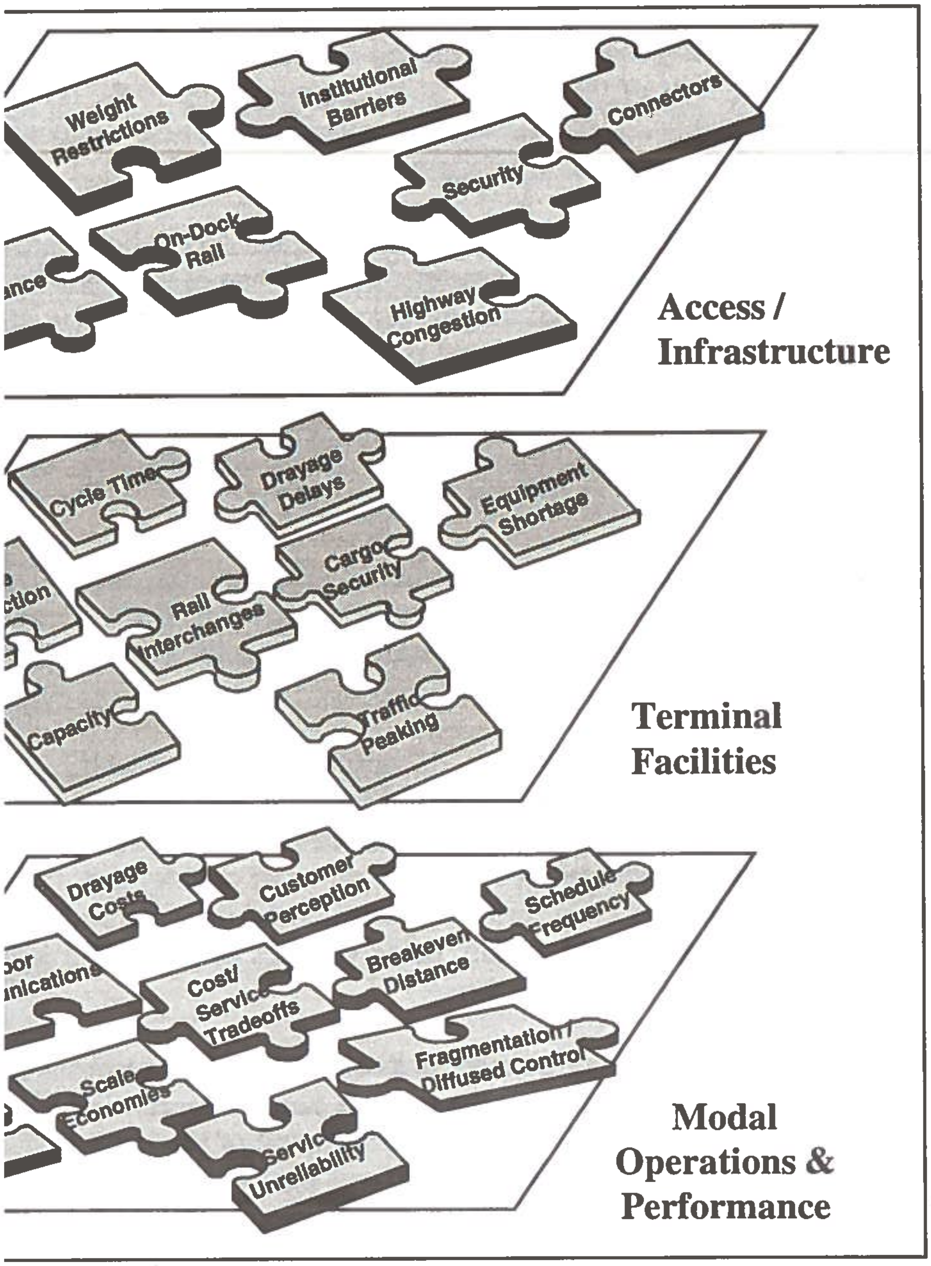
- ***Congestion Reduction.*** The impact on highway congestion of a continuing shift of freight traffic away from highway to intermodal can be significant. Currently more than 9 million container and trailer loads move the nation's domestic freight. The findings of a corridor study conducted for this report [see section 4] suggest that for each 10 containers that are carried on intermodal rail, a minimum of 7 trucks are taken off the highways.

- ***Lower Emissions.*** Intermodal operations have the potential to help achieve the desired national air quality standards. The ratio of diesel particulates and hydrocarbons per billion ton miles for rail is lower than truck by nearly a factor of ten; for nitrogen oxides and carbon monoxides, the ratio for rail is lower than truck by nearly a factor of three.

- ***Higher Fuel Efficiency.*** Rail linehaul operations are more fuel efficient than trucking. In 1989, freight railroads in the U.S. consumed 79 billion barrels of fuel to carry more than one trillion ton miles of freight. In comparison, commercial trucks consumed 407 billion barrels of fuel to carry 700 billion ton miles of freight. On a per-unit basis, this translates to 300 ton-miles per gallon for rail and 90 ton-miles per gallon for trucks.

- ***Greater Safety.*** Rail operations are safer than truck operations. Rail fatalities are roughly one per billion ton-miles, while trucking fatalities are four per billion ton-miles.

minal, conditions such as street paving, lane width, lighting, and
der access. These problems are compounded by unavailability of direct
n the event highway or bridge repairs are required.



ES-6. Intermodal Freight Challenges and Impediments

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- ***Institutional Barriers.*** These impediments range from jurisdictional restrictions on funding and constructing port access to difficulties in funding improvement projects that directly concern private rail terminal operations. The stymied efforts by the Santa Fe Railroad to acquire the needed permits to build access to its Corwith terminal in Chicago illustrate such barriers. Regulatory restrictions that involve specific design requirements for terminal construction are another example. The industry sees design specifications as impediments to operational improvements, and favors performance standards which leave the choice of technology or design to the operators.

3.2 TERMINAL BARRIERS

Terminal inefficiencies are caused by inadequate gate capacity, level of service, inefficient gate practices, and interchange operations. In turn, these inefficiencies lead to increased terminal congestion and service unreliability affecting drayage efficiency, equipment cycle times, and thus the overall costs of intermodal movements.

- ***Capacity.*** Capacity constraints in terminal facilities are a major impediment to improved intermodal performance. Increased traffic volumes, diversion from closed terminals, equipment inspection practices, shortages of lift equipment, and failure to automate are among the factors contributing to capacity constraints.

- ***Level Of Service.*** A terminal's level of service impacts mode choice as it influences the shipper's willingness to use the terminal. Terminal delays have a direct bearing on the shipper costs as they influence service levels. Slow service times lead some shippers to dray longer distances to terminals with better service, or even avoid intermodal altogether. Location of terminals within the drayage range influence the service level, affecting the relative costs of truck versus intermodal shipments. Terminals that are not readily accessible by large trucks raise the drayage cycle times and the breakeven distance for profitable intermodal movements.

- ***Gate Practices.*** Terminal gate practices influence operational efficiencies. Many terminals continue the manual, paper-based processing of the bill-of-lading, often due to incompatible or unavailable EDI systems. Container damage inspection practices that consist of a thorough walk-around to determine damage and assign liability are another source of gate delays.

- ***Interchange Operations.*** Rail interchange practices are a major impediment to efficient terminal operations. Interline transfers involving steel-wheel and rubber-tire interchange are fraught with inefficiencies, long delays, and unnecessary switching. The failure of railroads to share lines and equipment, and have effective run-through services and train switching operations have impeded growth of an efficient interchange system which can effectively compete with trucking.

3.3 OPERATIONAL OBSTACLES

Obstacles to efficient line-haul operations include below par service quality, equipment shortage and low fleet utilization rates, fragmented industry structure, and lack of standardized communication systems in the industry.

- ***Equipment Shortage.*** One of the major operational problems in the industry relates to equipment shortages.

  Utilization. Intermodal utilization rates are significantly below those for truckload carriers, thus creating greater cost burden for intermodal operators, given that equipment costs are a large component of the overall intermodal service delivery costs. An estimated 70 percent of all containers and trailers remain idle at any given time. Lack of standardization in equipment, and difficulties in forming neutral chassis and container pools are among the factors contributing to low utilization rates.

  Asset Ownership. With more than half of intermodal traffic managed by non-asset-owning intermodal marketing companies (IMCs) or steamship companies, a key problem with the industry's equipment shortage can be traced to asset ownership practices. With the exception of a number of major truckload carriers, IMCs own no equipment, thus contributing to the deteriorated equipment supply. The practice of exclusive fleet ownership by carriers further worsens the shortage and increases the number of empty backhauls. Any effective method of improving asset utilization should be accompanied by changes in the structure of the industry, including a restructuring of the IMC's role in equipment ownership.

- ***Service Quality***. Intermodal performance is often gauged by broad measures such as service quality, customer satisfaction, or service times. The below-par performance of intermodal rail, when compared to all-highway trucking, can be traced to two underlying problems that lead to unreliability of intermodal service: 1) traffic peaking, and 2) poor coordination.

Peaking. Peaking pressures at intermodal terminals are often the major sources of service problems and severe capacity shortage. Peaking is caused primarily by such problems as: the discrete nature of train departures and minimum volume requirements; the bunching of traffic through daily, weekly, and seasonal peaking that are driven by customer's logistics needs; and capacity pressures due to equipment and crew shortages and terminal congestion, leading to further drayage delays, long gate lines, and delays in train loading and unloading.

Difficulty of Coordination. Service unreliability is primarily caused by the difficulty of coordinating complex and divergent operations involved in intermodal service, leading to missed connections and line-haul service problems; delays affecting inbound or outbound trains and drayage that in turn lead to long terminal dwell times; drayage delays traced to the customer heads, gate inspection, and highway traffic; and management failures due to the segmentation of the functions performed by the third parties and carriers.

- *Fragmentation*. The intermodal industry fragmentation is inherent in the system and stems from dependence on multiple linehaul and drayage carriers, third parties, terminal operators, and equipment owners and lessors. Fragmentation has hurt the industry goal of achieving greater intermodal mode share through diverse incentives and diffused control and accountability.

  Divergent Incentives. This is the result of the highly decentralized industry structure that relies on incentive systems that, while benefiting a small segment of the industry, undermines the efficiency of the operations as a whole. Practices relating to equipment inspection and maintenance, and rules of liability for damage are examples of such divergent incentives.

  Diffused Control and Accountability. The decentralized nature of the industry undermines the performance of all intermodal carriers and prevents the carriers from offering effective door-to-door service and competing with truckload carriers.

- ***Cost-Service Tradeoffs.*** While it is understood that high quality service costs less in the long run, short-run tradeoffs are often made between cost reduction and service quality. These tradeoffs are budget-driven rather than guided by the desire to improve performance. The paradoxical outcome of these tradeoffs is that the service shortfalls that follow often lead to precisely opposite results and thinner profit margins. The mindset which fosters the cost-service tradeoff is sharply criticized in the response given below by Thomas Finkbiner, Vice President, Intermodal at Norfolk Southern. When offered a choice of reducing unit costs, increasing volumes, or raising rates to ration capacity in order to boost profitability, he responded:

> *What about service? Profits will flow from service not vice versa. Without service, all of that other stuff is just managing the deck chairs.*

- ***Lack of Standardized Communication Systems.*** Incompatible communication systems and EDI standards, and divergent interchange agreements have hampered the industry efforts to generate a seamless flow of containers across modes. Though EDI is available to all major carriers and widely used by the rail and marine industries and third party agents, only some 50 percent of all intermodal transactions are EDI-based. One reason is that small drayage firms and many small shippers lack automation and continue to depend on faxes. Incompatible systems and the multitude of software in use, requiring redundant investment on the part of shippers and draymen, are another deterrent. The problem of compatibility will gain increasing prominence as communication technologies such as Automated Vehicle Identification (AVI) and Weigh-in-Motion (WIM) penetrate the markets and require a link with the EDI systems. Another standardization issue arises with the *Intermodal Safe Container Act of 1991* that will go into effect in September 1996, and the need to incorporate the requirements of this Act into the existing EDI bill of lading.

4.0 CASE STUDIES

4.1 MID-ATLANTIC CORRIDOR

Methodology

The Mid-Atlantic Corridor Analysis was conducted by A&L Associates under contract with the John A. Volpe National Transportation Systems Center (Volpe Center). This study focused on the corridor along the eastern seaboard between the Mid-Atlantic states and two end-points--Jacksonville, FL, and Atlanta, GA. The study consisted of a corridor methodology section, an intermodal-truck cost comparison model, a circuity analysis, and an evaluation of terminal access and mode choice.

The corridor analysis methodology compared the distribution of truck traffic serving shippers in the corridor with the existing intermodal rail traffic by doing the following:

- Determined the rail portion of the intermodal traffic, including assigning the drayage portion to highway network after determining the shipment points.
- Determined the "all-truck" alternative route through a truck circuity analysis, and estimated the least cost point-to-point substitute truck route using zip code-level manufacturing employment data as a proxy for traffic generation.
- Compared the resulting drayage VMT in each service area with the alternate all-truck VMT, and estimated the impact of "avoided" truck shipments on VMT along the truck route.
- Used data from the *Waybill Sample* for rail traffic, the *Highway Performance Monitoring System (HPMS)* database for highway truck flows, the *Census of Manufacturers* for shipment origin/destinations, and the *Oak Ridge Highway Network* and the existing rail network for relating the movement of goods to routes and terminals.

Findings

The corridor analysis study appraised the congestion mitigation impact of intermodal operations; identified the relationship between intermodal service, terminal location, and the surrounding highway network; and compared the relative costs of single-mode and intermodal freight movements. Findings in these areas are detailed below.

Congestion Mitigation. For the two corridors in the study, the VMT avoided by intermodal goods movements was significant. The impact of intermodal service changes on highway congestion and air quality for the study corridors are as follows:

- Congestion reduction benefits of intermodal movements within the corridor proved to be significant, as indicated by the circuity analysis of the intermodal rail movements. With an average drayage distance at each end-point ranging between 40 and 97 miles, the impact of intermodal operations on congestion can be demonstrated through the "avoided" vehicles miles travelled (VMT) within the corridor. A typical intermodal move within the corridor generated only 21 percent of the VMT of the equivalent truck mode, representing a saving in VMT of 79 percent, or nearly 30 million vehicle miles. The average avoided truck VMT ranged from 440 to 880 miles (see Table ES-1).

- In the NJ/PA to Atlanta corridor, intermodal operations resulted in an 84 percent savings in highway VMT, corresponding to 13.7 million fewer vehicle miles of equivalent truck traffic. On the 863-mile long corridor from NJ/PA to Atlanta, shipping of freight intermodally generated a total of 2.6 million vehicle miles of drayage, compared to 16.4 million vehicle miles for the all-highway alternative; thus, generating only 16 percent of the VMT that would be generated by the truck mode (see Figure ES-7).

- In 12 of the 16 cases, truck linehaul distances (ranging between 570 and 1060 miles) were shorter than the corresponding intermodal linehaul distance (the combined dray and rail linehaul ranging between 600 and 930 miles). The intermodal circuity index (ratio of the combined rail and drayage distance to the all-highway truck distance) ranged from 0.99 to 1.28. In 10 out of 16 city pairs, the circuity index indicated that intermodal distance was longer than the equivalent truck movement.

- The impact on trucking congestion within the corridor can be illustrated by comparing the truck count with the equivalent intermodal count. In the Baltimore segment of I-95, for instance, the average daily truck count was 4,568, compared to an estimated 146 intermodal container moves, representing an intermodal mode share of 3.2 percent. The segment within the corridor which showed the greatest intermodal mode share was the I-95 segment in Jacksonville with 6.6 percent market share (8.5 percent if counting the empty backhaul of intermodal containers).

Table ES-1. Mid-Atlantic Corridor Avoided Highway VMT

	1991 IMU Volume	Corridor Length KM (Mi)	Substitute Highway VKT (VMT)	Average Drayage Distance KM (Mi)		Total Drayage VKT (VMT)	Avoided VKT (VMT)	Reduction in VKT
				North	South			
Alexandria Atlanta	14,800	1,083 (673)	16,023,525 (9,956,537)	148 (92)	156 (97)	4,497,331 (2,794,506)	11,526,195 (7,162,031)	72%
NJ/PA Atlanta	18,960	1,389 (863)	26,321,550 (16,355,420)	64 (40)	156 (97)	4,195,671 (2,607,064)	22,125,878 (13,748,356)	84%
Alexandria Jacksonville	14,880	1,262 (784)	18,773,415 (11,665,236)	148 (92)	146 (91)	4,378,480 (2,720,656)	14,394,935 (8,944,580)	77%
NJ/PA - Jacksonville	17,070	1,532 (952)	26,157,131 (16,253,255)	64 (40)	146 (91)	3,613,202 (2,245,135)	22,543,929 (14,008,120)	86%
TOTAL	48,640		61,118,490 (37,977,193)			13,071,483 (8,122,227)	48,047,006 (29,854,966)	79%

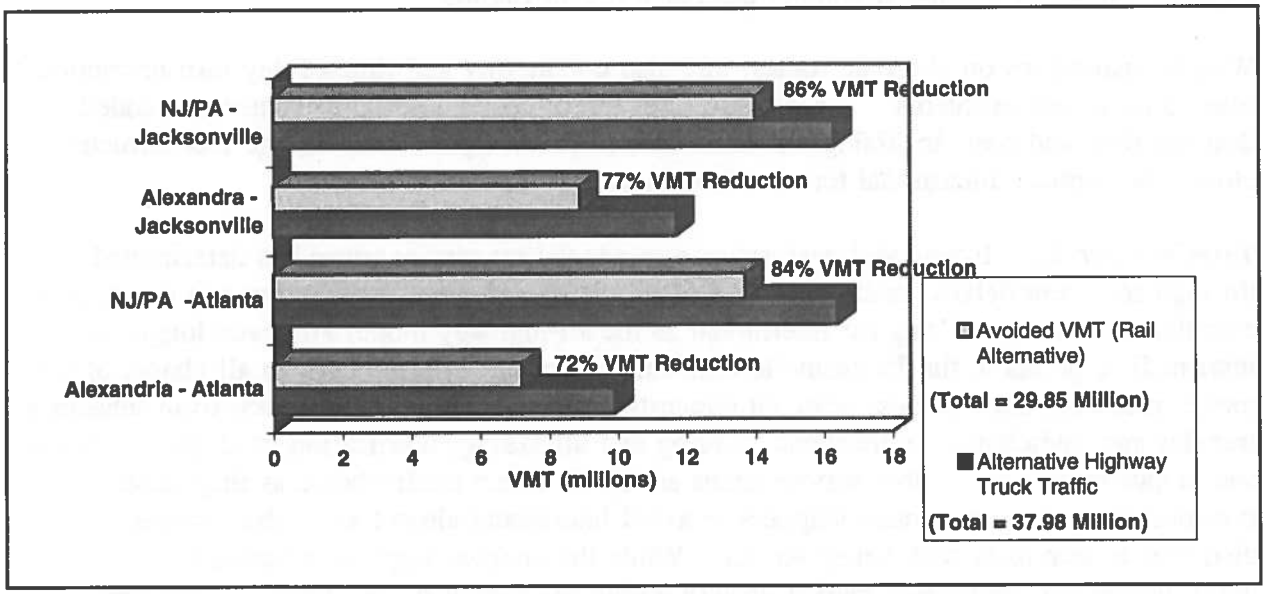

Figure ES-7. Congestion Mitigation Impact: Avoided VMT within the Corridor

Drayage. Drayage accounts for a large share of the total intermodal origin-to-destination costs and is a major factor in service quality as perceived by shippers. High drayage costs affect the profitability of intermodal service, and limit the markets in which it can compete with intercity trucking. This is especially true in shorter intermodal corridors, where an expensive dray at either end of the trip is likely to result in a price higher than a comparable truck rate.

Drayage length is a critical factor in intermodal cost competitiveness. Corridor drayage distances ranged from 12 to 230 miles. As a rule, intermodal is cost-effective when the drays are kept to a short distance, or when the break-even distance for intermodal is long enough for the per-mile line-haul savings to offset the added costs for terminals and drayage. Cost savings increase substantially when the length of the rail portion increases, and when there are no reverse-direction moves. Where drays were under 32 miles, intermodal costs were always lower than truck rates. Where drays were greater than 90 miles, intermodal was truck competitive with truck in only 3 of 8 cases.

Clearance and Weight Restrictions. Clearance problems in the Mid-Atlantic region precluded operation of double-stack trains. The ability to operate double-stack service is critical for single-track mainlines that are severely capacity constrained, or where track capacity cannot be expanded without extensive reconstruction.

Weight restrictions on alternate routes, and also commodity and time-of-day turn restrictions, often pose access problems. These restrictions often require circuitous routes and added drayage time and cost, including a notable case in Philadelphia when bridge reconstruction closed the primary intermodal terminal access route.

Terminal Service. Intermodal performance as gauged by service times has deteriorated through recurrent delays, raising the cost of providing service. Service times in the Atlanta corridor were twice as long for intermodal as the all-highway mode, and even longer to intermediate points in the Jacksonville corridor. Sources of delays exist in all phases of the move, including gate queues, terminal congestion, terminal processing times, train schedules, transfer and interchange connections, loading and unloading, notification of shipment arrival, and shipment pick-up. Slow service times adversely affect mode choice as they raise transportation costs and entice shippers to avoid intermodal altogether of dray longer distances to terminals with better service. While the analysis implied substantial opportunities for intermodal market growth within the corridors, this growth could only occur if significant improvements are made in service.

Freight Cost Model. The primary intent of the model was to improve understanding of the boundary conditions between intermodal freight movement and truck movement, and to explore their sensitivity to key factors affecting the basic elements of truck/intermodal competition. The model consisted of a truckload model and a rail model (including two drayage and linehaul sub-models). The costs used are consistent with common perceptions of operating costs for advanced truckload carriers.

Truckload Cost Model. The following unit cost elements, typical of actual operations, were applied to all cases.

Tractor ownership:	**$40/day**
Tractor maintenance:	**$0.20/mile**
Trailer ownership:	**$10/day**
Fuel:	**$0.80/gallon; 8 miles per gallon on highways and 4 miles/gallon on local streets**
Driver cost:	**$0.30/mile**
Truck costs:	**$0.85 to $1.00 per mile for origin-destination movements in the**

Rail Intermodal Cost Model. The intermodal model includes sub-models for drayage and for the rail line-haul.

Rail Line-Haul Sub-Model. This sub-model includes the two most important cost elements that reflect reasonably efficient operations:

Terminal costs:	**$25/lift at the original and destination terminals**
Line-haul costs:	**$0.50 per container-mile**

Drayage Sub-Model. This sub-model was structured to provide costs that are consistent with published prices and the experience of shippers and third-party agents:

Fixed drayage cost per trip:	**$40**
Drayage operating cost/mile:	**$2.00) for local streets; $1 for urban highway; and $0.70 for interstate**
Drayage operating cost/hour:	**$20**

The model, applied to cases representing the study corridors, shows the impact of variations in customer location, type of drayage operation, and terminal efficiency.

- Applying the parameters in the cost model to the study corridor traffic showed that intermodal costs ranged from $522 to $931, while the truck costs ranged from $565 to $985. Intermodal costs were always lower in those cases where drayage was done through efficient utilization of equipment and draymen and the customer's hub was located near the terminal.

- Intermodal costs were lower in 11 out of 16 routes evaluated. The highest single-route cost savings over truck was a 21.4 percent intermodal cost advantage for the Jersey City to Atlanta route (a $169 saving). Of the 5 routes with higher intermodal costs, the greatest difference was in the Funkstown, MD, to Gainsville, GA, route, where intermodal was 20.1 percent higher ($119 more expensive) than the equivalent all-truck move.

Mode Share and Mode Choice

- The intermodal market share in the corridor ranged between 1.9 percent and 8.5 percent of the total freight volume. This is consistent with the overall intermodal mode share in the U.S.; that is, substantial in long-haul intermodal corridors but rather small in the medium and short haul markets.

- Mode choice decisions are based primarily on price and service. On these criteria, intermodal service competes directly with over-the-road trucking, and its attractiveness depends on the extent to which intermodal cost advantages are outweighed by factors such as terminal location, access difficulty, and the geographic pattern of shipper distribution around the terminal.

- The shipper survey indicated that the mode choice decisions of intermodal customers are not influenced by congestion and air quality concerns. Shippers use a facility so long as it is cost-effective and physically accessible, regardless of the congestion- or air quality-related benefits (or costs) that might accrue from their mode choice.

- In general, intermodal service will not be selected if costs are higher than truck rates. Larger companies which ship longer distances and are cost sensitive are more likely to choose intermodal over truck. In some cases, imbalanced traffic levels will favor intermodal if no backhaul is available, even though it is more expensive in one direction. Intermodal may also be selected instead of truck if there are driver shortages along the route.

- Qualitative aspects such as terminal security, in addition to cost and service time, may dominate choices when the price and service of truck and intermodal are generally similar. Inadequate security along surface routes can discourage intermodal use. In locations such as Miami and Los Angeles, truck hijacking has become increasingly common.

4.2 TERMINAL FACILITIES ANALYSIS

This study was conducted by Mercer Management Consulting under contract with the Volpe Center. The study consisted of subtasks on terminal capacity, terminal access, and industry best practices.

Infrastructure Access and Connectivity Problems

- Terminal operations often interfere with highway traffic and reduce effective access, with consequences for drayage costs and door-to-door transit times.

- Physical access constraints are often exacerbated by gate operations. Terminal gate operating inefficiencies result in congested access routes, long exit/entry gate queues, and in-terminal delays for lift services. These inefficiencies are caused by inadequate gate capacity, traffic peaking, and restricted gate hours. Congestion within the terminal affects the cycle time required for drayage and thus the cost of intermodal movements.

- One of the major impediments to efficient terminal operations are rail interchange practices. Interline transfers at rail terminals are fraught with inefficiencies, long delays, and unnecessary switching, partly due to the fragmented rail infrastructure ownership and operation. The absence of a nationwide network that allows railroads to share lines, and equipment, or resources impedes further growth of a highway competitive intermodal system. Successful run-through services and train switching operations are critical factors for eliminating the redundant handling of steel-wheel and rubber-tire interchanges. The growth of intermodal freight depends on inter-company cooperation to extend rail haul length and avoid delays.

Best Practices

Intermodal carriers are pursuing several strategies to improve terminal operations in an effort to increase capacity, efficiency, and competitiveness of intermodal services. Best practices in terminal management include:

Gate Operations. A review of terminal gate operations identified various effective practices. Current gate configurations favor streamlining gate procedures by the use of reversible gates, two-stage gates, and specialized gates where applicable. Increasing the number of gates or using bi-directional gates ease gate delays and offer the flexibility of efficiently handling traffic peaks.

Innovations in gate processing techniques have proven successful. Two-stage gate processing has allowed pre-screening of movements before they clog the actual gates and allows for advance documents to be generated while drivers wait for inspection. Specialized gates allow for expedition of processing for specific traffic. Paperless gates improve processing speed and accuracy. Hand-held input devices have been used to mobilize gate personnel allowing them to create "virtual gates" as needed to accommodate traffic flow.

Security. Shipper mode choice is strongly influenced by cargo security within the intermodal terminal. Security provisions built into terminal designs include inspection spaces, perimeter fencing to prevent vehicles from exiting, guard rails to prevent trailer opening, better lighting, and video monitors.

Service Quality. Terminal delays have been reduced through the use of specialized terminal equipment and track configurations, coordination of pickup and delivery operations, and information systems for expediting terminal processing. Application of these terminal innovations has been beneficial in combatting gate queues and terminal congestion, and improving terminal processing times, train schedules, transfer and interchange connections, and notification of shipment arrival.

Carriers have begun facilitating customers' JIT inventory control practices by meeting their on-time performance requirements, offering regularly scheduled, reliable, and cost effective linehaul service.

Productivity. Several productivity issues were uncovered:

- Labor and equipment productivity have been boosted through mechanized and well managed intermodal interchange operations. Handling techniques, specialized equipment, and track configuration provide greater speed and efficiency in areas such as train assembly/disassembly. In-terminal track configuration practices include train-length tracks which minimize switching costs and delays, and easily allow for high volume loading and unloading without crane repositioning. Center-aisle parking practices minimize the distance between parking and trackside loading as well as unit search time.

- Productivity of terminal operations is impacted by advances in operations and service delivery through the improvements in processes, equipment, and information system technologies. Process improvement strategies increase the efficiency and customer appeal of intermodal transfer at junction points.

- Railroads have adopted new technologies designed to reduce weight, fuel, and handling requirements and increase capacity. Intermodal linehaul cost advantages have increased through the adoption of new technologies such as RoadRailer vehicles and double-stack trains.

- Computers advance intermodal operations through applications which encompass the entire distribution system. System improvement efforts are directed toward the unification of the entire process based on information technologies such as Electronic Data Interchange (EDI) and Automatic Equipment Identification (AEI). These systems can improve route optimization, equipment (railcar, trailer, container) tracking, electronic transfer of intermodal documents, order processing, damage claims processing, and rate information.

5.0 RECOMMENDATIONS

The study findings identify an array of policy alternatives that demand strategic investment and action on the part of the public and private sector stakeholders. The strategies are geared to improving the overall efficiency and performance of intermodal operations, removing the access barriers and operational bottlenecks, connecting the missing pieces of the intermodal puzzle, and ultimately helping the industry to gain mode share and achieve a seamless flow of goods and information [ES-8].

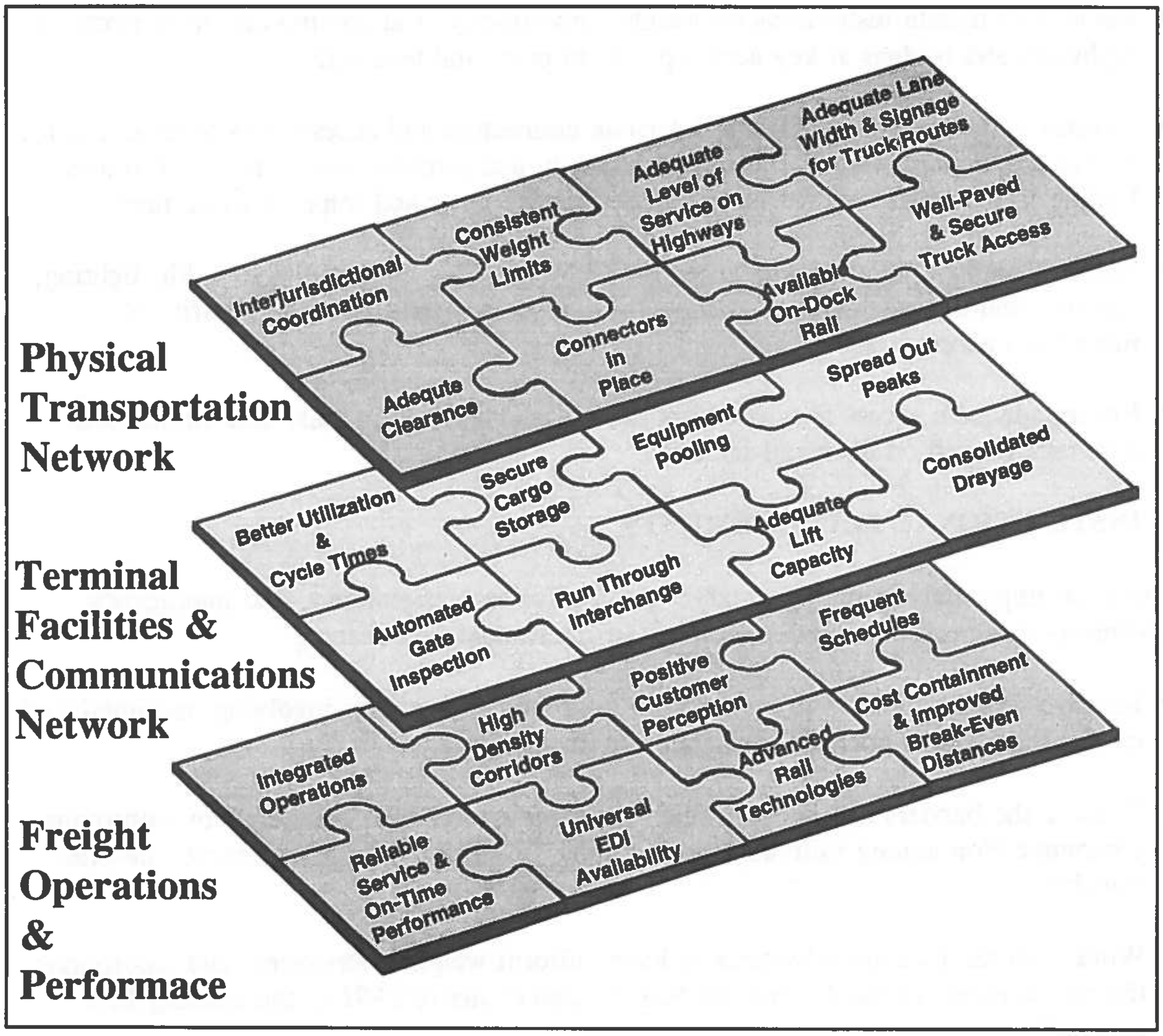

Figure ES-8. Seamless Flow of Goods and Information

5.1 ACCESS IMPROVEMENTS

These strategies target the improvements required to remove physical infrastructure access impediments. Removing these impediments is critical for improving the flow of intermodal traffic through the network:

- Provide adequate clearance on bridges, tunnels, viaducts, and highway overpasses required by drayage trucks and rail double-stack service.
- Remove or update restrictions on weight, time-of-day, and commodity movements on highways and bridges at key access points to ports and terminals.
- Construct the needed arterial and interstate connectors and access links to terminals to reduce circuity; provide adequate lane capacity and terminal access for truck routes leading to intermodal terminals to reduce drayage costs and improve cycle time.
- Enhance highway security and accessibility by ensuring adequate lane width, lighting, signage, and overall safety to assuage the shipper concerns over the security of intermodal access roads.
- Ensure adequate access to ports, airports, rail and truck terminals, tank farms; and construct needed on-dock rail facilities.

5.2 INSTITUTIONAL IMPROVEMENTS

Institutional improvement strategies target the institutional, regulatory, and interagency impediments that prevent smooth operations of intermodal interchange.

- Remove funding barriers to investing in improvement projects involving multimodal and multi-jurisdictional operations and multi-user terminals.
- Remove the barriers to a more efficient interline interchange operations by improving communication among railroads and initiating "run-through" agreements for interline transfers.
- Work with the industry advocates to have uniform weight restrictions, and incorporate the requirements of the *Intermodal Safe Container Act of 1991* in the existing EDI protocol.

- Standardize communication protocol and EDI formats to ensure interoperability of all data transmission mechanisms and compatibility of all software and operating systems.

- Remove the institutional barriers to formation of regional shipper and carrier alliances to help build a more efficient hub-and-spoke system; and achieve market density through freight pooling, track sharing, and joint terminal use.

5.3 TECHNOLOGY-ORIENTED IMPROVEMENTS

Ensuring efficient port and terminal operations and expanding capacity for existing facilities are made feasible by using supply-oriented solutions that include adoption of new technologies and streamlined operations, including:

- Increase capacity by correctly matching the equipment, terminal, and linehaul schedule capacity; adopting new methods of charging for container use; and modernizing container handling equipment.

- Improve terminal throughput and cycle time and reduce terminal delays through techniques such as drayage-by appointment; coordinating pickup and delivery operations; automating gate processing; using in-terminal track configurations that minimize switching costs and delays and crane repositioning; and using center-aisle parking practices that minimize the unit search time and the distance between parking and trackside loading.

- Enhance equipment utilization and terminal productivity by adopting automated inventory techniques and information processing systems; rationalizing gate operations and container damage inspection; and streamlining container use, storage policies, and terminal inspection processes; mechanizing terminal handling equipment and interchange operations; and providing greater speed in areas such as train assembly/disassembly.

- Ensure cargo security through installing specialized sensors, fences, gates, and video monitors.

- Apply ITS/CVO technologies such as AEI, AVI, and AVL to automate equipment inventory and inspection; streamline gate procedures by the use of "smart gates," reversible gates, and two-stage and bi-directional gates to allow pre-screening of movements before they clog the actual gates; pre-clear vehicles by generating advance documents while drivers wait for inspection; automate order processing through paperless gates and EDI transfer of documents, damage claim processing, and rate information; and use hand-held input devices to mobilize gate personnel allowing them to create "virtual gates" as needed to accommodate traffic flow.

5.4 MARKET-ORIENTED IMPROVEMENTS

This set of recommendations is geared to increasing the profitability and market share of intermodal freight operations by expanding the scope and density of the markets, improving service quality, and reducing operating costs.

- Improve quality of service and customer satisfaction by offering more reliable door-to-door delivery to satisfy the shippers service needs, by streamlining train schedules, developing on-line tracing systems, and automating order processing.

- Increase economies of scale and hence market share by generating networks of distribution hubs and load consolidation centers, and by negotiating customized service and volume discounts in exchange for volume guarantees and streamlined contracts.

- Maximize terminal location benefits by siting terminals at key locations throughout each metropolitan area, and design terminals to be collocated with major customers and truck distribution centers and within easy access to areas of economic activity, where maximum benefits from reduced traffic congestion and improved air quality accrue.

- Enhance demand and mode share by reducing the shipper's inventory carrying costs by meeting shippers' JIT requirements, offering faster and more reliable delivery, more frequent and regularly scheduled train departures, and shorter transit times.

- Expand the industry's market scope and density within each service area by reducing line-haul operating costs through greater productivity of labor, fuel, and equipment, and investing in such technologies as Iron Highway, RoadRailer and other bimodal vehicles that reduce the breakeven distance in short-haul lanes.

- Remove institutional barriers to asset ownership by encouraging non-exclusive fleet management and shared equipment pools; and provide incentives to non-asset owning IMCs to own and maintain a container and chassis fleet.

1. INTRODUCTION

Intermodal transportation by its very nature is a system based on interdependencies and joint operations. Physical linkage, inter-firm coordination, and timely information transmission are critical to maintaining the system functions and ensuring successful operations. Any intermodal freight move consists of essentially three interconnected components:

- Infrastructure access: Network links to the highway, rail, air, and waterway systems.

- Terminal facilities: Location of transfers, drayage, and loading/off-loading operations.

- Modal operations: Linehaul movements of rail, air, and water modes.

Because of the interdependencies inherent in an intermodal system, missing links, poor communication, or operational delays at any point have critical ramifications throughout the system. The interplay of factors that affect intermodal freight service and produce potential impediments are illustrated below. Figure 1-1 shows the interlinked nature of the network infrastructure, terminal facilities, and line-haul operations, and illustrates how inadequate access, terminal capacity constraints, equipment shortage, or inefficient operations impede efficient freight delivery and system performance.

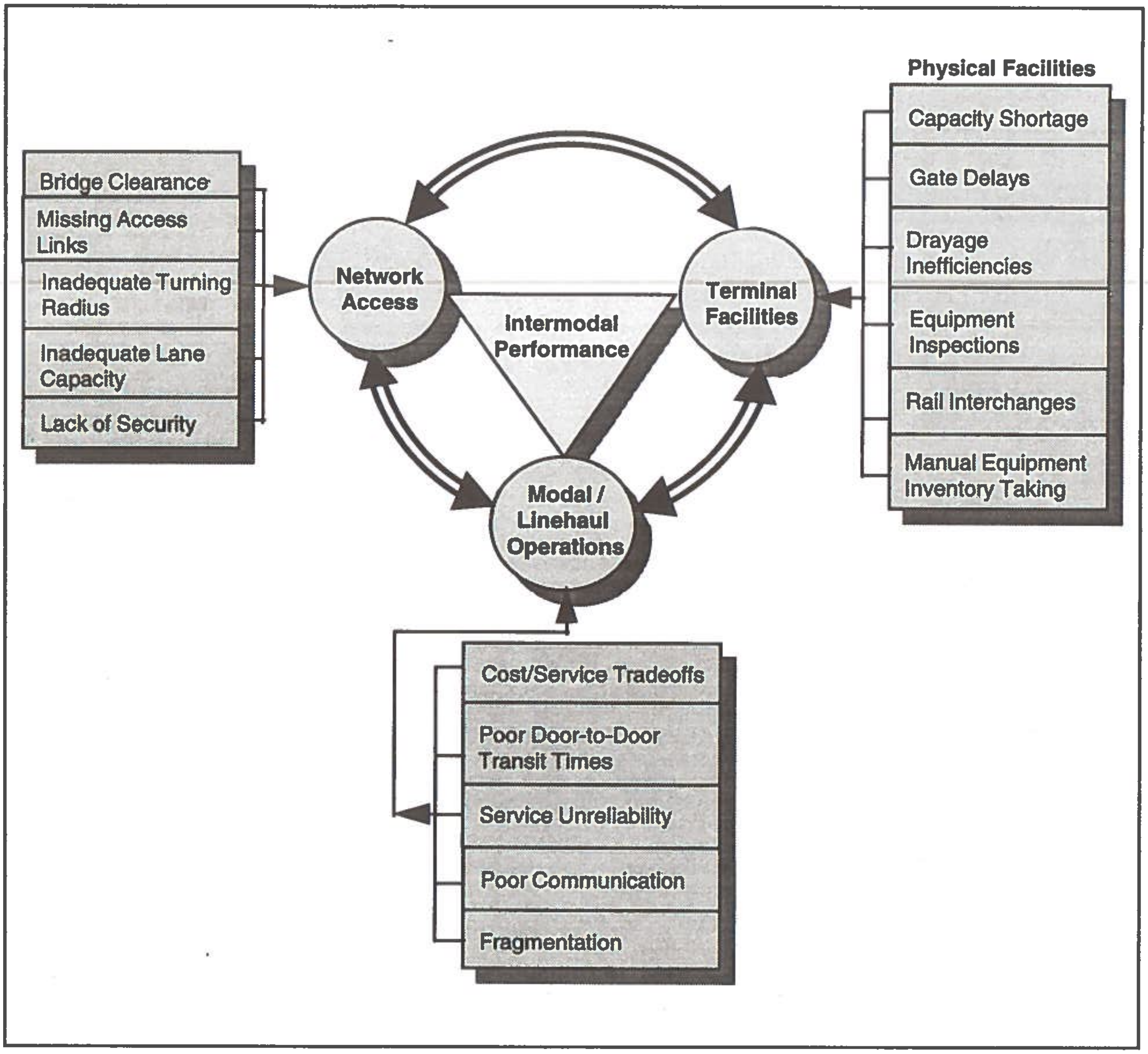

Figure 1-1. System Interdependence and Impediments to Performance

1.1 PURPOSE

The purpose of this report is to study the three components of the intermodal system--the infrastructure interface (network access), terminal facilities, and modal operations--and their implications both for freight mode choice and the overall performance of the U.S. freight transportation system. Within these components, the report reviews the latest research in intermodal dynamics; conducts an analysis of the Mid-Atlantic intermodal corridor; conducts an analysis of intermodal terminal facility operations and best practices; identifies the unmet needs in transportation infrastructure; and recommends policy options to enhance the performance of the intermodal freight system.

The primary impetus for this study has been to understand how intermodalism can enhance the efficiency of freight movements. The findings should provide critical knowledge to guide infrastructure and investment policy decisions at national and private industry levels.

1.2 MISSION

The primary mission of this study is to identify the extent to which intermodal freight operations can promote the goals and policy position adopted in Title V of the Intermodal Surface Transportation Efficiency Act (ISTEA), Section 5001 (e) amendment to Section 302 of title 49 USC:

> *It is the policy of the United States Government to encourage and promote development of a national intermodal transportation system in the United States to move people and goods in an energy-efficient manner, provide the foundation of improved productivity growth, strengthen the Nation's ability to compete in the global economy, and obtain the optimum yield from the Nation's transportation resources.*

The report starts from the premise that there exists a close link between the efficiency of the global economic system and the performance of the intermodal transportation system. It assumes that the efficiency of trade transactions, the nation's global competitiveness, the quality of life and environment within a country, and the performance of the transportation system are interdependent. Intermodal freight, which provides an efficient and least-cost alternative to the all-highway mode of moving goods, is a significant component of a national strategy for enhancing the overall efficiency of a nation's transportation system. This study attempts to explain how intermodal operations promote elements of this mission, including:

- Enhancing freight mobility by identifying methods of reducing highway congestion.

- Improving air quality by identifying modes with lower emissions.

- Improving the efficiency of State and Federal transportation investment outlays by exploring modal alternatives that retard deterioration of highway infrastructure and promote lower construction and maintenance costs.

- Enhancing freight transportation performance and resource efficiency by identifying modes which are characterized by lower cost, higher quality, and greater fuel efficiency.

- Enhancing the U.S. global competitiveness by identifying the most efficient and higher performance freight movement alternatives.

1.3 PROBLEM STATEMENT AND OBJECTIVES

In reviewing the three components of intermodal system, this report concludes that the challenges most important to the development of intermodal transportation lie as much in network access and terminal facilities as in modal operations. Technological advances in the industry have essentially made intermodal operations as highly efficient and competitive as single-mode operations. However, the lack of connectors, inaccessibility of terminal facilities, and operational inefficiencies relating to drayage and door-to-door service remain the Achilles heel of the intermodal industry.

The study maintains that the critical variables subject to policy manipulation are the availability of infrastructure access, the location and capacity of the terminal, and the quality of door-to-door service. (Figure 1-2 illustrates the interplay of these variables.) These variables strongly influence mode choice, which determines the intermodal share, and ultimately, profitability, performance, and competitiveness.

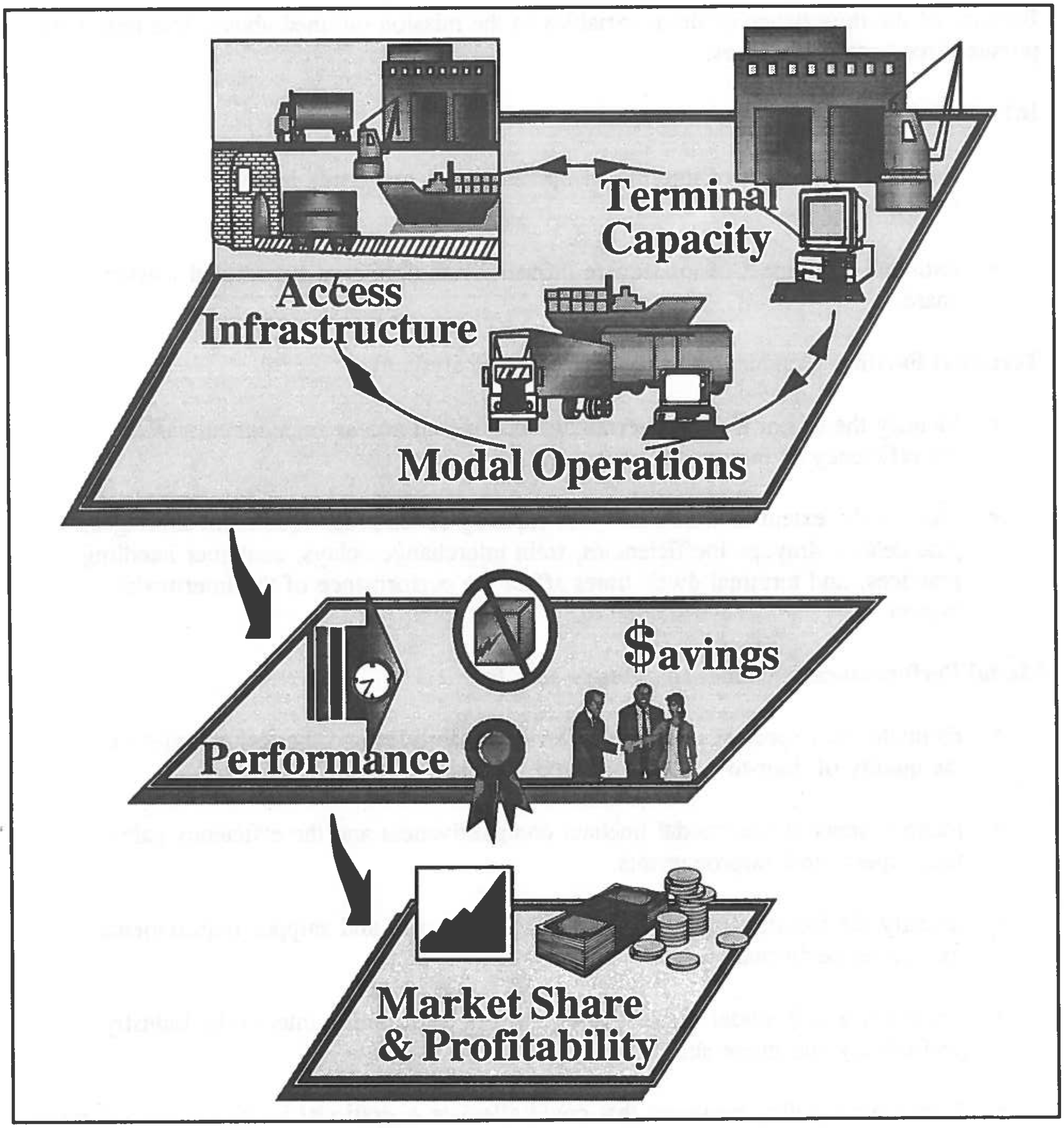

Figure 1-2. Transportation Performance: Interplay of Access, Location, and Mode Share

Because of the importance of these variables to the mission outlined above, this report will pursue three broad objectives:

Infrastructure Access: Conduct a corridor analysis to:

- Estimate the impact of intermodal operations on mitigating highway congestion.
- Estimate the impact of inadequate infrastructure access on intermodal market share.

Terminal Facility: Conduct an in-depth terminal analysis to:

- Identify the extent to which terminal location and access impediments affect the efficiency of intermodal operations.
- Identify the extent to which terminal capacity constraints, equipment shortages, gate delays, drayage inefficiencies, train interchange delays, container handling practices, and terminal dwell times affect the performance of the intermodal system.

Modal Performance: Conduct an industry scan to:

- Estimate the impact of intermodal carrier capabilities and the technologies on the quality of door-to-door service and resource utilization.
- Identify areas of intermodal linehaul competitiveness and the efficiency gains from operational improvements.
- Identify the factors determining freight mode choice and shipper requirements for carrier performance.
- Construct a cost model to identify the factors determining intermodal industry profitability and mode share.
- Recommend policy measures that could alleviate operational inefficiencies and access impediments.

1.4 PROJECT SCOPE

The scope of this study is limited to the rail-truck segment of the intermodal industry, which may or may not include a marine component. Admittedly, intermodal freight encompasses other combinations in addition to the truck-rail-marine alternative. The broader scope of the intermodal industry includes containerized movements of cargo by air and barge, non-containerized multi-modal movements of liquid bulk products by pipeline, rail, ocean vessels, and truck, and non-containerized multi-modal movements of dry bulk and breakbulk freight. Therefore, any future attempt to analyze the industry and its infrastructure needs should include the broader scope of intermodal.

Data availability has been the driving factor for limiting the scope of the present study to the truck-rail-marine operations. Currently, the only data available on movements categorized as "intermodal" or "multi-modal" are those for containerized shipments with a rail component. Thus, any analysis of industry performance is constrained by data availability.

1.5 DEFINITION

A widely used definition of freight intermodalism refers to *intermodality [as the] science--some call it an art--that deals with the movement of goods using multiple modes of transport* (Muller, 1989). The Dictionary of Science and Technology defines "intermodal" as *involving more than one mode of transportation, such as truck and rail or bus and rapid transit* (Academic Press, 1992).

A similar definition of intermodal appeared for the first time in 1986 in Webster's Third New International Dictionary: "intermodal" was formally defined as *being or involving transportation by more than one form of carrier during a single journey* (Merriam-Webster, 1993).

A better definition emphasizes coordination among multiple modes during a single journey, defining "intermodal" as *the sequential use of two or more forms of transport to complete a coordinated movement of goods* (McKenzie, North, and Smith, 1989). Another complementary definition of intermodalism emphasizes the single-control as well as single-journey aspects of intermodal operations, as *the practice in which one entity takes responsibility for the entire multi-modal movement of freight* (Hochstein, 1994).

Emphasis on single-responsibility and coordination underscores the critical importance of intermodal transportation as a *distinct distribution system*, rather than simply a mode of transportation. Pivotal to this system is the quality of service offered to the shipper through coordinated operations that minimize a shipper's logistics costs. The unique qualities of intermodal freight are best described as a well-integrated service delivery, rather than a purely mechanical definition that emphasizes only the multitude of modes involved in a move.

The integrated notion of transportation is an intrinsic feature of intermodalism and reflected in the objectives set forth in ISTEA's Sect. 2. Declaration of Policy. Section 2 calls for the establishment of a National Intermodal Transportation System that "*consists of all forms of transportation in a unified, interconnected manner...*" (Public Law 102-240, 1991).

Related to the notions of integration and single-responsibility component of an intermodal operation are the three ISTEA-derived concepts associated with intermodalism: *connectivity, choice, and coordination*. The concepts envision a transportation system in which all the transportation modes--over land, through the air, and across the water--are seamlessly linked, so freight or passengers can move from origin to destination using the most efficient modes. While the seamlessness of the operations underscores the significance of connectivity at the points of interchange, the efficiency component assumes choice among multitude of modes, so that the best combinations of modes in terms of price, transit time, and overall performance are selected, and the transfer of goods among the modes is well-coordinated and free of friction and delay.

The definition of intermodalism used in this study combines those discussed above as follows:

> *coordinated and sequential movement of unitized freight, with a single-party responsibility for the completion of the trip, using a combination of modes, with a possible marine link midway or at either end of the journey.*

The most common form of intermodalism involves moving containers or trailers on rail for the line-haul portion of the shipment--as trailer-on-flatcar (TOFC) or container-on-flatcar (COFC) service--and on truck for the door-to-door pickup at origin and delivery to destination sites (referred to as "drayage"). Though a fully multi-modal journey may also involve an air or pipeline segment, and possibly transloading of non-containerized cargo, for the purposes of this study, the above definition, as illustrated in Figure 1-3, is adopted.

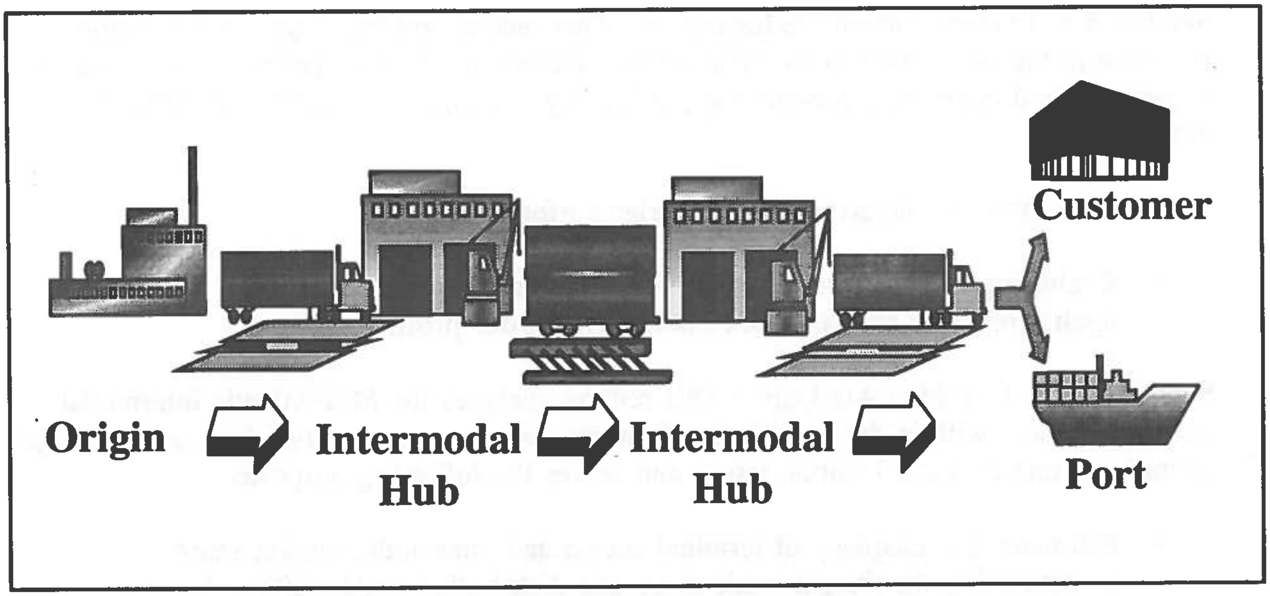

Figure 1-3. The Truck-Rail Intermodal System

1.6 ORGANIZATION OF THE REPORT

The remainder of this report, focusing on the three components of intermodalism--the infrastructure interface (network access), terminal facilities, and modal operations-- consists of the following:

Section 2 – An Environmental Scan – This section provides background information on the intermodal industry and provides an overview of the opportunities and challenges facing the industry by:

- Identifying the industry characteristics and the emerging industry trends through a literature review and a profile of industry activities and growth patterns.
- Reviewing the findings of the National Commission on Intermodal Transportation (NCIT).
- Reviewing the efforts to define the issues related to the National Transportation System (NTS) and the composition of the National Highway System (NHS).

Section 3 – Transportation Performance - This section sets the stage for the analysis provided in the later chapters by defining the determinants of transportation performance in general, and intermodal productivity, efficiency and quality of service in particular, by:

- Identifying the determinants of carrier performance.
- Evaluating the way production efficiency, productivity, and service quality relate to shipper mode choice and carrier profitability.

Section 4 – A Corridor Analysis – This section analyzes the Mid-Atlantic intermodal freight corridor, with in-depth analysis of intermodal operations, network access, drayage operations, and terminal location issues and serves the following purposes:

- Estimates the adequacy of terminal access and intermodal market share by estimating the freight mode share and distribution routes within the corridor's designated terminal catchment areas.
- Assesses the impact of intermodal movements on highway network congestion by estimating the tradeoffs of the all-truck freight flows vis-à-vis intermodal movements along the corridor.
- Constructs a freight cost model to evaluate the relative weights for each cost component of the highway and rail alternatives.
- Constructs a mode-choice model based on the relationships established in the freight cost model and augmented by a series of structured carrier and shipper interviews.

Section 5 - Terminal Capacity - This section provides an in-depth analysis of intermodal terminal efficiency and the operational factors that influence intermodal performance and market share, including:

- Terminal location and capacity
- Rail access problems
- Highway access, clearance, and drayage
- Operational constraints and traffic peaking
- Terminal best practices.

Section 6 - Conclusions and Recommendations - This section summarizes the study results and attempts to:

- Augment the findings of the Mid-Atlantic Corridor study and the terminal analysis by integrating them with the evaluation provided in section 3.

- Offer policy and strategic recommendations for alleviating access impediments and operational inefficiencies and improving performance.

2. ENVIRONMENTAL SCAN

This section is an overview of the intermodal freight industry: it reviews the current industry trends and a number of legislative initiatives. Section 2-1 provides an industry profile, with information on market share, growth in sales and activities, and a description of the customers using the services and the commodities shipped. Section 2-2 reviews the issues addressed in the NCIT Report to Congress. Section 2-3 reviews the NTS and the process of identifying the needs of the infrastructure components of the NHS.

2.1 AN INDUSTRY PROFILE

The intermodal industry is treated here as the segment of the U.S. freight transportation that deals with the movement of the cargo containers and trailers on a combination of rail, truck, and ocean vessels. This establishes a narrower scope for intermodal freight than the one offered in section 1.3, in order to preserve the consistency of the available statistical reports.

2.1.1 Market Share

Revenues from freight transportation in the U.S. in 1994 were $420 billion. Motor carriers had the lion's share of the revenues with $333 billion (79.3 percent),[1] rail claimed $33 billion (7.9 percent), water carriers $22 billion (5.2 percent), and air, oil pipelines, and freight forwarders the remaining $32 million (7.6 percent) (see Figure 2-1).

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[1] The motor carrier revenues consisted of $96 billion (28.8%) for public/for hire carriers, $109 billion (32.7%) for private/for-own-account carriers, and $128 billion (38.4%) for local carriers.

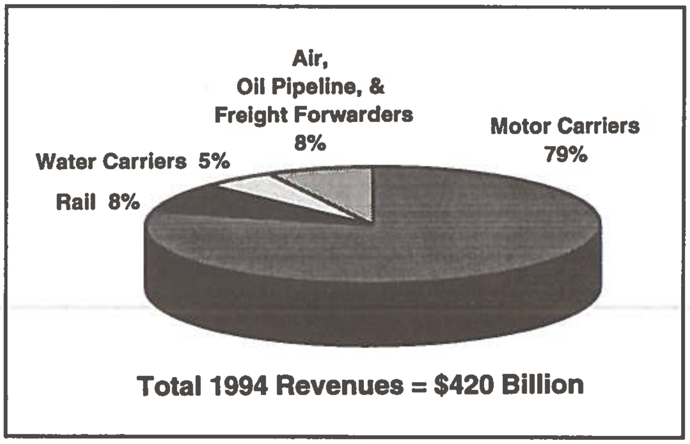
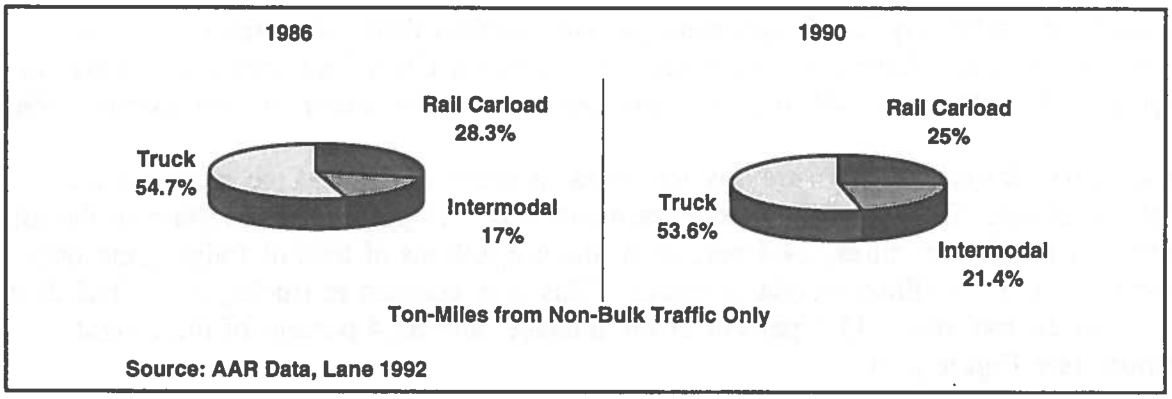


Figure 2-1. U.S. Freight Transportation Revenues

The intermodal portion of the annual freight bill of $420 billion is an estimated $8 billion, roughly 2 percent of the total freight revenues. Determining the intermodal market share, however, is less straightforward since the rail-truck combination mode is not feasible in all markets, especially in the local delivery and those involving private fleet operations. To more accurately designate the relevant intermodal market, some analysts define it as the *non-bulk cargo movements of more than 500 miles*. By this definition, the 1990 share of intermodal was 21.4 percent of the total ton miles, compared to 25.0 percent for rail carload and 53.6 percent for truck. By this definition, the intermodal share has increased in the past few years mostly at the expense of the rail carload (down from 28.3 percent of the market in 1986), and not to any significant degree due to a decline in trucking (Lane, 1992; see Figure 2-2).



Source: AAR Data, Lane 1992

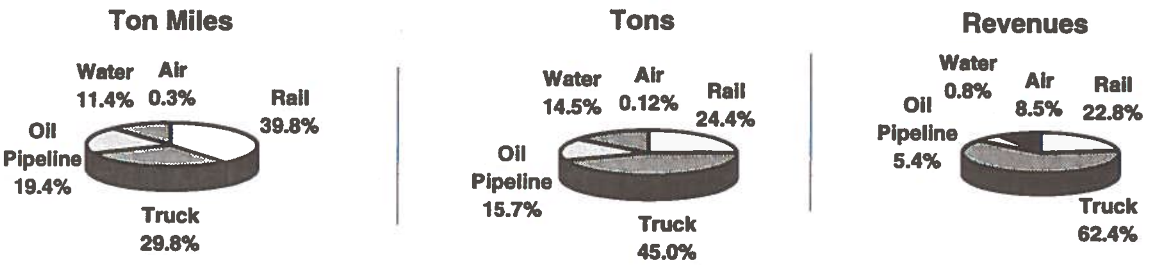
Figure 2-2. Market Share in Ton Miles for Movements Over 500 Miles

The intermodal market share varies by service corridor. In some long-haul double-stack lanes, more than 50 percent of the domestic freight market is served by intermodal. Along these high-density corridors, the total rail market share rises to nearly 80 percent if the rail boxcar traffic is added to the intermodal rail statistics (Lane, 1989b).

The length of the haul is the most critical factor in determining intermodal use. An estimated 70 percent of the shippers in the U.S have used intermodal rail in movements of more than 1,500 miles (though not exclusively) and more than 30 percent have used it for movements of more than 700 miles. Overall, some 20-25 percent of all manufacturing shipments are estimated to be hauled intermodally (Bearth, 1992).

The railroads' relatively low freight rates partially explain their low market share for intermodal services. Revenue per ton-mile of freight for Class I rail carriers in 1992 was roughly 2.58 cents, compared to 22.40 cents per ton-mile for motor carriers (Smith, 1990).

Market share for rail, as measured by ton miles, is much larger that the rail's share of freight revenues. In 1993, for instance, railroads had 39.8 percent of the share of the total 2.9 trillion freight ton miles, 24.4 percent of the 6.8 billions of tons of freight, and only 22.8 percent of the $131 billion freight revenues. This is in contrast to trucks, which had 29.8 percent of the ton miles, 45.5 percent of the tonnage, and 62.4 percent of the freight revenues (see Figure 2-3).

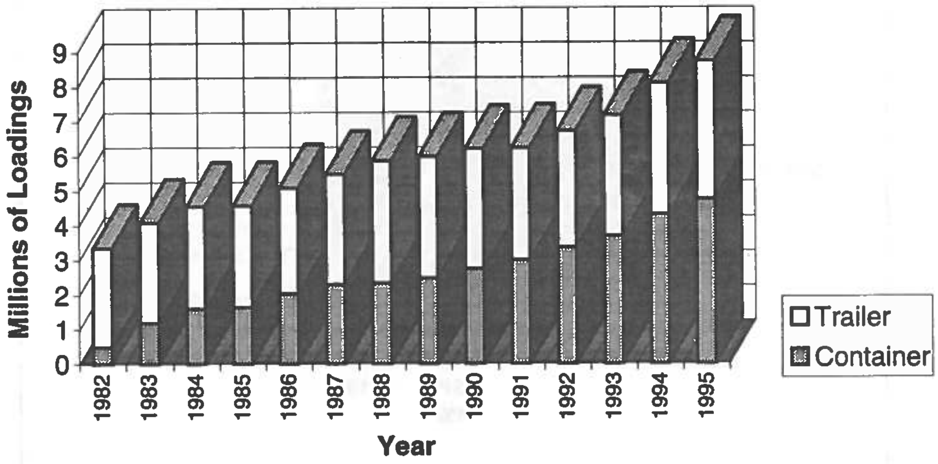


Source: ENO Foundation

Figure 2-3. Market Share Comparisions

2.1.2 Loadings

The intermodal industry moves more than 8 million loads of containers and trailers each year. The number of loadings have almost tripled since 1980, when 3.1 million loads were moved. The industry loadings have grown at an average rate of 6 to 7 percent in the past few years, with the most rapid growth occurring in double-stack lanes. Figure 2-4 shows the growth of intermodal trailer and container loadings from 1982 to 1995.

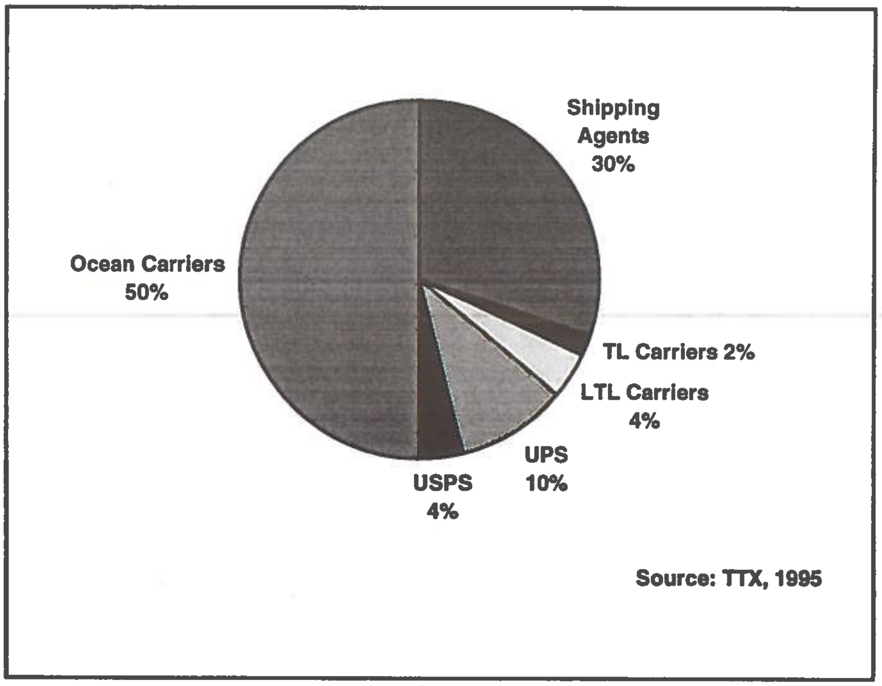


Source: TTX, 1995

Figure 2-4. Intermodal Trailer and Container Loadings

2.1.3 Customers

Customers of the rail intermodal line-haul service include the domestic subsidiaries of steamship lines, intermodal subsidiaries of motor carriers, and third-party shipper agents. Some 50 percent of intermodal shipments are made by ocean carriers; 30 percent by third party agents; 10 percent by United Parcel Service (UPS), constituting the largest single customer for the carriers; 4 percent by the U.S. Postal Service (USPS); 4 percent by less-than-truckload (LTL) carriers; and 2 percent by truckload carriers and a few direct shippers such as auto manufacturers (see Figure 2-5).



Source: TTX, 1995

Figure 2-5. Customers of Intermodal Services

2.1.4 Commodities

The commodities most commonly containerized or carried in intermodal trailers are general cargo "break-bulk" goods in finished packages and include:

- Food products
    - Canned or preserved fruits
    - Vegetables or seafood
    - Grain mill products
    - Beverages

- Paper and forest
    - Sawmill or planing mill products
    - Millwork
    - Prefabricated wood, plywood, or veneer
    - Paper

- Plastics and chemicals
    - Industrial inorganic or organic chemicals
    - Plastics, synthetic fibers, resin, or rubber

  - Miscellaneous chemical products

- Steel works and rolling mill plant products
- Automobiles and motor vehicle equipment and parts

The above containerizable general cargo commodities are key intermodal loads, but they are also subject to heavy competition from long-haul motor carriers. In 1987, 63 percent of these commodities were carried by railroads and 37 percent by long-haul motor carriers (Lane, 1989a). In recent years, motor carriers have increased their share of these commodity markets at the expense of the rail carriers.

Increasingly, intermodal carriers have begun carrying refrigerated products and "neo-bulk" cargo such as auto parts, lumber, and paper and pulp products. Though traditional bulk merchandise such as grain and coal are not transported as intermodal shipments, more and more high-value commodities such as coffee are transported in bulk in specially-lined containers. Another area of growth in intermodal shipment is perishable goods, making refrigerated containers ("reefers") a rapidly growing segment of the industry.

2.2 ISSUES ADDRESSED IN THE NCIT REPORT TO CONGRESS

This section provides an overview of the NCIT's report to Congress entitled "Toward A National Intermodal Transportation System." The NCIT was charged by Congress to "make a complete investigation and study of intermodal transportation in the United States and internationally." Congress viewed intermodalism as the cornerstone of the NTS concept and deemed improvements in the U.S. intermodal transportation system critical to the Nation's economic well-being.

The NCIT report addressed several areas affecting the expansion or development of a fully intermodal NTS:

- Transportation policy
- Existing intermodal system status
- Laws, regulations, and institutions
- Funding and finances
- Research, education, and technology development
- Government structure

The following sections review the NTS goals, the impediments identified by the NCIT, and the recommendations for advancing an efficient national freight intermodal transportation system.

2.2.1 NTS Goals

The goal of the NTS is to reap the potential benefits of intermodalism by optimizing the contribution of each mode to the overall transportation system, thus reducing the cost and improving the quality, cost, timeliness, and safety of passenger and freight transportation. Specific potential contributions of intermodalism include:

- Increasing economic productivity and efficiency and maintaining the Nation's competitive position in an increasingly global economy.
- Using the Nation's transportation infrastructure more efficiently. Maximizing utilization of the transportation system by reducing the burden on over-stressed infrastructure components and shifting it to infrastructure with excess capacity. Leveraging the relative strengths and efficiencies of all the transportation modes.
- Generating higher returns from public and private infrastructure investments.
- Improving mobility, service, convenience, and the general quality of life.
- Reducing energy consumption, and contributing to improved air quality and environmental conditions.

Intermodalism has taken hold in the freight sector. The growth of intermodal services has exploded since the 1980's when ocean carriers and railroads launched doublestack rail container service. The success of intermodalism has been driven by deregulation, competition, and industry innovations in technology and logistics practices. The new partnerships between ocean carriers, railroads, truckers, and shippers which followed provide efficient, cost-effective, and seamless service and drive dramatic changes in land and ocean shipping.

2.2.2 Impediments

Transportation Inefficiencies: Intermodal Transportation Lacks Integration

Single Mode Focus - The lack of a coherent, coordinated, and comprehensive national transportation policy which encompasses all modes has handicapped intermodalism by ignoring the importance of intermodal connectors. Traditionally, management, planning, policies, and funding (particularly at the Federal level) have focused on individual modes and have not encouraged and accommodated intermodalism. Transportation policy needs to capture the synergistic potential of the nation's transportation system. An integrated national system *must* focus on users--on moving people and goods--*not* on individual modes and vehicles. Transportation planning, policies, and investments must be carefully targeted to maximize the potential contribution of each mode to the overall system.

Terminal Access and Urban Congestion - Barriers to safe and efficient movement of intermodal freight occur at connections between modes (points of transfer) where congestion and conflicts are most common. Therefore, these connections must be improved to maximize the potential of the nation's transportation system. Intermodal connectors, such as roads between freight terminals and major highways, are currently among the weakest links in the transportation system because infrastructure investments are not keeping pace with demand. (Postponed improvements of infrastructure construction and maintenance contribute to delays and congestion.) While intermodalism has taken hold in the freight sector, its continued growth has far outstripped its support structure in the following ways:

- The lack of adequate connectors between the interstate highway system and the existing nation's port, rail, airport, and truck terminals results in urban congestion, air pollution, negative impacts on adjacent neighborhoods, and delivery delays for shippers.
- Narrow city streets and low bridge clearances produce major barriers to intermodal movement.
- New terminal development or expansion of existing facilities has not been accompanied by upgraded access routes.

Safety at Grade Crossings - Grade crossings impair the efficiency of both the road and rail systems and are safety hazards. Removal of grade crossings, wherever possible, would result in increased efficiency, safety, and savings.

Problems at Ports and Borders - Several issues occur at international and state borders:

- Congestion at International Ports and Border Crossings - Delays at port and border areas (mostly the result of institutional inefficiencies) reduce the reliability and efficiency of intermodal operations and are also barriers to the free flow of freight. Congestion and processing costs are significant problems on both the Mexican and Canadian borders, as well as at their international seaports and airports. Problems include:
    - Inadequate staffing
    - Delays for drug interdiction inspections
    - Lack of coordination between inspection agencies within a country

  - Inconsistent requirements and procedures at border crossings
  - Excessive paperwork and bureaucratic red tape
  - Facilities typically open only during "regular business hours"

- Equipment Utilization - Equipment is under-utilized for cross-border shipment. The North American Free Trade Agreement (NAFTA) places restrictions on its trading partners (U.S., Canada, and Mexico) from using another country's intermodal equipment (trucks, vessels, containers, and chassis) in domestic operations. These restrictions reduce the efficiency and competitiveness of the North American trading system. Currently, equipment must be "imported" to be used in-country.

- State and Local Taxes - The imposition of taxes—state and local sales tax and property tax—on leasing and owning containers used exclusively in international commerce could negatively impact the free flow of intermodal freight.

Joint Use of Passenger and Freight Infrastructure - Freight and passenger systems share common needs and problems. Therefore, transportation planners must design systems that meet the requirements of both. Passenger systems, for example, need access to rail lines used exclusively for freight.

Investment Inadequacies: Investments Are Not Keeping Pace With Demand

Funding Unmet Needs - The Nation needs additional transportation investment inspired by a vision of a coordinated intermodal transportation system. In an era of deficit reduction and financial constraint, it is critical that the Nation strategically target transportation funds to gain the most capacity from the existing infrastructure by investing in missing links and improving connections. The demand for funding for the construction, maintenance, and safe operation of intermodal links continues to increase, while federal funding of transportation programs is modally directed, thus discouraging investment in intermodal transportation.

There is currently inadequate funding to cover the identified unmet transportation needs of surface transportation (highway, bridge, and bus and rail transit deficiencies), airport, seaport, inland waterway, and intercity passenger rail systems. This backlog could be partially addressed by funding Federal transportation infrastructure programs at authorized levels and by targeting these funds strategically. In addition, practices such as the diversion of user fees from transportation trust funds contribute to the widening gap between investment needs and funding capability.

Innovative Public and Private Financing - Expanding and encouraging the use of innovative financing mechanisms can increase and leverage investment or reduce public agency costs for intermodal transportation projects. Identified approaches include facility/vehicle leasing, joint public/private project development, and congestion pricing. States must also be free to take advantage of flexible, innovative financing mechanisms such as tolls, private sector matches, the ability to match funds through investment credit provisions, or the creation of revolving loan funds. In the private sector, intermodalism has led to new and productive partnerships. The ISTEA creates an important opportunity to develop similar public sector initiatives and public-private partnerships supporting the growth of intermodal freight and passenger services.

Flexibility and Eligibility - Although ISTEA takes an intermodal approach and displays new flexibility for funding transportation capital programs, federally funded programs still have several *modal* eligibility restrictions. For example:

- ISTEA funds, except Congestion Management and Air Quality funds, cannot be used for freight or intercity rail projects.
- The Airport and Airways Improvement Act restricts the use of airport funds to on-airport projects.
- Harbor Maintenance Trust Funds cannot be used for constructing containment areas for dredged disposal.

Federal fund restrictions to cover construction *only* have forced construction solutions that exclude other possibilities requiring operating or maintenance efforts. The traditional *modal* funding structure puts *intermodal* projects at a disadvantage. Flexibility is needed in the spending of federal and state transportation funds for intermodal projects.

States should be able to focus their funds on projects that make sense for them, rather than have the types of projects dictated. The national commission urged minimizing restrictions to allow investment decisions to be evaluated across modes and modal tradeoffs to be made. Eligible projects should include:

- Connectors that link the NHS, ports, and truck and rail terminals.
- Multimodal terminals that connect various services.
- Rail and highway projects (bridge clearance, grade crossings, Amtrack, rail clearances, and other joint-use projects that increase system capacity).

Regional and National Projects - Transportation planning and coordination between suburban and rural areas, and between states, is often inconsistent. The strong local focus of ISTEA (which emphases the empowerment of metropolitan planning organizations (MPOs) and states) might prove a barrier to projects of national or regional significance. This could be especially true for projects that may not have obvious benefits for their immediate local or regional area. In addition, the traditional passenger focus of MPOs might be an obstacle to freight projects, requiring them to compete for funds under a process that inherently favors local passenger and transit. There needs to be greater flexibility and expanded eligibility in the use of federal and state transportation funds for intermodal projects of public benefit.

Funding Research, Education, and Technology Development - Funding research, education, and technology development face major obstacles due to restrictions produced by the traditional *modal* funding system. Other obstacles include:

- Training for transportation professionals often fails to incorporate *intermodal* considerations.
- The *modal* organization of transportation data and the resulting absence of *intermodal* data inhibit the development of *intermodal* systems.
- Independent research by *modal* agencies that cuts across individual modes lacks coordination. Separate research fosters inefficiencies and encourages redundancy.

Fragmented Decision Making: Intermodal System Lacks Coordination

Fragmented Responsibility for Intermodal Policy and Decision Making - A fundamental barrier to the growth of intermodal transportation exists in the very nature of Congress, federal agencies, and many state governments because their transportation functions are divided, funded, and managed by mode. Though these functions also include building connections between modes, the current mode-based institutional structure makes final responsibility for strengthening intermodal links unclear. This narrow focus, as well as the overlapping levels of government and special jurisdictions, inhibits intermodal planning and policy development and complicates patching together funding and approval for intermodal projects. These inefficiencies reverberate adversely throughout the economies of every state and region of the Nation.

Obstacles to Efficient Planning and Project Delivery - Regulations that accompany Federal transportation funding frequently add costs and delays to projects. This problem is magnified for intermodal projects because they are often governed by the regulations of more than one agency and encumbered with multiple layers of inconsistent procedures. This lack of consistency is a significant barrier for intermodal projects that rely on multiple funding sources. Smaller sized projects, already burdened with administrative overhead, are discouraged from applying for the funds they need to keep local services running.

Conflicting National Goals Impact Intermodal Transportation Policy - The country has adopted national goals with inherent policy conflicts embedded in them. Federal agencies outside of DOT have roles that directly or indirectly affect transportation policy. Intermodal construction and expansion projects are often delayed by the conflicting policies and regulations of multiple government agencies: for example, dredging projects are tied up by environmental issues. All affected interests must, as a first step, agree on a coordinated approach. It would allow the responsible parties to identify policy conflicts, recommend modifications, and avoid long-range problems.

MPOs and Intermodal Planning - ISTEA has imposed substantive new planning and programming requirements on MPOs to undertake integrated planning that does the following:

- Links transportation and land use.
- Ties transportation to environmental and socioeconomic concerns.
- Addresses urban congestion, growth demands, and air quality concerns.

MPO staff may not be capable of handling their expanded role; MPOs, for example, are not traditionally trained in freight planning. MPO organizational structures also have a credibility gap since, in many cases, important transportation providers and users are not represented and thus remain outside the process. The gap between public planning and private sector decision making needs to be bridged as well.

2.2.3 Recommendations

The NCIT made the recommendations listed in Table 2-1, recognizing that federal policy should support private sector innovation, provide maximum flexibility for state and local transportation officials, and not intrude unnecessarily into private sector operations.

Table 2-1. NCIT Recommendations

Make Efficient Intermodal Transportation the Goal of Federal Transportation Policy

1. Maximize safe and efficient movement of passengers and freight by incorporating individual modes into a National Intermodal Transportation System.
2. Ensure federal policies that foster development of the private sector freight intermodal system and reduce barriers to the free flow of freight, particularly at international ports and border crossings.
3. Adopt federal policies that foster development of an intermodal passenger system incorporating urban, rural, and intercity service, including a viable intercity passenger rail network.

Increase Investment in Intermodal Transportation

4. Fund federal transportation infrastructure programs at authorized levels and strategically target these funds for maximum impact.
5. Develop innovative public and private financing methods for transportation projects.
6. Allow greater flexibility and expanded eligibility in use of state and federal transportation funds for intermodal projects of public benefit.
7. Provide federal funding incentives for intermodal projects of national or regional significance.
8. Expand the intermodal focus of research, education, and technology development efforts.

Restructure Government Institutions to Improve/Support Intermodal Transportation

9. Restructure the U.S. Department of Transportation to better support intermodal transportation.
10. Streamline and expedite the transportation infrastructure planning and project delivery process.
11. Require Department of Transportation concurrence on other federal agency actions that affect intermodal transportation.
12. Strengthen the MPO process to accomplish the goals of ISTEA.

2.3 NTS AND THE PROCESS OF IDENTIFYING INFRASTRUCTURE NEEDS

In 1994, intermodalism took a new direction with the development of the NTS, a concept proposed by U.S. Department of Transportation (DOT) Secretary Peña. The NTS concept--initially presented in the June 23 and August 24, 1994, issues of the *Federal Register*--proposed to include components from highways (initially the NHS, as defined by Congress), aviation, public transportation (intercity bus and transit), railroads, ports and waterways, pipelines, and intermodal connections. It is intended that all the modes encompassed in the NTS be interconnected to promote critical national interests such as:

- Clean air
- Reduced energy consumption

- Safe, comfortable, and cost-effective transportation
- Quality of life

This commitment to a multimodal NTS departs from the traditional federal government focus on developing and financing individual forms of transportation. America's need for a seamless transportation system requires a shift from individual transportation means and fragmented projects to enhancement of the Nation's entire transportation system.

The DOT's strategic plan states the goal of establishing, in keeping with ISTEA, an NTS that integrates all modes of transportation--for both people and freight--and that emphasizes connections, choices, and coordination of services to position this country as an effective economic competitor in the global market. The NTS will:

- Map the nation's major transportation networks for all *modes*.

- Identify local, regional, and national bottlenecks; missing linkages; and new components needed for our existing infrastructure across all *modes*. This will lead all levels of government and the private sector to target investments to meet those needs.

- Enable the DOT to assess, *for the first time*, the conditions and performance of the entire national system. This will permit the development of more effective national and global policies and the identification of strategic investments.

- Implement ISTEA's mandates to integrate all *modes* into the metropolitan and statewide transportation planning processes: cost-benefit analyses for capital projects, management systems addressing operations, and congestion relief. Intermodal system requirements must take into account the full transportation picture. When considering short-haul needs, for example, decision makers should be able to choose between building additional airport capacity or rail passenger service.

- Encourage transportation decision-makers, at all levels, to favor investment that furthers the interdependence of local, regional, and national networks and thus leverages the benefits of all.

- Engender confidence among citizens that tax dollars are being invested wisely and strategically.

The NTS concept is being developed in concert with Congress, other federal agencies, state and local officials, the transportation industry, and interested citizens. After outreach meetings designed to gather comments on the NTS, the DOT will develop the following three NTS products:

> **Transportation System Geographic Information System (GIS) Displays** - will be valuable as a policy planning and decision-making tool to analyze and illustrate transportation system components and service levels and their interaction with national economic, environmental, and social goals. The GIS will provide information on:
>
> - National transportation status
> - Economic and usage patterns
> - Intermodal connections
> - Land use
> - Evaluation factors: environmental, energy, safety, and social
>
> **National Transportation System Report** - will include a discussion of the outreach process, a vision for future national transportation, the condition of the transportation system, the state of the ISTEA planning process, and proposed legislative and regulatory actions. It is also expected to present the strategic goals and objectives of the NTS and the steps needed to attain them. The report will also highlight the innovations and progress being made in integrated, intermodal planning by the state and metropolitan transportation agencies.
>
> **Legislative Proposal** - will "detail specific legislative changes necessary to address the concerns identified through the NTS outreach effort and by the NCIT, as well as additional policy directions highlighted by the ongoing data and analytic efforts within the DOT, states, and MPOs."

The NHS, the first major component of the NTS, is congressionally mandated under ISTEA and includes interstate highways, strategic roads, and priority corridors. (The NTS was unveiled at the same time the DOT announced its NHS plan.) The 159,000 mile network equals just 4 percent of the 3.9 million miles of U.S. roads, but accounts for more than 40 percent of the U.S. vehicle miles and 70 percent of the miles traveled by large trucks.

The NHS will form the cornerstone of the NTS by linking premier highways with major travel destinations, including seaports, airports, rail terminals, and public transportation facilities. These linkages are intended to complement the NTS, leading to a seamless transportation system unifying all transportation modes. One of the amendments approved for designation in the NHS is the Alameda Corridor in Southern California. The 26-mile corridor would separate rail lines from street traffic on the principal route connecting downtown Los Angeles with the ports of Los Angeles and Long Beach. The amendment also makes freight intermodal connectors eligible for NHS funding by defining them as public highways connecting the NHS to ports, airports and other intermodal facilities.

The NTS will encompass the transportation components that make important contributions to regional, national, and international interests--economic, security, and safety. The criteria for becoming part of the NTS are not yet defined, but will take assess the contribution that a facility makes to economic, defense, social, and environmental goals at the regional, national, and international levels. The NTS will consider for participation all high-use facilities that carry vehicles, passengers, or freight; facilities that fill gaps within and between existing modal facilities; facilities important for emergency or defense operations; facilities with social benefits; privately owned and operated transportation facilities; and any newly developed mode of transportation.

The NTS will focus, particularly, on intermodal connectors and hubs--facilities that serve as collection and transfer points between modes because it is at these points that the greatest travel delays and transportation inefficiencies occur. The NTS is intended as an analytical tool for planners, other public officials, and private transportation firms across the nation to use in identifying and clearing up such bottlenecks. The congressionally mandated NHS intermodal facility identification process will identify most of these bottlenecks and include them in the NTS. While data on these intermodal connections will be collected from a variety of sources, mode by mode, it is hoped that the NTS will facilitate analysis of the intermodal effectiveness of these connections including airports, train stations, freight terminals, ports, and bus and transit depots.

3. TRANSPORTATION PERFORMANCE: IMPLICATIONS FOR PRODUCTIVITY, EFFICIENCY, AND SERVICE QUALITY

This section examines the determinants of transportation performance and evaluates their application to intermodal policy objectives, by:

- Identifying the components of logistic and transportation performance.
- Relating them to intermodal operations, terminal capacity, and access infrastructure.
- Evaluating the differences among them as applied to goals and strategies to improve intermodal transportation.
- Reviewing a number of interrelated terms such as efficiency, productivity, capacity utilization, service quality, and performance.

The scope of this analysis extends beyond the conventional productivity analysis and covers broader performance issues relating to customer requirements, market share, and service quality. Section 3-1 addresses the relationship between transportation and logistics efficiency as relating to shippers' inventory control requirements; section 3-2 evaluates the dimensions of performance; section 3-3 relates performance criteria to mode choice and evaluates the implications of the shipper perception for mode share and industry profitability.

3.1 TRANSPORTATION AND LOGISTICS EFFICIENCY

Logistics efficiency and transportation efficiency are closely linked; both impact the overall performance of an economy. Transportation is a component of an economy's logistics costs, accounting for more than half of the total outlays. Logistics is essentially about inventories: how much, where they are stored, and how they are moved. Logistics can be defined as:

> *Managing the movement and flow of inbound and outbound materials from the supplier to the warehouse, to the operational departments, and to the customer.*

In 1994, the total investment in the United States in the inventory of all goods- and service-producing industries was $1.179 trillion. The logistics costs involved in transporting, warehousing, carrying inventory, and administering these inventories amounted to $730 billion.[1] Transportation accounted for 57 percent, storage and warehousing for 9 percent, inventory carrying costs for 29 percent, and logistics administration for the remaining 5 percent (see Figure 3-1). These are referred to as "logistics supply chain" costs and include the costs involved in moving and maintaining the inventories of manufacturing, mining, agriculture, and service industries.

The supply-chain relationships governing the logistics of goods movement depend on the interlinked flows of materials as well as information shared between suppliers and buyers at all stages of production and distribution. These relationships cover an array of functions ranging from distribution, materials handling, inventory control, warehousing, and delivery.

Logistics efficiency can be viewed as how well an organization manages the outlays needed to distribute and manage its total output produced. At the national level, the share of logistics in the national production on a time-series basis has been used as an indicator of changes in the nation's logistics efficiency. As a measure of efficiency, the share of the total GDP spent on moving the products or holding them as inactive inventories in storage, indicates how well the supply chain is linked together.

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[1] Data based on *Survey of Current Business* and *U.S. Statistical Abstract*, U.S. Department of Commerce, obtained from Robert V. Delaney, "Is Logistics Productivity At A Crossroad?" presented at Sixth Annual State of Logistics Report, National Press Club, Washington, D.C., June 5, 1995. In addition to the estimate of logistics supply chain, this report also reviews another estimate of total logistics costs, referred to as "physical distribution" costs, which amounted to $660 billion. These costs were based only on the inventory carrying costs of the manufacturing and trade industries and, unlike the latter estimate, exclude mining, agriculture, and service industries. The transportation components for both estimates were identical. The following definitions apply:

Storage/Warehousing - Includes plant warehousing of finished goods, retail stockroom, raw materials, inbound and outbound freight consolidation facilities, and bulk goods storage facilities (e.g. tank farm and grain elevators).

Inventory Carrying Costs - Include interest rate ($40 billion) plus the costs of insurance, loss and damage, shrinkage, depreciation, and obsolescence ($110 billion). Inventory costs are influenced by inventory turnover which is the ratio of the cost of goods sold to the average inventory.

Logistic Administration - Includes order entry/order processing, customer service, sales forecasting, production planning, sourcing/purchasing, inventory management, transportation management functions of the buyer, and logistics management.

Freight Transportation - Includes motor carriers: (public/for hire, private, and local services, $333 billion) railroads ($33 billion) water carriers ($22 billion,) oil pipelines ($10 billion) air carriers ($17 billion) and freight forwarders ($5 billion).

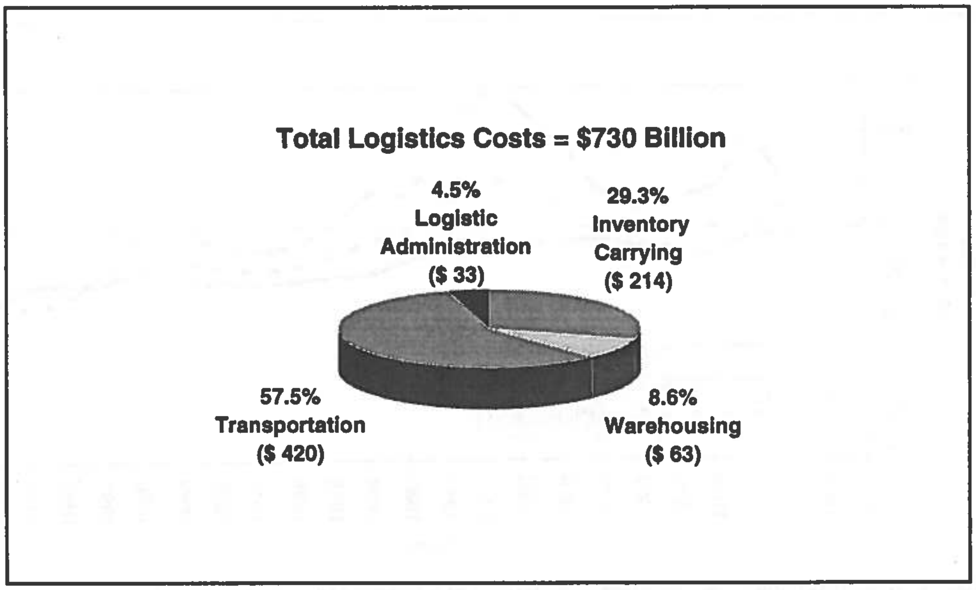
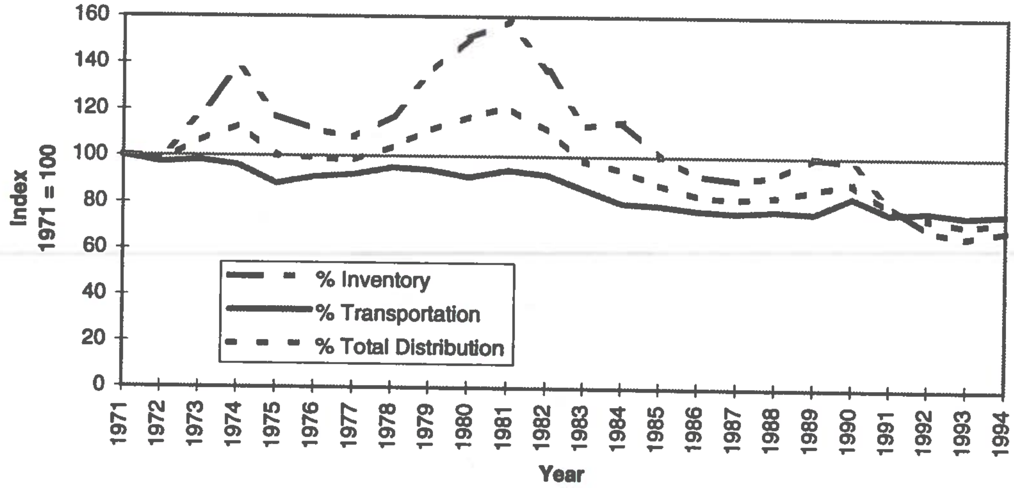


Figure 3-1. Logistics Costs

The share of logistics costs in the GDP in the U.S. has declined from a high of 18 percent in 1981 to 10.8 percent in 1994. Though highly aggregated, the statistics indicate a move in the direction of reduced relative costs of logistics. In 1971, transportation accounted for 8.3 percent of the GDP while in 1994 this percentage had declined to 6.3 percent. Similarly, inventory carrying costs in 1971 were 6 percent of the GDP while in 1994 they were 4 percent. So, as the GDP has grown, our businesses have been spending a steadily declining portion of their revenues on moving inventories or holding them idle (see Figure 3-2).



Source: Robert Delaney, "Is Logistics Productivity at a Crossroad," Sixth Annual Press Conference - Cass Logistics, June 1995.

Figure 3-2. Index of Inventory Carrying, Transportation, and Total Logistics Costs as a Percentage of GDP

Figure 3-3 shows indices created to trace the changes in logistics and transportation costs as a percentage of the GDP between 1971 and 1994. With 1971 as the base, the portion of the national output spent on transportation declined by 24 percent in 1994 (index = 76) and the portion spent on inventory carrying costs declined even more, that is, by 31 percent (index = 69.)

Logistics costs, while declining, still claim a high and visible share of a firm's expenditures, motivating cost cutting and streamlining measures. As firms engage in an array of cost cutting strategies--ranging from total quality control to benchmarking and re-engineering--to improve their bottom line and market share, interest in the quality of management and moving business inventories has mounted.

The view, supported empirically in varying degrees, that transportation is a major obstacle to reducing logistics costs has gained some acceptance. Increasingly, many shippers have begun viewing transportation as a potentially unpredictable component of logistic operations, particularly when international or intermodal movements of goods is involved. Poor transportation performance is often cited as one reason for the declining global competitiveness of the U.S. exporter; the following statement reflects this view:

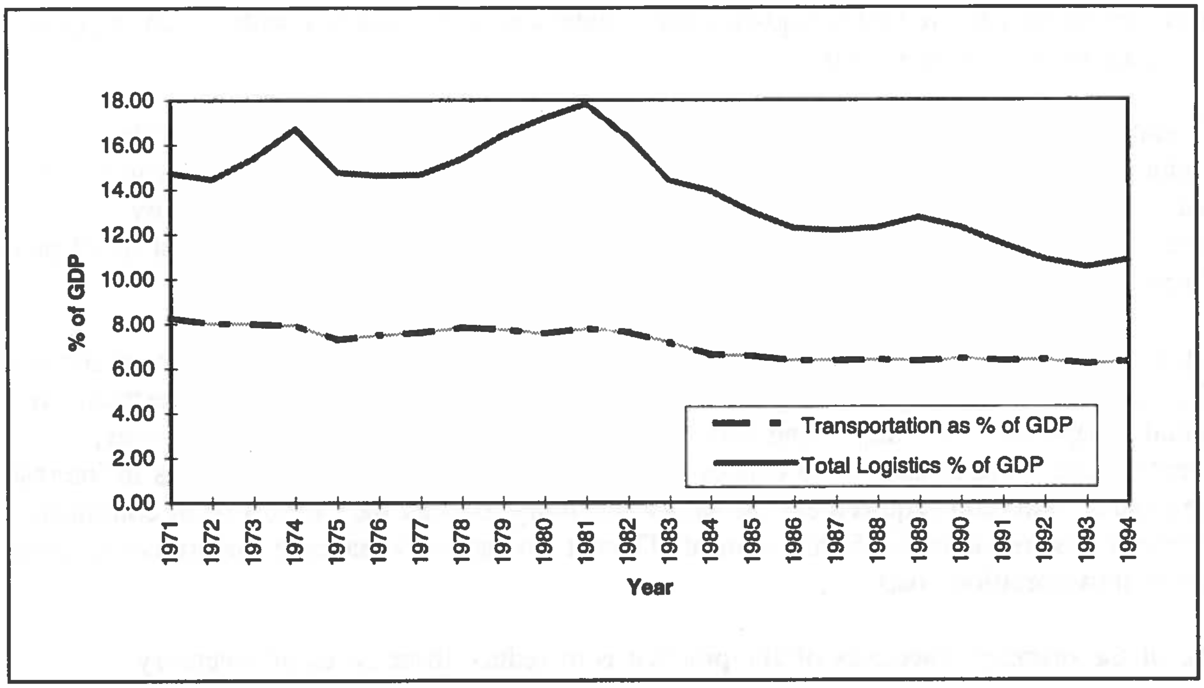


Figure 3-3. Transportation and Total Logistics Costs as a Percent of GDP

> *... managers responsible for structuring and operating a customer-responsive overseas logistic system will have to view transportation as a potential weak link in the chain, and act accordingly. For with a few exceptions, the U.S. international freight transport industry cannot meet the challenge presented by the rapid globalization of the marketplace.*[2]

The sections that follow explore the factors impacting transportation efficiency and identify the extent to which intermodal freight can influence the overall performance of the goods movement system and help meet the challenges posed by the globalization of our economy.

3.1.1 Just-in-Time Inventory Control: Implications for Transportation Efficiency

Transportation is to a large extent intertwined with inventory control and warehousing, reflecting the critical link between the shipper's need to reduce inventories and the transportation carrier's goals of improving operating efficiency. The growing practice of JIT

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[2] Kent N. Gourdin and Richard L. Clark, *Can US Transportation Industries Meet the Global Challenge?* (Charlotte: University of North Carolina), Department of Geography and Earth Sciences, Transportation Publication Report No. 29, 1990.

inventory control for reducing logistics costs underscores the urgency with which shippers are trying to cut logistics costs.

JIT started out as a manufacturing practice centered around eliminating waste in the production process. JIT is applied as a strategy that treats waste elimination not just as a cost cutting technique, but as a corporate strategy that ensures long-term goals by controlling the flow of materials, quality of products, and employee involvement in all phases of production, purchasing, and distribution.[3]

Implementing the JIT principles enables a firm to cut response time to market by as much as 90 percent, thus not only reducing inventory costs, but also cutting back on investment in capital equipment while improving service quality. Beyond a certain level, however, inventory and warehousing costs cannot be reduced much further, as fluctuations in interest rates and a minimum requirement for safety inventory exhaust the savings from continued inventory cost reductions. Exhaustion of JIT cost savings thus makes it imperative to make cuts in transportation costs.

One of the primary objectives of JIT practice is to reduce three types of inventory:

- Safety stock: serves as the buffer
- Cycle stock
- In-transit stock

The widespread practice of JIT-inspired efforts to reduce these stocks, coupled with several other trends in transportation deregulation and changes in types of raw materials used in goods production, has altered a firm's and shipper's requirements:

- Shipments are smaller but higher value.
- Shipments are bulkier but lighter weight.
- Cycle times are shorter.
- Shipments are more likely to be customized.

The implications of JIT practice for transportation have been significant. Service providers have had to respond to new delivery requirements by providing:

- More frequent deliveries
- Faster linehaul speed

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[3] Edward J. Hay, *The Just-in-Time Breakthrough: Implementing the New Manufacturing Basics* (New York: John Wiley and Sons, 1988).

- More reliable schedules and transit times
- Smaller loads

The confluence of the need to minimize stocks and respond more quickly to shipper needs has led to unique constraints for the freight transportation industry as the carrier is required to offer:

- Faster and more reliable modes of transportation in order to respond to the shipper's shorter lead time for replenishing safety stock kept at a minimum level.

- More frequent deliveries to satisfy the shipper's reduction in the average size of the orders to keep cycle stock to a minimum.

- Shorter transit times so that at any given time the waiting period for a load is shorter, keeping the in-transit stock to a minimum.

Figure 3-4 illustrates the logistics constraints on how efficiently goods and inventories are moved, underscoring the challenges faced by shippers as well as carriers. The following section addresses the performance of intermodal freight vis-à-vis the above challenges.

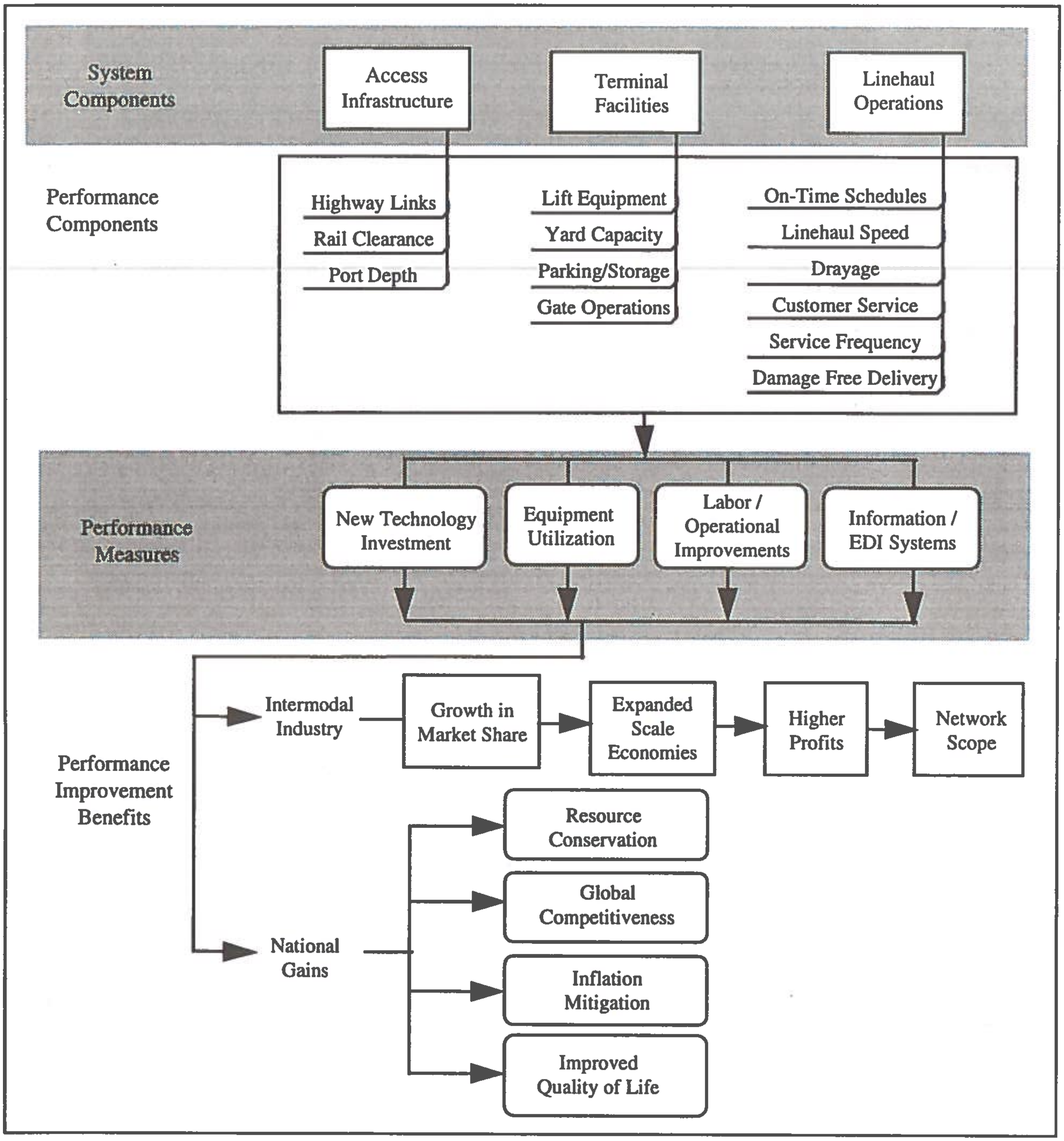

Figure 3-4. Intermodal System Performance

3.2 DIMENSIONS OF PERFORMANCE: PRODUCTIVITY, EFFICIENCY, CAPACITY UTILIZATION, AND SERVICE QUALITY

The terms productivity, efficiency, and performance are often used interchangeably. Further complicating the matter and blurring the distinction between the concepts are new concepts such as service quality, capacity utilization, and re-engineering that have entered the daily business vocabulary when the effectiveness of moving goods or people is evaluated. The following statements about productivity, efficiency, and capacity illustrate this:

> *Some 70% of the nation's rush-hour drivers have to endure stop-and-go conditions at great cost to the economy. In Los Angeles alone, the tab for lost productivity, wasted fuel and polluted air comes to $6 billion a year - or $3 a day per vehicle.*[4]

> *While intermodal services traditionally have been marketed on the price advantage over long-haul trucking, shippers are far more sensitive to service.... carriers will lose customers more quickly than they gain them by delivering goods late. Or in the case of overall quality service, such as protection against damage, carriers have much more to lose than gain by letting their service slip....There isn't much of an up side in advertising that you don't damage cargo...It's like an airline advertising that its planes don't often crash."*[5]

> *Capacity crunch on the nation's rail system can be mitigated by better management of the nation's rail system...We've got to rethink the way we operate.. The only time the customer cares about your internal business is when you are not delivering on your commitments...*[6]

> *The image of rail-carrier efficiency has recently been tarnished as the lines had to contend with ranges of nature ranging from mid-western flooding, which washed out bridges and put hundreds of miles of track under water, to blizzards of epic proportions."*[7]

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[4] Bruce Ingersoll, "Keep it Moving: The problem: traffic gridlock. One solution: congestion pricing," *Wall Street Journal*, January 20, 1993.

[5] Statement by David Yeager at the 1994 Annual TRB Conference, quoted in Robert James "Rails must adjust to avoid becoming victim of intermodalism's success," *Traffic World*, January 24, 1994.

[6] Statement of Kip Hawley, Union Pacific Railroad, in an address at the 1994 TRB Annual Conference, quoted by Rip Watson, "Transport Experts Say Efficiency, Technology Strengthen Intermodal", *Journal of Commerce*, January 18, 1994.

[7] Doug Harper, "Picking Out Best Transport Mode Not an Easy Task," *Journal of Commerce*, June 23, 1994.

This section attempts to sort out the differences in application of the myriad terms to the performance and the impact of specific improvements on operations.

Performance

Performance is defined as the extent to which operations performed by a given mode or transportation system produce the desired results. It is often used as an umbrella term encompassing both quality of service and cost effectiveness of operations. Performance improvement, thus, relies on an array of strategies to reduce costs while providing a higher quality of service.

When assessing the extent to which the operations conform to customer expectations, performance evaluation often focuses on qualitative criteria. When assessing concrete market manifestations of good service, a high level of performance is considered synonymous with efficient service delivery or increased productivity levels.

Implied in the use of the term performance is that in every industry segment there are accepted standards to which service providers should conform, whether quantitative financial performance standards or more qualitative customer satisfaction standards. In general, desired performance can be evaluated by one of two types of measures:

> **Financial performance measures**: These measures include cost, revenue-based, quantitative measures that relate to how well the inputs for a service or production process are utilized and the output delivered; other specific measures include:
>
> - Productivity
> - Efficiency
> - Capacity utilization
> - Profitability
> - Operating ratio
>
> **Quality of service measures**: These measures include demand-related and qualitative criteria associated with how well the final product meets the user expectations, and how important customer perception is in mode choice. The assessment criteria are centered on the premise that while cost-reduction measures have clear benefits for improving a firm's bottom line, intermodal performance ultimately translates to how individual carriers respond to the customer needs. The performance of an intermodal carrier is thus predicated on a fine balance between cost containment and how the carrier is perceived to satisfy the service requirements. The criteria most commonly used for a qualitative assessment of performance include:

- Service quality
- Customer valuation
- ECR (Efficient Customer Response)
- TQM (Total Quality Management)

The sections that follow describe the elements of financial and service measures of performance to enable us to better assess the role of intermodal freight in transportation system efficiency.

3.2.1 Financial Performance Measures

Productivity

Productivity is generally defined as the *ratio of real output produced to the real input consumed* in the process of producing the good or service, where:

- Output is a measure of the amount of work accomplished by an activity (e.g., number of containers loaded and unloaded, tons of freight delivered, and freight ton miles carried).

- Input is a measure of the resources consumed to accomplish the work, (e.g., labor hours used, gallons of fuel consumed, cubic feet of storage used, and acres of terminal) amounting to total cost incurred adjusted for inflation.

In intermodal rail, there are essentially three ways of improving productivity:

- Improvements in resource use (labor, fuel, and supplies) per unit of output.

- Increase in traffic volume and market density, which makes for more intensive use of capital, labor, and material resources.

- Changes in traffic mix toward longer hauls, less resource-intensive movements, or elimination of light density lines.

The first method is the most commonly employed productivity booster, with industry statistics clearly attesting to its success. The other two have been found more difficult to achieve, posing a challenge to an intermodal carrier.[8] Figure 3-5 shows the trends in labor

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[8] Productivity measures can be based on a "total factor" or "partial" productivity indicators. Total factor productivity is measured through an index that relates changes in output to changes in both labor and equipment (including terminal space and information systems). Partial productivity measures, the most commonly used

productivity in the rail industry from 1980 to 1992.

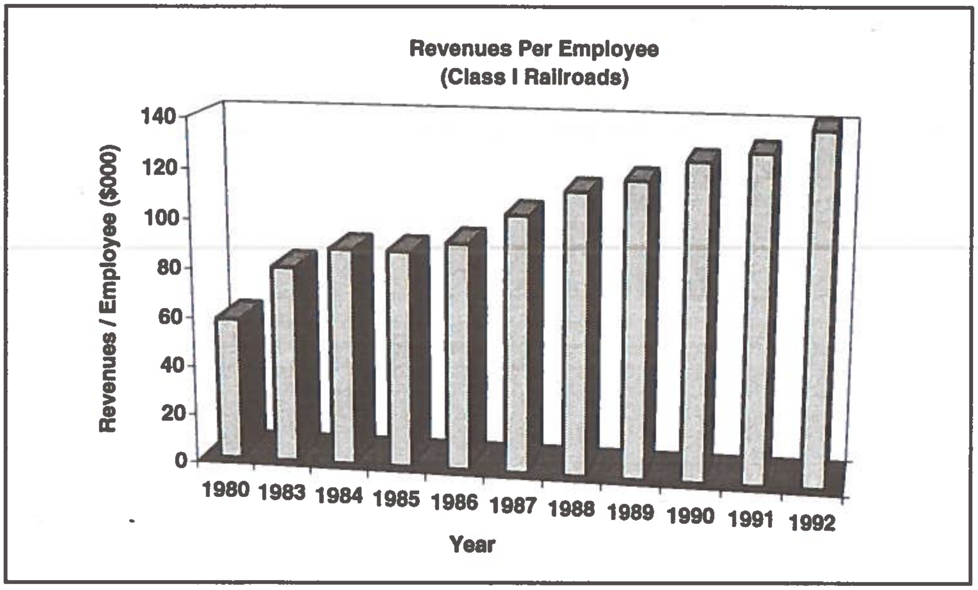

Figure 3-5. Rail Labor Productivity

A productivity measure identifies the change in the process of producing the output in such a way that more output is produced given the input. In this respect, rises in the ratio of output to a given input due to a decline in price of an input do not denote "real productivity" improvements since the output-input relations have not changed. (See the discussion below.)

The only meaningful gains in productivity accrue from a rise in the level of output, given a set of inputs, while holding prices constant. Rising productivity is tantamount to increasing the amount of output generated without a corresponding increase in the amount of resources used. Examples of such productivity increases include increases in terminal throughput per labor-hour, or increases in revenue ton mile per crew member; similarly, an increase in vehicle load due to using the vehicle's carrying capacity more fully.

Improvements in productivity are generally permanent. Any cost reductions that result from increasing throughput, for instance, are permanent improvements that endure regardless of changes in selling price, product mix, volume, or labor cost.

A "real" measure of productivity is estimated by controlling the effect of price fluctuations

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productivity measure, refer to a single factor such as labor or equipment.

when calculating the ratio, and by avoiding misleading accounting tools:

Real Productivity = real output produced/real input consumed,

where real means:

- Value of the output produced or the input consumed, unaffected by changes in inflation, negotiated prices, or by altering the units of measurement.
- Output produced has value and is not merely a reflection of the amount of effort expended without producing market value. Thus, increasing the circuity of a freight route and adding ton miles cannot be used as an indicator of rising output.

Declines in factor prices (e.g., freight rates or minimum crew size) that relate to institutional or regulatory changes such as rate deregulation or reduction in the power of unions, can be indicative of real productivity improvements to the extent that they affect the production process. As such, price declines are due to a more efficient allocation of resources and increased market competition, and are conducive to long-run efficiency gains and productivity improvements. Recent rail downsizing programs and reductions in minimum crew sizes are examples of such productivity improvements.

Surrogate Measures for Productivity

The term productivity is often applied to measurements other than the strict relationship between input and output outlined above. Other measures relating to unit costs, revenues, or market share have often served as a surrogate for an operation's productivity. Also, many "gross" measures of productivity are often used that are misleading since they only give the appearance of reducing costs or raising revenues.[9]

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[9] *Gross Measures of Productivity* improvement are misleading, as productivity can be affected by a number of factors not all of which relate to real productivity gains. Gross measures of productivity include changes in units of measurement or changes in per unit costs, as follows:

- Changes to the basis of measurement - These changes are due to factors not consistently related to performance and may indicate no real improvement
- Changes to per-unit cost paid for resource - These are changes that occur due to a drop in factor prices, including fuel costs, taxes, or labor costs. As indicated above, price declines that alter the production function will impact productivity figures in the long run.

EVALUATION CRITERIA

A key process involved in evaluating how the service provider performs its functions, is by developing a number of *evaluation criteria*. Performance or quality evaluation is thus based on a more or less formal process of:

- Determining the service provider's goals and objectives.
- Identifying the indicators of success or failure.
- Determining whether the operations performed meet the stated objectives.

The process involves establishing a set of *standards* against which performance is evaluated, given the organization's objectives and the indicators for success or failure. These standards can be expressed in one of two ways:

- A *target productivity rate*, used when the work performed is uniform and predictable (e.g., the number of loads per hour per crane).
- A *standard measure* established specifically for individual operations under specified conditions (e.g., 9 hours for the linehaul transit time along a given corridor.) Such standards are often arrived at through the process of benchmarking.

The appraisal of each mode's performance is done through mapping out the processes involved in service delivery and evaluating them against a number of criteria. Performance measures such as delivery time (length of time required for pick up, linehaul, and delivery); cost (linehaul, drayage, and terminal operations); or quality of service (reliability, on-time delivery, or damage free cargo) are used as evaluation criteria for each mode.

Figure 3-7. Evaluation Criteria

INTERMODAL INDEX

The Intermodal Index represents the findings of annual market research sponsored by the Intermodal Association of North America (IANA) and the National Industrial Transportation League (NTL), and is conducted by Mercer Management Consulting.

The 1994 Intermodal Index measured "modal performance" by comparing the customer ratings of intermodal and truck service for the four categories of attributes for shipments moving 500 miles or more. Service criteria have dominated the rankings of the most important factors in carrier and mode selection. Price is often ranked below service quality, equipment availability, and ease of doing business:

Service

- Quality of delivery
- Service reliability
- Low risk of service failure
- Quality of pickup
- Door-to-door transit time
- Low likelihood of damage

Equipment

- Availability
- Quality
- Dimension and size

Price

- Price

Administration/Sales

- Overall ease of doing business
- Freight bill accuracy
- Quality of customer service
- Payment of damage claims
- Information on shipment in transit
- Quality of salespeople
- EDI capability

In 1994, in 15 of the 17 performance indicators in the Index, the shippers rated over-the-road trucks ahead of intermodal carriers. Only in price and EDI capability did the shippers rank the performance of intermodal ahead of trucks.

Figure 3-8. Intermodal Index

Identifying "customer requirement" is the key in distinguishing between poor performance and superior performance. This means that the carrier can provide the lowest cost and fastest delivery, but if it doesn't meet the specific requirements of the customer, the service generates no value. Isao Shintani, the president of the "K" Line America and the leader of the ocean liner's re-engineering effort has been quoted as demanding:

> *Don't specify the design, specify the requirement!*[14]

Focusing on requirements as opposed to specific service attributes such as rapid delivery or low cost are key to a high performance industry or carrier. As Theodore Prince of "K" Line America pointed out, meeting the customer requirements would often mean delivering an array of service levels tailored to the customer's needs:

> *In the future, it may not be necessary for all cargo to move at the same rate as long as it arrives in a reliable stream at the customer's destination.... We may be working with customers to provide varied levels of service. They don't want everything arriving at once and cluttering up their receiving areas.*[15]

Benchmarking and re-engineering are two performance-related concepts that closely relate to identifying customer requirements and devising strategies for performance improvements.[16]

3.3 MODE CHOICE: THE CONVERGENCE OF PERFORMANCE AND PROFITABILITY

Having reviewed the myriad measures of intermodal performance, the report concludes that cost-savings and service quality notions, despite the distinctions drawn between them, converge on a single issue: the customer's decision to use or not to use a particular mode. Mode choice, thus is the ultimate performance indicator and a direct path to profitability and increased market share.

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[14] Robert Mottley, "'K' Line's Intermodal Strategies," *American Shipper*, August 1995.

[15] Theodore Prince, quoted in Robert Mottley.

[16] Benchmarking is defined as the on-going process of searching for industry best practices considered critical to superior performance. It is a commonly used technique by which the supplier compares its products and services to those of its peers and competitors, establishing points of reference for the evaluation process. A set of shared goals is a key element of successful benchmarking, as the practice is often done in alliance with a number of partners.

Re-engineering has become a widely-used practice for evaluating the processes involved in production and delivery. It is built around the idea of reunifying an operation's component tasks into coherent production or service processes and then evaluating every facet of the process to see if it satisfies the customer. Producing a value to a customer is key to the process and is closely related to setting criteria for evaluating performance and efficiency. The process emphasizes "customer satisfaction" as the ultimate criterion for success and the key to increasing market share.

The distinction between the two dimensions of performance deserves special attention. The first is the efficiency/cost-reduction dimension of intermodal service (encompassing productivity, utilization, and other cost control measures); and the second, the service quality dimension (encompassing customer responsiveness). Both sets of measures evaluate how well labor, equipment, public infrastructure, and terminal facilities are employed to produce a high quality freight service. Both dimensions essentially address how resources--input--are employed to produce the desired service or product--output.

The input and output sides of the service delivery process work together as two blades of scissors to satisfy a single market demand. Approaching the issue from the input and production perspective places more emphasis on productivity, efficiency, and capacity utilization. Approaching the issue from the output and service delivery perspective places more emphasis on the overall performance, service quality, and value for the customer.

The distinction between the efficiency and service quality perspectives has been described as the difference between mere *cost reduction* and *effectiveness*, i.e., achieving broader objectives. This distinction is also expressed as the difference between *"doing things right,"* and *"doing the right thing"*:[17]

> *When businesses improve productivity and efficiency, they succeed to "do things right;" when they upgrade service quality, customer satisfaction, and the overall performance, they succeed to "do the right thing."*

Another issue to resolve is that of the commonalities between the two perspectives and the convergence of the two. This convergence occurs when the performance criteria are related to mode choice. Before considering the mode choice issue further, the criterion of efficiency--*To what extent do intermodal freight operations enhance or diminish the overall efficiency and performance of the transportation system*--must be joined to the the threefold analytical framework presented in section 1, that is: access infrastructure, terminal capacity, and modal operations. Linking efficiency with the analytical framework produces a rephrasing of the critical issues of the report:

- To what extent does a shift in intermodal freight operations reduce or increase the costs and quality of providing infrastructure access, operating terminal facilities, and providing linehaul freight service?

- What are the impediments to least-cost, high quality intermodal infrastructure access, terminal operations, and linehaul operations? What are the unmet needs.

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[17] Patrick Byrne and William J. Markham, op. cit.

- What should be the strategies for improving the overall efficiency and performance of intermodal carriers?

Mode Choice: Getting to the Sources of Poor Performance

Finally, mode choice is where the ultimate convergence of efficiency/cost-reduction and service quality components of intermodal performance occurs. In the choice among transportation modes, there are some inherent tradeoffs that involve a choice among three key criteria:

- Speed
- Reliability
- Price

These are essentially the critical performance evaluation criteria that were addressed in section 3-2. Traditional freight service patterns had left the choices unambiguous: if maximization of speed and reliability was the goal, the modes of choice were clearly air cargo or truck; if low price was the goal, rail, marine, and pipeline were the selected modes.

The key-note speech of the chairman and CEO of Santa Fe Pacific Railroad at the '95 Intermodal Expo in Atlanta (in May 1995) went to the roots of poor performance while illustrating the complexity of the concept of efficiency. Robert Krebs pointed out the gap between the efficiency of the intermodal linehaul and terminal interchange operations:

> *Santa Fe can move a box from Los Angeles to Chicago in 48 hours, but it takes 40 hours to get it the next 30 miles....Interline service management shows promise for improving service, but I'm afraid that most railroads won't realize the benefit of that until 1997."*[18]

Krebs' statement underscored a number of key operational, access, and institutional issues that impact the efficiency as well as the quality of intermodal service and ultimately mode choice, including:

- The gap between the highly efficient intermodal linehaul service and inefficient interchange moves.

- Lack of needed investment in transportation infrastructure.

- Inefficient drayage service.

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[18] Jack Burke, "Mood at Intermodal Expo Reflects Slowdown," *Traffic World*, May 15, 1995.

- Lack of cooperation between railroads on interline agreements.
- Continuing perception that intermodal is a standby service.

Poor On-Time Performance

The on-time performance record of an intermodal carrier is often considered a key determinant of how highly a freight customer ranks the service. Anecdotal evidence suggests that in 1994 intermodal service was reported to have on-time performance ratings as low as 66 percent; compared to 95 to 98 percentage ratings for trucking.

Studies on the intermodal industry performance, however, have indicated that there is no intrinsic technological reason for poor intermodal on-time performance. Explanations for poor performance, include:[19]

- Ramp-to-ramp train performance is approximately 80-90 percent of the time. This compares favorably to the trucking performance of roughly 95 percent.
- Most modes do not monitor point-to-point performance closely. Truckload motor carriers have standard transit times measured in days and are often set differently for each customer. Containerships, similarly, evaluate on-time performance according to the day and not the hour. The carriers with relatively tighter standards are airlines which allow a time window of 15 minutes for arrival.
- Railroads use the most stringent criteria, considering even a one minute delay as late. Many trains that arrive late by the tight railroad standards may still arrive within the 1-4 hour windows often allowed for the customers of truck shipments.
- On-time performance varies by length of trip: as trip length increases, variations in scheduled arrival times increase as well. With intermodal service occurring mostly in corridors of more than 1000 miles, allowance should be made for unanticipated delays.

Unreliability

This is often used as the surrogate term in the industry for the industry's poor performance.

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[19] Mercer Management, *Intermodal Service Quality*, report prepared for the Association of American Railroads, January, 1993.

The findings of the Mercer study on intermodal performance[20] point to unreliability as the major avoidable intermodal service problem, as manifested in:

- Line-haul service problems: often due to missed connection.
- Terminal operations delays: affecting inbound or outbound trains, individual units, and draymen, leading to long terminal dwell times.
- Drayage delays: often traced to terminal, over-the-road, and customer problems.
- Management failures: often due to the functions left to third parties and result in coordination problems.

Mercer's study explains the intermodal unreliability as rooted in the following:

- Peaking - This is the major source of unavoidable reliability problems, resulting in severe capacity shortage, and is caused primarily by:
  - The discrete nature of train departures - Train operations are guided by minimum volume requirements, causing traffic peaking, in contrast to the continuous and flexible stream of truckload movements.
  - Bunching of traffic - Daily, weekly, and seasonal bunching of loadings and unloadings that are driven by customers, shipping and logistic preferences lead to severe terminal peaking problems and are often unavoidable.
  - Capacity pressures - These result in equipment and crew shortages, and terminal congestion results in drayage delays, long gate lines, and delays in train loading and unloading.
- Internal and External Fragmentation - This problem is inherent in the industry, which depends on multiple linehaul and drayage carriers, third parties, terminal operators, and equipment owners and lessors. The symptoms of fragmentation are exhibited in the following problems:
  - Poor communication: Barriers to good communication include differing EDI standards and varying interchange agreements. This problem is exacerbated by

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[20] Mercer Management, *Intermodal Service Quality*, prepared for Association of American Railroads, January 1993.

the inherent complexity of the intermodal service.

- Cost/service tradeoffs: While it is understood that higher quality costs less in the long run, short-run tradeoffs are often made between cost reduction and service quality. These tradeoffs are budget-driven rather than guided by the desire to improve performance. Service shortfalls, due to such tradeoffs, often result, paradoxically, in precisely opposite results and lead to thin profit margins.

- Divergent incentives: These are the results of the fragmented, highly centralized, industry structure that rely on incentive systems which benefit a small segment of the industry and undermine the efficiency of the operations as a whole. Practices relating to equipment inspection and maintenance and liability rules for damages are examples of such divergent incentives.

- Diffused control and accountability - Fragmentation of the industry prevents effective door-to-door service to compete with truckload carriers. The decentralized nature of the industry undermines the performance of all intermodal carriers, even those with door-to-door service capability.

In closing, an interesting exchange on the merits of cost-reduction versus quality improvement sums up the issues involved in mode choice, performance, and profitability. The exchange occurred at a panel discussion at the '95 Intermodal Expo in Atlanta in May with Thomas Finkbiner, Vice President-Intermodal, Norfolk Southern. The moderator had put a question to the panel on the best strategy for the intermodal industry for raising profits:

> *Offered a choice of reducing unit costs, increasing volumes, or raising rates to ration capacity as the most important means of improving profitability, Finkbiner exploded, "What about service? Profits will flow from service not vice versa. Without service, all of that other stuff is just managing the deck chairs."*[21]

Improving service quality, customer satisfaction, and the overall carrier performance stimulates demand and enhances market share, and thereby improves profitability. To the extent that the user of intermodal service demands a wide range of performance qualities from the service provider, no single measure that focuses exclusively on costs or quality of service is adequate.

Freight mode choice is further explored in section 4, with further concluding remarks and recommendations in section 6.

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[21] Jack Burke, op. cit.

4. INFRASTRUCTURE AVAILABILITY, ACCESS, AND HIGHWAY CONGESTION

This section centers on the issues of infrastructure availability, access, and highway congestion by presenting the Mid-Atlantic corridor analysis, a focused study of intermodal impact.

4.1 INTRODUCTION

Intermodal goods movement has undergone dramatic growth in recent years. Among the most significant factors affecting this rise are increased domestic and international trade, structural changes in the trucking industry, advances in intermodal technology, and improvements in service. The success of intermodal freight transportation--combined with its perceived ability to achieve a variety of transportation, environmental, and economic development goals--has raised its visibility among policy makers. Symbolic of this recognition was the passage of the Intermodal Surface Transportation Efficiency Act of 1991. For the first time, states and regional planning agencies were mandated to study and develop plans for goods movement, both in the context of identifying facility needs as well as meeting other mandates, such as congestion reduction and Clean Air Act (CAA) compliance. Furthermore, ISTEA permitted the expenditure of some federal highway funds on projects that would improve access to intermodal terminals.

These mandated requirements, combined with the growing importance of intermodal freight movement, in general, have resulted in a need to understand it on several levels. The present and potential impact of intermodal on metropolitan and interstate roadway networks must be determined. The relationship between intermodal service, terminal location, and the surrounding highway network must be appraised and compared to the relative costs of single mode freight movements.

A better understanding of the way intermodal traffic is distributed within terminal catchment areas and estimates of the relative cost difference between an intermodal move and a single mode move will provide a more accurate picture of the impact of intermodal service changes on highway congestion, air quality, and infrastructure improvement. The drayage portion of the intermodal trip is of particular interest since it has the most direct impact on the public road system.

In July 1993, the Volpe Center contracted with A & L Associates to perform a study of intermodal service for a specific freight corridor related to the foregoing factors. The components of the study consisted of:

- Estimating the distribution of intermodal traffic within the terminal catchment areas and assessing the impact on the highway network, both within the terminal regions and along the corridor.
- Identifying and assessing the trade-offs of highway versus intermodal freight movements within the corridor. Through a series of structured interviews and the construction of a model comparing the cost of intermodal service with a similar all-highway move, the primary factors determining the attractiveness of intermodal service were identified. The model allowed a user to examine the boundary conditions between intermodal and highway shipments and to explore the sensitivity of costs to factors such as terminal location, access difficulty, and shipper distribution about the terminal.

The study focused on the corridor along the eastern seaboard between the Mid-Atlantic states and two end-points--Jacksonville, FL, and Atlanta, GA. The Mid-Atlantic region was defined as the 360-kilometer (224 mile) I-95 corridor between northern New Jersey and Washington, DC. Routes to the two southern end-points have high highway traffic volumes, are relatively short in length (950 to 1600 kilometers [600 to 1000 miles]), have competitive rail service, and traverse large metropolitan areas with congestion problems.

4.1.1 Background

Intermodal goods movement has the potential to significantly reduce vehicle miles traveled (VMT) by over-the-road trucks. This reduction is particularly attractive to metropolitan areas suffering from traffic congestion. Large trucks, typified by the "eighteen-wheeler" combination vehicle, accounted for 5.7 percent of VMT on urban interstate highways in 1992.[1] Although this percentage may appear modest, the actual impact on traffic flow and congestion caused by large trucks is disproportionate to their share. For example, a 14-meter (45-foot) tractor-trailer combination has an impact equivalent to 3.8 passenger vehicles on a moderately congested roadway.[2] Furthermore, truck traffic is not broadly distributed over a regional roadway network, but concentrated on specific sections.

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[1] U.S. Department of Transportation, Federal Highway Administration, *1992 Highway Statistics*, p. 207.

[2] Association of American Railroads, *Policy Reporter*, Volume I, No. 6.

Providing intermodal service is more complex than providing single mode service. Multiple parties, including carriers and "third party" marketing agents, are usually involved, and a single source of publicly available traffic data does not exist. At best, information can be pieced together from participating carriers and third parties, who are often reluctant to share their records. The Interstate Commerce Commission's *Rail Waybill Sample* contains detailed information on just the rail portion of an intermodal move, which precludes performing a simple traffic assignment to estimate the equivalent highway routing. Similarly, since most intermodal traffic moves under "freight all kinds" (FAK) billing, specific commodity information is often unavailable.

The ultimate origin and destination of shipments can be estimated, however, from manufacturing employment data by ZIP code (available in the *Census of Manufactures*) as a proxy for traffic generation. Prior goods movement studies have generally found that the level of employment is the best single predictor for goods movement trips.[3] Once these shipment points are determined, intermodal traffic from the *Waybill Sample* can be assigned to a highway network. A & L used a refined version of a model originally developed for estimating the effect of intermodal traffic on VMT in Southern California.[4] 1991 was selected as the baseline year since the most recently available *Waybill Sample* was for 1991.

4.1.2 Findings

For the two study corridors, the VMT "avoided" by intermodal goods movement was significant. With an average distance of 126 kilometers (78 miles) at each end-point, a typical intermodal move generated only 21 percent of the VMT of the equivalent highway move. Not surprisingly, the ratio of drayage VMT to all-truck VMT was highest for the shortest origin-destination pair. In both corridors, intermodal represented 2 to 5 percent of freight volume, not including the considerable additional intermodal traffic traveling beyond corridor end-points. In the urban regions along the corridors, the proportion of intermodal to combination vehicle traffic ranged from 1.9 percent to 8.5 percent.

While the analysis implied that substantial opportunities for intermodal market growth exist in the corridors, this growth will only occur if significant improvements are made in service and capacity. This conclusion was reinforced by results from the Intermodal/Highway Cost

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[3] Ken W. Ogden, *Urban Goods Movement: A Guide to Policy and Planning* (Brookfield, Vermont: Ashgate Publishing Co., 1992). Provide a review of previous goods movement studies.

[4] See Clark Frazier, et. al, "Analysis of Truck Mileage within an MPO: Does Intermodal Goods Movement Make a Difference," *Proceedings of the 1993 Geographic Information Systems for Transportation Symposium*,
pp. 221-232.

Comparison model, which demonstrated that intermodal's competitiveness is marginal in this corridor. In the Atlanta corridor, service times were twice those for motor freight, while in the Jacksonville corridor, service times to intermediate points were even worse. Slow service times at smaller terminals will encourage intermodal shippers to dray longer distances to terminals with better service or to avoid intermodal service altogether. At the same time, the carriers also faced capacity constraints in their yards and on their mainlines. Clearance problems in the Mid-Atlantic region have precluded operation of double-stack trains, a technology considered to have the lowest operating cost and frequently the cheapest method for increasing capacity on single-track mainlines.

Improvements in capacity and service levels are planned in both corridors. Terminals are being expanded in Atlanta and Jacksonville, and by 1995 double-stack trains should begin operating between Kearny and Atlanta via Harrisburg, the route that is also the longest. Thus far, carriers have been reluctant to acquire double-stack clearances on the more direct routes north from Alexandria, due to cost and institutional considerations.

4.1.3 Section Organization

This section is organized as follows:

- Section 4.2 describes the two study corridors.
- Section 4.3 discusses terminal catchment areas and highway routing choices in the corridors.
- Section 4.4 examines terminal location and access issues which impact the relative costs of intermodal versus all-highway movements. (The results from the survey of intermodal participants are included here.)
- Section 4.5 presents the intermodal/highway cost comparison model and some illustrative results.
- Section 4.6 offers conclusions and considerations for further research.

Additional information is contained in the report appendices:

- Appendix A provides more maps and graphs.
- Appendix B provides a technical discussion of the model used for estimating circuity.
- Appendix C provides a discussion of the model approach.

- Appendix D provides a memorandum that details the data sources used in the study.

4.2 STUDY CORRIDORS

The factors most critical to selecting the corridors were these:

- They were interstate.
- They traversed large metropolitan areas with significant congestion problems.
- They were more representative, in distance, of a typical truck trip, rather than intermodal haul.

While intermodal has had the greatest visibility and success in long (1609 kilometers [1,000 miles] plus) corridors such as Chicago to Los Angeles, such traffic represents a small percentage of the highway miles driven by commercial vehicles. Most intercity goods movement occurs over distances of less than 805 kilometers (500 miles).[5] The selected lanes also had to be competitively served by multiple rail carriers, to protect the security of any carrier- or shipper-specific data that would be drawn from the ICC Rail Waybill Sample.

Instead of selecting only one corridor for analysis, two related corridors were selected:

- Mid-Atlantic region to Atlanta, GA
- Mid-Atlantic region to Jacksonville, FL

In many respects, these corridors are similar: they have a common end-point in the northeast, are served by the same carriers (Norfolk Southern and CSXI), are similar in length, and carry similar volumes. In addition, for most of the distance, each defines the other's service territory on one side. In many cases highway routes are also similar, with the highways along the Atlantic coast among the most heavily congested in the United States. Of the 23 metropolitan areas considered to have severe highway congestion in 1989, with Volume Capacity ratios greater than 1.0, four were along the study corridors: New York,

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[5] In 1991, average interstate length of haul ranged from 367 kilometers (228 miles) for truckload carriers to 948 kilometers (589 miles) for less-than-truckload carriers, with a weighted average of 641 kilometers (398 miles) (*Transportation in America*, 1993). A single number for average length of haul for all interstate traffic is not particularly meaningful, due to the distinct market niches served by different types of truck operators.

Philadelphia, and Washington, DC, which were located in the Mid-Atlantic region and Atlanta, which was at the southern end.

Clearance restrictions in the Mid-Atlantic region have prevented operation of double-stack container trains north of Alexandria in both corridors. Trailers dominated the equipment mix, although container usage has grown considerably since 1991. Steamship container traffic was not a significant factor, which was not surprising, considering the proximity of both corridors to the Atlantic coast. Southern ports such as Jacksonville, FL, Savannah, GA, and Charleston, SC, have lower landing costs than the Mid-Atlantic ports and provide a more direct access to southern hinterlands, including Atlanta.

The two corridors are discussed in more detail in Sections 4.2.1 through 4.2.4. Since 1991 waybill data were used in this study, intermodal services that operated in 1991 are described. Some changes that have occurred since 1991 are reviewed in Section 4.2.3.

4.2.1 Mid-Atlantic Region to Atlanta, Georgia

By rail, the distance from Philadelphia to Atlanta is approximately 1,385 kilometers (860 miles). By highway, the distance ranges between 1,350 and 1,420 kilometers (840 and 880 miles) depending on the route selected. In 1991 intermodal volume amounted to 49,892 units, of which 19,400 were southbound and 30,132 were northbound (see Table 4-1). An additional modest volume of 360 IMUs moved locally within North and South Carolina.[6] Not surprisingly, the bulk of the traffic traversed the entire corridor from Atlanta to the Mid-Atlantic region. However, traffic to and from the fast-growing Piedmont region of western North and South Carolina accounted for one-third of the traffic in this corridor.

NS and CSX Intermodal (CSXI) both operated one scheduled daily TOFC/COFC train in each direction with additional sections added when traffic volumes warranted. Both carriers served the Washington region with their own terminals in Alexandria, VA. Further north, CSXI had its own terminals in Baltimore and Philadelphia, and it also interchanged traffic with Conrail at Philadelphia for northern New Jersey destinations. During 1991, the Baltimore terminal was not used for southeastern traffic, and most northern New Jersey/New York traffic was drayed to or from Philadelphia (see Figure 4-1).

Lacking its own line north of Washington, NS had been at a competitive disadvantage vis-á-vis CSXI in providing service to New Jersey and New York. One potential option, using

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[6] All ICC Waybill Sample data shown in this report were aggregated in a manner so as not to reveal any carrier or shipper-specific data. Given that most cities were served by only one carrier, regions large enough to encompass multiple terminals served by multiple carriers were developed. In the case of North and South Carolina, any grouping smaller than the two states combined would have revealed carrier-specific information.

Table 4-1. 1991 Mid-Atlantic - Atlanta Intermodal Traffic Volumes

To:	From: New Jersey/ Pennsylvania	Baltimore/ Alexandria	Carolinas	Atlanta	Total
New Jersey/ Pennsylvania			4,880	10,080	**14,960**
Baltimore/Alexandria			1,360	9,240	**10,600**
Carolinas	880	480	360	4,572	**6,292**
Atlanta	8,880	5,560	3,600		**18,040**
Total	**9,760**	**6,040**	**10,200**	**23,892**	**49,892**

Conrail's trackage rights on the Amtrak-owned Northeast Corridor (NEC) from Alexandria to northern New Jersey, was not feasible because of economic, physical, and institutional barriers. As a result, containers and trailers destined for northern New Jersey were drayed from Alexandria. This situation changed in 1989 when NS and Conrail inaugurated a new service to Kearny, NJ, that completely bypassed the NEC. Named the *Atlanta Flyer*, the train employed a formerly little-used NS branch line from Manassas, VA, to Hagerstown, MD, and then on Conrail to Kearny via Harrisburg and Allentown, PA. Although less direct than the CSX route to Philadelphia, the *Atlanta Flyer* brought the NS railhead to the large northern New Jersey and New York markets. Traffic from Philadelphia and southward still was drayed to Alexandria.

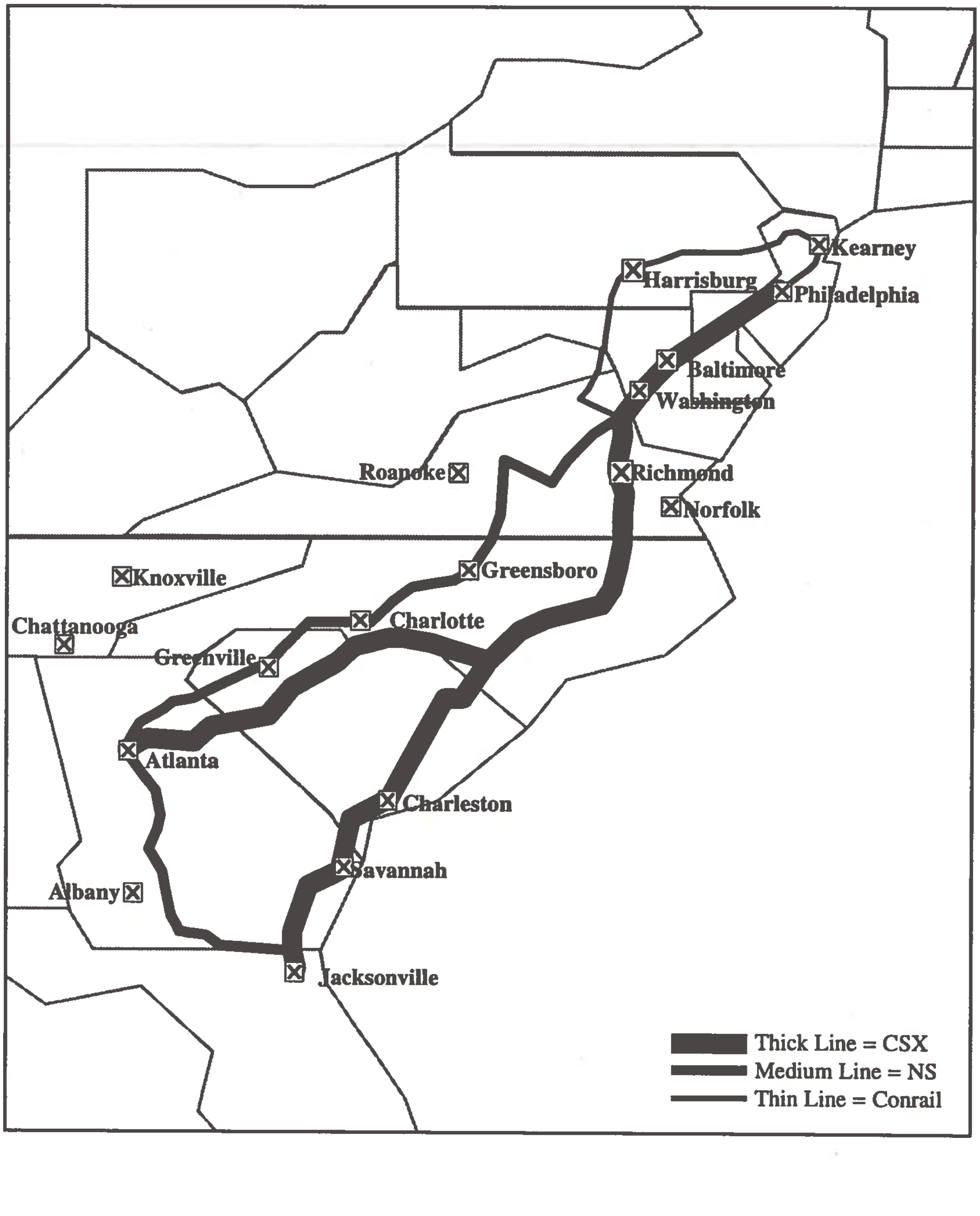

Figure 4-1. Southeast Intermodal Rail Corridors

Service times between Alexandria and Atlanta were similar for both carriers, with published schedules listing availability at destination 29 hours after origin terminal cutoff times. From Philadelphia, CSXI's scheduled availability in Atlanta was 36 hours after cutoff time. Even though NS's route through Harrisburg extended the length of a trip by 160 kilometers (100 miles), the scheduled service time from Kearny was similar.[7]

NS dominated the Piedmont region, operating terminals in Greensboro and Charlotte, NC, and Greenville, SC. CSXI had a terminal in Charlotte, but otherwise did not have significant market presence.

Highway routing options depend on where the traffic originates or terminates in the mid-Atlantic region (see Figure 4-2). From Philadelphia, Baltimore, and Washington, there are three preferred routes, two of which traverse interstate freeways in their entirety, and the third uses US-29 between Washington and Greensboro, NC. Although US-29 is largely a four-lane highway and the distance is shorter by approximately 50 kilometers (30 miles) than either I-70 (or I-66)/I-81 or I-95/I-85, this alternative route is less attractive for overhead truck traffic than it first appears. US-29 is an older divided highway that was not built to interstate highway standards, and it traverses several urban areas with the resultant lower speeds and more difficult driving conditions.

From northern New Jersey an additional route is available. Traffic can travel on I-95 down to Baltimore/Washington, and thence via the Washington-area options described above. Alternatively, traffic can travel west through Harrisburg, PA, on I-78, and then on I-81 south to Fort Chiswell, VA. Depending on the destination (or origin) in Atlanta, several options are available south of Fort Chiswell. Most likely would be I-77 to Charlotte, NC, and I-85 on to Atlanta. Although the Harrisburg route is about 55 kilometers (35 miles) longer than any of the I-95 options through Baltimore/Washington, it bypasses the congested coastal regions. As a result, the route is time-competitive and perhaps more reliable.

4.2.2 Mid-Atlantic Region to Jacksonville, Florida

Unique among major lanes connecting the Mid-Atlantic region with the rest of the nation, the Jacksonville lane had a strong outbound traffic imbalance from the Mid-Atlantic region. The total 1991 IMU count of 50,030 was similar to the Atlanta lane, but southbound IMUs amounted to 28,590 units, while northbound IMUs amounted to 20,440 (see Table 4-2).

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[7] To the shipping public, the schedule is the time when a trailer or container is due at the origin terminal and when it is available for pick-up at the destination terminal. This is in contrast to a train's *operating* schedule, which is shorter by several hours. Some major shippers, such as United Parcel Service, have special arrangements that allow them to deliver trailers up to train departure time and pick them up immediately upon arrival at destination.

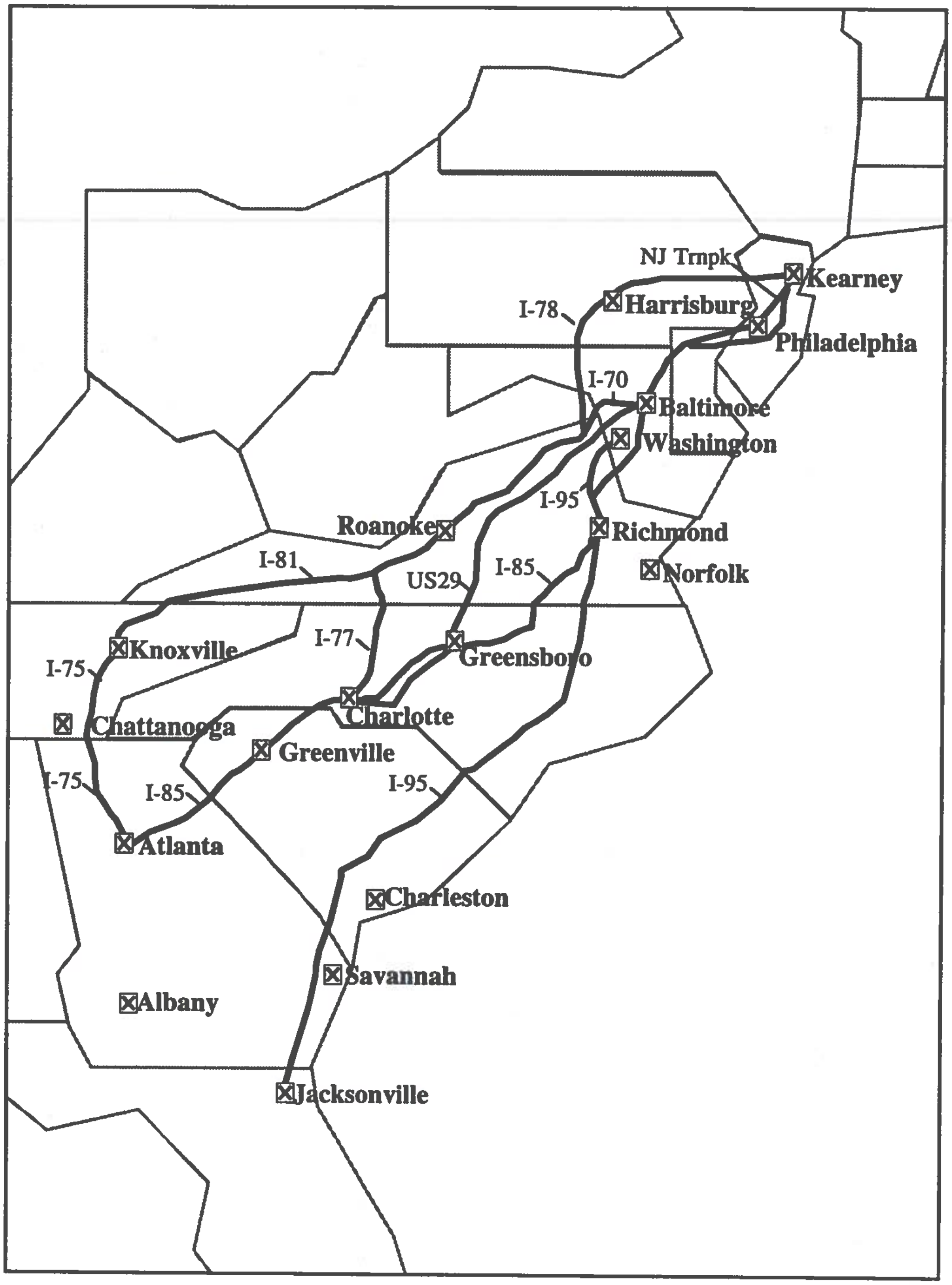

Figure 4-2. Southeast Intermodal Substitute Truck Routes

1,000 IMUs also moved between terminals along the corridor in South Carolina and Georgia. Intermediate volumes were similar to the Atlanta corridor, representing 34 percent of total corridor traffic. From Jacksonville to Philadelphia the driving distance was approximately 1,430 kilometers (890 miles), while the rail distance on CSX was 1,395 kilometers (867 miles).

Table 4-2. 1991 Mid-Atlantic - Jacksonville, Florida Intermodal Traffic Volumes

	From:				
To:	New Jersey/ Pennsylvania	Baltimore/ Alexandria	So. Carolina/ Georgia	Jacksonville	Total
New Jersey/ Pennsylvania		40	1,320	6,120	**7,480**
Baltimore/Alexandria			960	4,920	**5,880**
So. Carolina/Georgia	520	760	1,000	7,080	**9,360**
Jacksonville	10,950	9,960	6,400		**27,310**
Total:	**11,470**	**10,760**	**9,680**	**18,120**	**50,030**

In contrast to the Atlanta lane, where NS was the stronger carrier, CSXI was the dominant carrier in the Jacksonville lane. CSX had a direct route along the coast, while NS used a more circuitous route through Atlanta that was 370 kilometers (230 miles) longer than the CSX 1,190 kilometer (740 mile) route from Alexandria (2,110 kilometers - 1,310 miles from Kearny via Harrisburg). Both carriers operated daily TOFC/COFC trains in both directions. CSXI's service time to Jacksonville from Philadelphia and Kearny was 34 hours, while the service time from Alexandria was 28 hours. Even though Charleston, SC, and Savannah, GA, were both located on the CSX coastal main line, they were served by connections through Atlanta (handled as an adjunct to the considerable east-west volume from the ports). As a result, traffic to these locations required an additional day of travel. NS, which routed its Jacksonville traffic through Atlanta, provided a service time of 49.5 hours from Alexandria and 61.5 hours from Kearny.

I-95 is the preferred highway route for the entire corridor, although efficient alternatives are available in several locations. The largest variation is US-301, which bypasses the Washington metro area and provides a marginally more direct route for traffic originating from or terminating in Baltimore and north. As with US-29 in Virginia, US-301 is an older highway that was not constructed to interstate highway standards. In addition, the Potomac

River is crossed at Dahlgren, VA, on a toll bridge. For traffic destined north of Baltimore, the most efficient route is I-695 across Baltimore Harbor, which is also a toll facility. Selection of US-301 will most likely be determined by the traffic conditions on I-95.

4.2.3 Service Developments Since 1991

The 1993 intermodal service patterns for these corridors were quite similar to those that existed in 1991. Traffic growth in both lanes has exceeded national intermodal growth rates, and both carriers have experienced capacity problems at their terminals. The major change at CSXI was the closure of the Alexandria facility and the shifting of Washington area traffic to Baltimore. In 1991 the Baltimore facility did not handle traffic for the Atlanta and Jacksonville (Florida) corridors.

The 1993 sale of 50 percent of NS's Triple Crown subsidiary to Conrail was expected to bring major changes, particularly in the Atlanta lane. A major element of the sale was a commitment to establish, by 1995, sufficient clearance for domestic double-stacked containers between Atlanta and Alexandria, Harrisburg, and Kearny. The ability to operate double-stack service is more critical than it first appears, particularly in the Harrisburg-Hagerstown-Manassas segment. This former branch line is severely capacity constrained, and track capacity could not be expanded without extensive reconstruction. Double-stack technology permits an effective doubling of train capacity for a given length, while also substantially lowering unit costs when sufficiently high traffic volumes are present. By using double-stack equipment, NS and Triple Crown will be able to more readily accommodate growth in this corridor and pursue opportunities that they would otherwise have to forgo. CSX can handle stacked domestic containers to Alexandria, but clearance problems prevent access to Baltimore from the south.

Triple Crown RoadRailer service was introduced to Harrisburg in 1993, but only from the west. Although RoadRailer's low clearance requirements are attractive for the lanes that were the subject of this study, Greensboro, NC, to Atlanta so far is the only section of the corridor to host RoadRailer service.

4.2.4 Clean Air Act Non-Attainment

As noted earlier, an objective of this study was to identify the VMT effects that intermodal might have on intermediate urban areas along a major corridor. This impact is of particular relevance for regions that are not in compliance with the federal CAA. To this end, all of the non-compliant regions traversed by the study corridors were identified from Environmental Protection Agency (EPA) reports. Table 4-3 summarizes the results. Not surprisingly, much of the heavily developed and congested Mid-Atlantic coastal region, from

New York south to Alexandria, was not in compliance with the CAA requirements for ozone and carbon monoxide, pollutants that are largely created by transportation equipment.

For the Jacksonville corridor, all regions south of Richmond, VA, were compliant with 1991 CAA mandates. The "transitional" designation applied to Jacksonville for ozone indicated that while Jacksonville was in compliance during the 1987-89 period on which the 1991 CAA amendments were based, it did not meet standards for ozone in prior years.

In addition to urban areas in the Mid-Atlantic region, the Atlanta corridor had as many as nine non-attainment areas. All of the large Piedmont cities--Greensboro, NC, Raleigh-Durham, NC, and Charlotte, NC--plus rural Cherokee County on South Carolina's northern border, were non-compliant for ozone. Raleigh-Durham and Charlotte were also non-compliant for carbon monoxide. The bypass route from northern New Jersey and New York by way of Harrisburg, PA, passed through two non-attainment areas, Allentown and Harrisburg.

2. Partitioning the network into intermodal terminal service areas.

3. Allocating terminal traffic.

4. Assigning the traffic to the highway network.

Once the distance, travel time, and truck traffic had been estimated for alternative intermodal and all-highway routes, circuity and various VKT impacts were calculated.

The intermodal VKT within each terminal service area was compared with the alternative all-highway VKT to calculate terminal circuity. Because Federal policy is concerned with more than just the shipment end-points, the impacts of "avoided" truck shipments on intermediate cities along any potential truck route were also examined.

4.3.3 Circuity and Intermodal VKT Calculations

A drayage-to-truck VKT ratio for each terminal pair, using the least-cost cordon point, was calculated and applied to the 1991 traffic volumes. The five substitute truck routes were tested for each intermodal terminal-railroad combination using the same Origin-Destination matrix (the employment-based weights) as the intermodal terminal assignment. The distance-truck traffic product for all the corridor links was summed to obtain an average substitute truck trip length for each intermodal terminal. Substitute trip lengths were calculated for traffic between the ZIP codes served and I-95, I-85, US-29, I-77, and I-81 points on the border of North Carolina and Virginia.

Estimating the relative circuity of intermodal drayage with the equivalent motor carrier movements consisted of three steps, repeated for each terminal serving a region:

1. Dividing the intermodal traffic into *dedicated* and *general* traffic. *Dedicated* traffic has a known origin or destination within the corridor, generally a large shipper or a port. The origin or destination for *general* traffic is unknown and must be assigned.

2. For the *dedicated* traffic - selecting a route in the corridor, based on the ultimate destination, and then generating the corresponding highway distance from that location to the cordon and comparing it with the distance from the intermodal yard to the facility. (For example, a shipment from Jacksonville destined to Kearny, NJ, would cross the cordon line on Route I-95.)

3. For *general* traffic - selecting a route within the corridor, based on the ultimate destination, and then assigning the traffic to the ZIP codes within the terminal service area, based on each ZIP code's share of manufacturing employment. (For example, a

ZIP code responsible for 3 percent of the terminal service area's manufacturing employment would be assigned as the source of 3 percent of the intermodal traffic.[8]) The highway distance from each zone to the intermodal terminal and to the cordon line is then calculated. This is then summed over all the shipments handled by the intermodal terminal.

4.3.4 VKT Impact on Intermediate Non-Attainment Regions

This study focused on estimating the potential impact of intermodal freight on intermediate regions, particularly those not in compliance with CAA mandates. Such regions (the Washington, DC, metropolitan area, for example) have severe congestion problems exacerbated by large truck volumes on certain highway segments.

All Standard Metropolitan Areas (SMAs) that the corridors traverse were specified using county boundaries. Some link traffic volumes were available through the Highway Performance Monitoring System (HPMS). Since HPMS links are not consistently geocoded, substituted end-to-end intermodal truck volumes were manually applied against selected HPMS links. The resulting traffic volumes are estimates as, in most cases, the 1990 HPMS truck volumes are based on "sample" link traffic mixes.

Rural links were selected to determine "base" intercity traffic levels for comparison with intermodal truck diversion trips. Since HPMS commercial vehicle estimates do not explicitly count heavy trucks separately, the percentage of heavy trucks was estimated based on link characteristics.[9] While the VKT of diverted intermodal traffic can be calculated directly once a route is selected, the relative impact of that traffic on all truck traffic was based on the existing levels of truck traffic in the HPMS data.

4.3.5 Results

The results of the analysis are given in Tables 4-4 through 4-7 and in Appendix A. Table 4-4 is a summary of terminal drayage. Table 4-5 summarizes highway distances and truck kilometers avoided by use of intermodal in the corridor in 1991. Table 4-6 shows the effect

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[8] The percentage of employment is calculated for each terminal and the ZIP codes it serves.

[9] The percentage of heavy trucks in the commercial vehicle mix increases in more rural sections where the percentage of commercial vehicles is also larger. Since corridor truck counts are virtually nonexistent, the factors were estimated based on the State of California I-5 truck counts. Observed counts ranged from 60 to 70 percent heavy trucks in the most rural sections to under 20 percent in urban sections. In rural sections, total truck traffic could be as high as 20 percent of the measured flow, with the result that heavy truck traffic can range from 12 to 15 percent of total volumes in rural areas and as low as 1 to 2 percent in urban areas.

The net reduction in highway miles traveled as a result of intermodal service in 1991, shown in Table 4-5, is significant, even with the relatively short corridor length and modest intermodal volumes. Not surprisingly, the ratio of VKT produced by drayage to VKT for the comparable highway move was highest for the closest origin-destination pair and lowest for the most distant origin-destination pair. However, even the shortest-length route from Alexandria to Atlanta produced a reduction in VKT of 72 percent. Intermodal traffic on the longer corridors—Jacksonville to northern New Jersey and Atlanta to Northern New Jersey, for example—produced greater reductions in VKT of 86 percent and 84 percent, respectively.

Table 4-5. Dray - Highway VMT Ratios

	1991 IMU Volume	Corridor Length KM (Mi)	Substitute Highway VKT (VMT)	Average Drayage Distance KM (Mi)		Total Drayage VKT (VMT)	Avoided VKT (VMT)	Reduction in VKT
				North	South			
Alexandria Atlanta	14,800	1,083 (673)	16,023,525 (9,956,537)	148 (92)	156 (97)	4,497,331 (2,794,506)	11,526,195 (7,162,031)	72%
NJ/PA Atlanta	18,960	1,389 (863)	26,321,550 (16,355,420)	64 (40)	156 (97)	4,195,671 (2,607,064)	22,125,878 (13,748,356)	84%
Alexandria Jacksonville	14,880	1,262 (784)	18,773,415 (11,665,236)	148 (92)	146 (91)	4,378,480 (2,720,656)	14,394,935 (8,944,580)	77%
NJ/PA - Jacksonville	17,070	1,532 (952)	26,157,131 (16,253,255)	64 (40)	146 (91)	3,613,202 (2,245,135)	22,543,929 (14,008,120)	86%
TOTAL	48,640		61,118,490 (37,977,193)			13,071,483 (8,122,227)	48,047,006 (29,854,966)	79%

Tables 4-6 and 4-7 compare intermodal rail shipment volume with corridor truck volumes. Rural highway volumes were drawn from HPMS truck counts in the counties adjacent to the cordon line.[12] For the Jacksonville corridor, an IMU volume of 118 trucks per day represented approximately 4.5 percent of all truck traffic in the most rural section of I-95. When adjusted for the significant load imbalance between northbound and southbound freight volumes (assuming excess loads from the north return empty), truck volumes would increase by an additional percentage point, from 118 to 139 per day.

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[12] The HPMS commercial vehicle volumes were converted to truck volumes from commercial vehicle volumes. The commercial vehicle counts were converted to heavy trucks using the factors in "Annual Vehicle-Miles of Travel and Related Data - 1992" table from the Office of Highway Information Management. The peak totals were set to 40 percent and the off-peak to 60 percent, based on Mannheim.

Table 4-6. Cordon Point Truck Traffic

Cordon Highways	Adjusted Daily Truck Counts			Daily IMU's (range)		Distributed	
	Min	Max	Mean			IMU's	percent
Atlanta Corridor							
US 29	233	401	305	0 - 138	0 - 45.24%	6	2.05
I-77	1,553	2,882	2,415	0 - 138	0 - 5.71%	50	2.05
I-81	2,146	3,210	2,678	0 - 138	0 - 5.15%	55	2.05
I-85	1,156	1,438	1,321	0 - 138	0 - 10.44%	27	2.05
Jacksonville Corridor							
I-95	2,539	2,670	2,598	118	4.56%	118	4.56
I-95 (empty backhaul)	2,539	2,670	2,598	139	5.37%	139	5.37

Table 4-7. Selected Metro Area Truck Traffic

Region	Adjusted Daily Truck Counts			Intermodal Traffic (Daily)	
	Min	Max	Mean		
Baltimore I-95	1,650	6,432	4,568	146	3.2%
Richmond I-95	3,979	6,000	4,691	119	2.5%
Richmond (empty backhaul) I-95	3,979	6,000	4,691	148	3.2%
Greensboro I-85	4,093	9,367	7,292	138	1.9%
Charlotte I-77/85	4,908	7,929	6,391	138	2.2%
Cherokee County I-85	2,486	2,757	2,621	138	5.3%
Atlanta I-85	1,272	7,598	4,429	140	3.2%
Jacksonville I-95	1,284	3,450	2,281	151	6.6%
Jacksonville (empty backhaul) I-95	1,284	3,450	2,281	195	8.5%

While these statistics suggest that intermodal only had modest market share in both corridors, it is important to note that the IMU counts with which the highway truck volumes were compared do *not* include the considerable additional intermodal traffic that traveled beyond the corridor end-points. The HPMS truck volumes do include this traffic, with the result that the calculations ***understate*** the actual share of traffic transported by intermodal in the corridors.

In the case of the Atlanta corridor, traffic crossed the cordon line on I-85, I-77, I-81 and US-29. Since the distances on all four routes were similar, the actual route largely depends on a shipper's location within the Atlanta terminal service area and prevalent highway conditions. Even though origin-destination trip data for commercial vehicles were unavailable, the HPMS truck counts do give a sense of route preferences. For example, low truck volumes on US-29, when compared to the IMU count and truck counts on the other three route options, imply that US-29 is not a likely choice for inter-state truckers. If the IMU count is distributed among the four routes based on the HPMS truck counts, intermodal as a percentage of highway traffic would amount to approximately 2 percent. This adjustment is shown in the last column of Table 4-6.

Although intermodal traffic as a proportion of truck traffic in urban areas was found to be generally comparable to that found at the cordon points, the impact was as great or greater in most cases. Noteworthy is the percentage for Jacksonville, where intermodal represented 6.6 percent to 8.5 percent of total traffic. On the Atlanta corridor, intermodal traffic represented over 5 percent of total truck traffic on I-85 in Cherokee County, which was a rural non-attainment area for Ozone.

4.4 INTERMODAL TERMINAL ACCESS

The basic attraction of intermodal service is that it is less expensive to move trailers and containers over a railway than over a highway—primarily because labor, fuel, and equipment costs per box are much lower for a train than for a tractor trailer. This inherent line haul advantage is offset by the cost of moving the box to and from the terminal (drayage) and by the costs of assembling and disassembling the train in the terminal. In recent years, the line haul cost advantages have been increased by widespread adoption of double-stack cars and RoadRailer vehicles. Handling costs at terminals have been reduced by closure of low density hubs, improvements in information systems, terminal mechanization, and better coordination with major shippers. The result has been that intermodal services are now of great strategic importance to railroads, and they are often used by motor carriers for long haul movements.

Although railroads have been quite successful in capturing long-haul intermodal traffic, the many improvements that have taken place have still been insufficient to capture a significant share in medium and shorter-haul markets. The critical reasons for this lack of success have been cost and service issues associated with drayage and terminal location. The following sections take a closer look at these components in an examination of intermodal operations and the impacts of terminal location on intermodal usage. The examination is presented in the context of a survey of intermodal consumers and suppliers in the study corridor.

4.4.1 Intermodal Operations and Service

Service Characteristics

Intermodal service can be characterized as a hub and spoke system with terminals which concentrate loads for rail line haul. Intermodal service can be divided into five parts:

1. Drayage to the intermodal terminal (including pickup).
2 Assembly onto a train.
3. Railroad line haul, which may include interchange across carriers.
4. Unloading the trailer or container from the train at the destination terminal.
5. Drayage to the final destination or consignee.

Each stage of the intermodal shipment has the potential to add some delay. For example, upon arrival at the initial terminal, the shipment is held for the appropriate train schedule. Once en route, if the shipment has to be transferred to a connecting train or interchanged with another carrier, the shipment will be subject to the delays associated with waiting for transfers and connections. At the destination, there are additional opportunities for delay, starting with unloading the shipment from the train, continuing with notification of shipment arrival, and ending with pick-up of the shipment for delivery to the consignee.

Despite the many opportunities for delay on an intermodal trip, railroads have shown they have the ability to provide high-quality service. Martland and Wang examined double stack service across ten corridors and found that while there was some variability in service between carriers, the overall level of service was generally quite good.[13]

Both railroads and shippers have undertaken measures to reduce these delays. Specialized terminal equipment and track configurations can reduce the time, to some extent, required to load or unload a train. Shippers, particularly those who ship high volumes, can influence train schedules and coordinate their pickup and delivery operations with the railroad. Information system improvements are reducing the processing times in terminals.

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[13] Carl D. Martland and Shou-Jeng Wang, *Service Reliability of Double-Stack Container Trains in the United States, Working Paper 93-1*, (Cambridge: AAR Affiliated Laboratory, Center for Transportation Studies, Massachusetts Institute of Technology, February 1993).

Although the line haul portion of intermodal movements frequently occurs at speeds as high or higher than the legal speed limits for trucks, the same is not necessarily the case for drayage operations, discussed further in the following section.

Drayage Operations

The first and last step in an intermodal trip is the transporting of the box to or from the terminal (drayage). Intermodal providers offer a range of services in this regard, but they can be summarized as consisting of three types:

- *Drop and pick*—in which the drayman leaves an empty trailer or container and picks up a loaded one (or vice versa).
- *Waiting for loading and unloading*—in which a single trailer is loaded or unloaded while the drayman waits.
- *Empty front or backhaul movements*—in which the drayman delivers a trailer for loading or unloading and then returns without one, making a second trip at a later time.

In any of these schemes, the driver "drays" the loaded trailer to the intermodal terminal and after paper processing, takes the load to a designated location within the terminal for holding or for transfer to a rail car. At the final terminal, the driver picks up the load from a designated location and after processing, drives it to the consignee. At peak periods, gate queues or terminal congestion can add significant delays.

The most efficient drayage operations reported are those of large shippers who are able to manage their own supply of boxes and organize drop-and-pick drayage operations to avoid waiting for loading and unloading. Each time a load or empty is drayed to a destination, it is exchanged for another box destined for a terminal. Truck drivers may circulate among several railroad terminals in the same region.

Large shippers may gain priority access to trains when they arrive at the intermodal terminal destination and may have agreements with the terminal operators to deliver loads after the cutoff time for ordinary shipments. In other cases where service is less critical, some shippers have negotiated lower priority treatment in return for a lower rate. One result has been that low-volume shippers using third party operators are experiencing greater variations in service levels, depending on the demands of larger customers on a particular day.

Mode Choice Factors

It is interesting to consider precisely what intermodal's target market is. In the past, when intermodal service was extensively co-mingled with other carload traffic, the market consisted primarily of traditional railroad shippers who were or had been using carload services. Indeed, one of the early concerns among rail executives was how to structure intermodal services to avoid cannibalizing the boxcar market. As service improved, the market appeared to shift towards a more specialized set of shippers and business partners. Norris reviewed the intermodal market and found specific examples from the shipper community of domestic distributors, exporters and international traders, and food products manufacturers.[14] What each of these groups has in common is that they are generally large, have a sophisticated understanding of logistics costs, and are service sensitive (defined primarily as "predictable service").

Intermodal service competes directly with over-the-road trucking in price and service. Shippers are generally considered to make their mode choice based on the effect of price and service on their total logistics cost.[15] Recent studies of shipper behavior have suggested that there may be some shippers who are less knowledgeable than others. Vieira showed that shipper perceptions of service may dominate the actual level of service received.[16] Lawrence and Shugart distinguished between sophisticated and unsophisticated customers and suggested that some seek to either minimize price or transit time rather than calculate their total logistics cost.[17] In any case, the relative importance of price and service depends on a number of shipper-specific factors, such as the value of the commodity being shipped, the costs associated with stockouts, and the firm's general approach to inventory management. As more firms have moved to JIT approaches to inventory and production, the importance of service quality and reliability has increased.

For the longest hauls, intermodal can be as fast and as reliable as truck service and less expensive. For the shortest hauls, truck service is generally faster, more reliable, and

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[14] Bahar Norris, *Intermodal Freight: An Industry Overview*, (Washington: U.S.DOT-FHWA Publication PM-42-BBNI, March 1994).

[15] Paul O. Roberts, *Factors Influencing the Demand for Goods Movement*, Report CTS 75-16 (Cambridge: Center for Transportation Studies, Massachusetts Institute of Technology, 1975).

[16] Luiz Vieira, *The Value of Service in Freight Transportation*, Unpublished Ph.D. Dissertation, Department of Civil Engineering, Massachusetts Institute of Technology, 1992.

[17] Lawrence, Martha B. and L. A. Shugart, "Evaluating Marketing Strategies for the Intermodal Firm," *Proceedings of the Thirty-Fifth Annual Meeting*, Transportation Research Forum (Arlington, Virginia: Transportation Research Forum, 1993, pp. 175-192).

cheaper. For intermediate hauls in the range of 800 to 2,400 kilometers (500 to 1,500 miles), intermodal service is generally cheaper, but is also slower and somewhat less reliable. Intermodal service over any distance will be attractive to shippers when the cost savings are enough to offset any disadvantages related to poorer service levels.

Intermodal service is priced on a city pair basis, but the rates by direction may be different. Unlike truck, where opportunities for backhaul are a major determinant of rates, intermodal rates are not as sensitive to the availability of a backhaul. Shippers using integrated truck carriers select the provider and let the provider decide the most efficient and effective modal choices given the price and transit time requirements of the service.

Recent shipper surveys suggest that problems with the use of intermodal service, where it is available, are primarily related to slower transit time, less reliable service, and fragmented responsibility.[18] Kang used a logit model to examine shipper mode choice among New York/New Jersey metropolitan area shippers. He concluded, not surprisingly, that larger companies, which ship longer distances and are cost sensitive, are more likely to choose intermodal over truck.[19]

These observations suggest that intermodal service, in general, will not be selected if it costs more than truck. In some cases, however, imbalanced traffic levels favor intermodal—even though it is more expensive than truck in one direction—if no backhaul is available. Intermodal may also be selected instead of truck if there are driver shortages over some or all of the trip.

There are other factors besides price and transit time that may influence the choice between intermodal and truck. Interviews with intermodal service providers suggested that the qualitative aspects may dominate decisions when truck/intermodal price and service are generally similar. In particular, intermodal may not be used if the terminal is remote from highway access or is located in an unattractive area with perceived security problems, poorly maintained streets, narrow lanes, difficult turns, or indirect routes. Several railroad marketing officials suggested that unless an intermodal terminal is near limited-access highways, use will drop dramatically. Presumably the cost of difficult terminal access,

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[18] Mercer Management Consulting, Inc., *Intermodal Service Quality* (Washington: Association of American Railroads, Intermodal Policy Division, January, 1993); Linda K. Nozick and Edward K. Morlok, "An Operational Model of Intermodal Rail-Truck Service, *Proceedings of the Thirty-Fifth Annual Meeting*, Transportation Research Forum (Arlington, Virginia: Transportation Research Forum, 1993, pp. 149-162).

[19] Kyungwoo Kang "Logit Model of Intermodal Decision in the New York-New Jersey Manufacturing Shippers," *Proceedings of the Thirty-Fifth Annual Meeting*, Transportation Research Forum (Arlington, Virginia: Transportation Research Forum, 1993, pp. 163-173).

bumpy streets, and security problems will show up as higher drayage costs and increased loss and damage claims for intermodal.

4.4.2 Interviews with Intermodal Participants

Detailed information regarding the most important factors in selecting intermodal versus highway haulage was found to be scarce. This is particularly true with drayage; the authors identified only one study that systematically assessed drayage patterns and practices. The presumption of most researchers (and the authors) is that the primary factors are service levels, rates, and total logistics costs.[20] To confirm this and to gain insight into any other factors that might influence mode choice, a cross-section of shippers, third-party intermodal marketing companies, and carriers was interviewed about terminal access and drayage practices.

The specific goal of these interviews was to identify:

1. Range of options available in present-day drayage operations.
2. Concerns about terminal access and the likelihood of their influencing a shipper's selection of intermodal service.
3. Key concerns about intermodal terminals that determine whether or not intermodal service will be used.

Ten participants active in the study corridor--three IMCs; four large shippers; one steamship operator; and two rail carriers, NS and CSX--were contacted by telephone.

Discussions regarding drayage practices were used to define the different drayage scenarios applied to the model described in section 4.5. Pick-up and drop-off practices have become more similar to truck practices, although *drop and pick* still appears to be more common. The use of assigned pools (a group of trailers is assigned to a specific shipper), which allows for efficient drop-and-pick drayage operations, is also more prevalent in intermodal than among the integrated carriers. However, pools can cause substantial inefficiencies in equipment utilization, and equipment owners have been attempting to reduce this practice. Waiting for loading and unloading has the drawback of requiring drivers to wait, incurring a cost that can represent a substantial part of the overall cost of a short dray.

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[20] See previously cited works by Norris, Roberts, and Kang.

Another key element that can have a substantial impact on the economics of intermodal service is how draymen are compensated. Respondents indicated that compensation is usually determined by the type of dray, with different schemes used depending on its length:

- Hourly rates for short haul drays are typical of deliveries in urban regions.
- Distance-based rates for longer-haul drays.

While the former scheme may be provided by company-employed drivers (perhaps with a cartage company or the shipper), the latter most commonly are contracted owner-operators. In some instances, a combination of the two schemes may be used (zone-based system).

There are several factors potentially affecting terminal access:

- Truck access routes to intermodal terminals may follow local streets between designated truck routes and the terminal.
- Conditions such as street paving, width, lighting, and signage may hinder access.
- Time-of-day, turn restrictions, and weight or commodity restrictions may require circuitous routes.
- Direct routes may not be available in all directions, or alternate routes may not be available if major highway or bridge repairs are required.
- Security along surface routes can pose problems and impose additional costs for intermodal service providers.

However, intermodal users suggested that these issues were *not* of great significance in the study corridor, *nor* in their use of intermodal in general. The only corridor-specific issue identified was a situation in Philadelphia, where weight restrictions on alternate routes became a problem when bridge reconstruction closed the primary intermodal terminal access route.

Although security was not a concern for users of the study corridor, it has become an important issue along other corridors for the IMCs and the carriers. In addition to problems with pilferage and break-ins at terminals in locations such as Miami and Los Angeles, truck hijackings have become increasingly common. Security was an area where intermodal has a clearly perceived disadvantage.

4.4.3 Terminal Location and Access

Terminal location and access is a key issue at the boundary between private markets and public policy. Railroads take the view that terminals should be located to best manage their operations and serve their customers. Public policy makers, on the other hand, may be concerned with the management of traffic congestion, noise, air quality, and overall land use. Given the size of the freight market and the important policy issues involved, this difference of perspective has led to some conflicts. This section covers this issue, insofar as terminal location and access affect the relative costs of truck versus intermodal shipments.

The location of intermodal terminals relative to economic activity is a major consideration for a railroad, which must build a large fixed facility with a relatively long service life. The difficulty of assembling enough land in a suitable location acts as a deterrent to the relocation of existing terminals that may be too small or poorly located. Many intermodal terminals are located on existing railroad property, usually a current or former freight yard. Shippers, however, originally located along rail rights of way, are no longer constrained to such locations; they are likely to have relocated to sites close to inter-regional highway interchanges or at those locations best suited for local distribution in the metropolitan area. In addition, the best location for reducing traffic flow and congestion may be quite different from the location of these older intermodal sites. From a highway management perspective, it may be particularly desirable to have several intermodal terminals within a metropolitan region (the case in Los Angeles), so traffic can move to and from the nearest terminal.

The size of the intermodal market, which is related to terminal location, affects service levels. The capacity of the intermodal terminal operation and maximum train frequencies may limit traffic levels. Highway access and operations improvements to terminal access routes may improve the competitiveness of intermodal services.

A final factor shaping the location decision is the market power of very large customers. A number of terminals under consideration or construction are collocated with the facilities of large customers, such as UPS. In general, these sites are good for overall highway access (so the customer can deliver to its customers) and reducing or eliminating significant drayage. However, there may be current or potential customers for whom the new location will not be as attractive.

An intermodal terminal service area is typically rather large and may encompass more than one area of concentrated economic activity. Each terminal must generate enough traffic to justify train operation in one or more corridors. Although most traffic using a terminal is likely to originate or terminate nearby (within a 50-to 80-kilometer radius), some traffic may reach more remote locations in directions which extend beyond the rail corridors served by the terminal. Competing railroads can be expected to have overlapping terminal service areas, but in some cases a railroad may serve different corridors from different terminals located within the same region.

Terminal Location and Drayage Efficiency

A number of implications for the relative costs of truck versus intermodal goods movement depend upon terminal location and consequent access. They are related to the efficiency of drayage to and from the terminal.

If the amount of economic activity in the service area is large and the density of activity close to the terminal is high, most drays will be relatively short. If the terminal cannot be located in the center of the economic activity or if the area is not very dense, drays will be much more expensive. In the northern end of the I-95 corridor at Kearny, NJ, for example, most of the economic activity (as measured by employment) is less than fifty kilometers (thirty miles) from the terminal. Access, however, is restricted by a limited number of routes to and from New York City. The terminals in Atlanta and Jacksonville, on the other hand, are located in smaller and less dense areas, which result in a typical dray of 80 to 160 kilometers (50 to 100 miles).

Another important factor is proximity to major contract shippers and truck distribution centers. In some cases (Worcester, MA, for example), the intermodal terminal is located to minimize the cost of drayage for the United Parcel Service. The cost of drayage is relatively low when loads can be moved between the intermodal yard and a distribution center quickly and there is no need to wait for loading or unloading of trailers.

Integrated truckload carriers can optimize drayage movements and short-haul intercity truck load moves, thereby capturing some or all of the savings in drayage, as proposed by Spasovic and Morlok.[21] The ability to schedule drayage and combine it with truckload moves is more likely to assure a backhaul and would expand the portion of the terminal service area feasible for drayage.

In shorter intermodal corridors, an expensive dray at either end of the trip is likely to result in a price higher than truck. The parts of the catchment areas located between terminals are most subject to this condition. In short corridors, the service area could be expected to be especially small with the bulk of the traffic dominated by a few large customers with nearby facilities. Some longer drays may be expected to occur in directions that extend the corridor (and do not increase the disadvantage of drayage relative to truck) or where the dray at one

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[21] Lazar N. Spasovic and Edward K. Morlok, "Using Marginal Costs to Evaluate Drayage Rates in Rail-Truck Intermodal Service," *Transportation Research Record, 1383*, 1993, pp. 8-16.

end is short, or if the shipment is international. In such short corridors or markets, the quality of terminal access may be crucial to the competitiveness of intermodal transport.

4.5 INTERMODAL/TRUCK COST COMPARISON MODEL

In general terms, long-distance trucking costs are substantially higher than the line haul costs of intermodal service. However, drayage and terminal costs must be added to obtain the total cost of intermodal service. In effect, the break-even distance for intermodal must be long enough for the per-mile line haul savings to cover the added costs for terminals and drayage. To gain better insight into the factors affecting the basic elements of truck/intermodal competition, a spreadsheet model was developed (see Table 4-8). The primary intent of the model was to improve understanding of the boundary conditions between intermodal freight movement and truck movement and to explore their sensitivity to key factors. The factors included in the model reflect the results of interviews with intermodal providers, industry data, and elements of models previously developed by the authors. In addition to the cost analysis, truck and intermodal transit times were estimated for service level comparisons.

The model comprises a series of components that allow the user to specify information on the origin-destination pair and some general parameters. The model focuses on the operational differences between truck and intermodal, so administrative, marketing, and regulatory costs are assumed to be equal across the modes. Sections 4.5.1 to 4.5.3 discuss the truck and intermodal elements of the model; the results of applying it to several cases are presented in section 4.5.4.

4.5.1 Truck Performance Component

The truck performance component calculates the cost per mile for a truck trip based on a number of factors, including:

- Distance, with a distinction made between intercity highway mileage and mileage on local access roads to and from the highway system.
- Labor costs, measured in either cost per mile (as is usual with inter-regional operations) or cost per hour (local operations).
- Fuel costs, based on fuel efficiency in both local and highway mileage.
- Driving speed, over the local and highway network. (These were estimated from speed limits on the selected routes in the Oak Ridge U.S. Highway network.)

- Wait time for loading and unloading at the origin and destination and to meet a requirement that pickup and delivery be made at a time specified by the shipper and consignee. (For example, if the shipper specified that the delivery be made at 1800 hours and the driver arrives at 1400, he must then wait an additional four hours.)

- Backhaul factors, specified as the percentage of trip length that must be travelled to acquire a new load. If the trucker has no backhaul available, the figure would be set at 100 percent; if there is always a backhaul at the same consignee, the figure would be 0 percent. Generally, the figure used was set in the 25-50 percent range.

- Equipment costs, including a charge per day for the tractor and trailer and a per kilometer charge associated with its use. (These figures were obtained from some of the providers and tested for consistency with current purchase costs for new equipment.)

- Utilization factors, which account for the time the trailer typically is held by consignees before loading and after unloading.

These factors were used to determine a set of truck performance measures for a given origin-destination pair. The performance measures include the total cost of the trip, the cost per mile, the loaded trip time, and the cycle time for tractors and for trailers. In addition, costs were derived for various elements such as fuel costs, driver costs, equipment costs for tractors, and trailers.

4.5.2 Intermodal Performance Component

The intermodal performance component represents the sum of the drayage and the rail elements that make up an intermodal service offering. Each is discussed separately.

Drayage Performance

With several notable exceptions, the drayage component is quite similar to that of the truck sub-model discussed in section 4.5.1. Drayage parameters also include terminal access time and operating hours to account for the delays that may be incurred at the intermodal terminal. A peaking factor for gate queues is not explicitly modeled but can be included in the terminal waiting time. The drayage component generates essentially the same performance measures as the truck sub-model; these are then summed in the overall intermodal sub-model.

Rail Performance

The rail component estimates the costs and service level for both the line haul and terminal portions of intermodal movements. The line haul portion calculates costs and service based on a set of per mile costs and average speeds over the rail network. In addition, it determines whether or not trailers connect with the train schedule. If a connection is missed, the shipment is delayed until the next scheduled train departs. In very busy corridors where three or more trains depart daily, missing a scheduled connection may not be a serious problem. In the Mid-Atlantic corridor, service was one scheduled train per day in either direction.

Terminal parameters include lift time (loading and unloading), ordinarily expressed as a minimum cutoff time. Availability of trailer/container storage space is not explicitly modeled; it should be noted, however, that in a congested yard, storage may affect the speed of operations, or in some cases, cause the boxes to be moved to a secondary storage location for later pickup.

4.5.3 Cases Modelled

This section presents the results of applying the model to three illustrative cases from the study corridors. The cases represent examples of all-highway versus intermodal costs and service; they are based on varying geographic locations and the varying pick-up and delivery practices used by different types of intermodal customers. The cases are as follows:

1. **Variations in customer location.** Three scenarios for the location of the shipper/consignee were considered in this case:
   - Near the intermodal terminal on each end of the move. (This should be *most favorable* to intermodal movements.)
   - Away from the intermodal terminals and requiring a reverse move to and from them, the highway distance is less than the rail mileage. (This should be an *unfavorable* situation for intermodal.)
   - Beyond the corridor and, in effect, extending it.
2. **Variations in the type of customer pick-up and delivery.** Three types of drayage were discussed under section 4.4.1 "Drayage Operations." The two most common--*drop and pick* and *waiting for loading and unloading*--were examined with the model.

3. **Changes in terminal efficiency.** One of the most common concerns expressed by interviewees was congestion at terminals. Apart from the obvious impacts on timely pick-up and delivery, terminal congestion can have a very significant effect on the cost of providing intermodal service. Draymen handling short-distance metropolitan deliveries are usually compensated on an hourly basis, so unproductive time spent waiting at terminals can quickly add up to a substantial portion of the overall drayage cost.

Selecting Sample Origin/Destination Pairs

For this analysis, locations within four terminal service areas were selected. In addition to the two southern end points, Jacksonville and Atlanta, the two northern terminals considered were Kearny, NJ, and Alexandria, VA. Kearny represents the longest line haul from Jacksonville and Atlanta, while Alexandria represents the southernmost terminal in the mid-Atlantic region. The difference of 360 km (224 miles) between Kearny and Alexandria permitted exploration of the effects of corridor distance on intermodal economics.

Sample origin and destination ZIPs were selected as follows:

1. The distance from every ZIP centroid in each of the four terminal service areas to the intermodal terminal and to the cordon line was calculated from the least cost (shortest path) routing, based on distance and speed limit.

2. The difference between the distance to the cordon line separating the northern and southern sections of the corridors and the distance to the terminal was calculated.

3. The ZIPs were stratified into ten groups by relative distance from the lowest (the worst circuity) to the highest (the best circuity).

4. Within each group, the highest employment ZIP code was identified.

5. For each terminal service area, three representative highest-employment ZIPs were selected: one with a short dray; a second with a long dray, but low relative distance (backtrack); and a third with a long dray, but a high relative distance (corridor extension).

The ZIP centroids for the efficient dray were selected to approximate the locations of major less-than-truckload (LTL) facilities within each terminal service area. The selection of short dray ZIP centroids for Alexandria required a search for centers of manufacturing employment within 10 miles of the terminal because the closest ZIPs in the initial screening were in Baltimore.

Cost Model Factors

Unit costs typical of actual operations were used in the model, but no attempt was made to calibrate for any specific operation. In the truckload model, the following cost elements were applied to all cases:

Tractor ownership cost:	$40/day
Tractor maintenance cost:	$.124/km ($0.20/mile)
Trailer ownership cost:	$10/day
Fuel cost:	$.21/liter ($0.80/gallon); 3.4 km/liter (8 miles per gallon) on highways and 1.7 km/liter (4 miles/gallon) on local streets
Driver cost:	$.19/km ($0.30/mile)

Calculation of the truck and trailer cycle times was based on assumptions concerning trip distance, average speed, pickup and delivery time, hours/day for driving, detention time at the destination for the trailer, and empty mileage associated with the load. For the study corridor, typical cycle times for the tractor were in the range of 1.5 to 3 days; typical cycle times for the trailers were 4 to 8 days.

Using this model, truck costs were estimated to be in the range of $.52 to $.62 per km ($0.85 to $1.00 per mile) for origin-destination movements in the corridor. These costs are consistent with common perceptions of operating costs for advanced truckload carriers.[22]

The intermodal cost model included sub-models for drayage and the rail line-haul. The rail model included the two most important cost elements and reflects reasonably efficient operations:

Terminal costs:	$25/lift at the original and destination terminals
Line-haul costs:	$.31 per container-km ($0.50 per container-mile)

The drayage model was structured to provide costs consistent with published prices[23] and the experience of shippers and IMCs. It included three cost elements:

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[22] Gerhardt Muller, *Intermodal Freight Transportation*, Second Edition (Westport, Connecticut: Eno Foundation for Transportation, 1990), p. 81.

[23] Linda K. Nozick and Edward Morlok, "An Operational Model of Intermodal Rail-Truck Service," *Proceedings of the Thirty-Fifth Annual Meeting*, Transportation Research Forum (Arlington, Virginia: Transportation Research Forum, 1993), pp. 149-162.

Fixed cost per trip: $40
Operating cost - distance: $1.24/km ($2.00/mile) for local streets; $.62/km ($1/mile) for urban highway; and $.43/km ($0.70/mile) for interstate
Operating cost - time: $20/hour

The cycle time for drayage was based upon the travel time plus terminal time plus pickup/delivery time. An example of an efficient dray would be a 3.2-km (2-mile) round trip movement with a 1-hour cycle time. The predicted cost in this case would be $62. This is equivalent to the lowest price members of the study team had heard quoted for a short dray (although the costs for high-volume rubber interchange conducted on a contract basis can be under $40 per trailer). More typical for a short dray would be a 16-km (10-mile) round trip with a 2-hour cycle time. The predicted drayage price in this case would be $90-$100, depending upon the portion of the move on local streets. This is equivalent to the drayage prices quoted for short-distance movements between a port and a nearby rail yard. Drayage costs rise rapidly with the length of haul and the drayage cycle time. The predicted price for a 320-km (200-mile) round trip dray, with no backhaul and requiring a drayman for an entire 8-hour day, would be approximately $400. If a backhaul were available, the predicted price would drop by almost 50 percent. These prices are also consistent with the rates quoted by various intermodal operators.

4.5.4 Results for the Three Cases

Table 4-8 summarizes results from the model for the three cases outlined in section 4.5.3. The sample origin-destination pairs are listed in the same order under each intermodal terminal pair:

- Short dray
- Long dray with low relative distance
- Long dray with high relative distance

The table is divided into the following two sections:

1. Standard Drayage--represents the traditional drop-and-pick style approach to drayage and considers the three terminal-distance scenarios for the first case outlined in section 4.5.3.

2. Efficient Drayage--represents the performance of typical drayage, as practiced by high-volume carriers (such as the USPS or UPS), with hubs located near the terminals and high utilization of equipment and draymen.

The standard drayage scenarios assume that each load generates a similar length empty dray to account for trailer repositioning, etc. The efficient drayage scenarios assume that draymen handle revenue trailers in both directions.

allowed comparision of total logistics cost between intermodal and lin-haul truck haulage using typical scenarios for the study corridors. The issues involved are complex, and the modest resources that were available for this study prevented examination of these issues in any great detail. Nevertheless, a number of conclusions can be drawn.

While not suprising, the results from the cost model support the generally accepted hypthesis regarding mode choice. In particular, terminal location relative to the actual origin and destination are crucial. There are two primary effects of terminal location. First, the terminal location relative to the existing economic geography determines the drayage distances and the cycle time required for drayage. Since drayage costs rise rapidly with the cycle time, intermodal transportaiton will be most attractive to customers located vry close to the intermodal terminals. In the situations examined, intermodal transportation was always less expensive than truck transportation if the customers were located close to the terminals, thereby minimizing drayage costs. This suggests that terminals should be located near the potential market, that terminals should be located where there is room for major customers to locate their facilities, and that multiple terminals provide better opportunities to customers than a single, centralized terminal.

The second effect of location concerns the direction of the drayage. If the drayage is in the direction of the equivalent truck move, then there is only a modest penalty for using intermodal, reflecting the higher costs of using local rather than an intercity trucker. On the other hand, if it is necessary to back track in order to reach the intermodal terminal, then this adds another penalty because the intermodal trip will be longer than the truck trip. In the cases studies, long drays did not necessarily make intermodal uncompetitive, except in the cases that required backtraking. If it was necessary to backtrack at each end of the trip, then the intermodal option was always more expensive than direct trucking.

It appears that the organization or structure of drayage operations is very important in mode choice. This conclusion is consistent with other studies,[24] and it helps explain why drayage companies and IMC's generally offer several distinct types of services. It also suggests that research into the specific boundary conditions between various drayage types may be useful in predicting intermodal volumes and levels of service within markets. The model constructed as part of this research effort appears capable of estimating the boundary distances.

In addition to the model and results, the research produced some general insights regarding traffic congestion, air quality and terminal security. To a large extent, these factors do not influence intermodal customers, who will use a facility so long as it is cost-effective and

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[24] Lazar N. Spasovic and Edward K. Morlok, *Using Marginal Costs to Evaluate Drayage Rates in Rail-Truck Intermodal Service*, Transportation Research Record, 1383, 1993, pp. 8-16.

physically accessible. Security within the intermodal terminal is important, but the quality of the access is not critical, except as it affects the previously mentioned cost of drayage. Traffic congestion and congestion within the terminal is relevant to customers, since these factors both affect the cycle time required for drayage.

Although air quality does not enter into mode choice decisions, it is a major concern for public agencies. Intermodal operations can reduce truck travel within air quality districts. The results of this report suggest that the customers most likely to use intermodal are those located close to the terminals; for these trips, only a short truck move is required, and the air quality benefits are clearly maximized by using intermodal. The other group of customers who might use intermodal are those with long drays in the direction of the truck move. In general, these moves require a dray within the air quality district, as opposed to a truck move through the district, so air quality benefits may again be positive.

From a public policy perspective, it is therefore important to promote the location of intermodal terminals at several key locations throughout each metropolitan area. This will provide the maximum potential for reducing traffic congestion and enhancing air quality. Locating terminals so they are readily accessible by large trucks will also minimize disruption to other traffic, reduce drayage cycle times, and reduce the breakeven distance for intermodal movements.

Beyond the issues of drayage and terminal location, several other issues that were not examined in this project are equally critical in influencing the prospect for expanding market share in shorter length corridors. These issues are:

- *Service Times*. When service times are double those for motor freight, as was the case in the Atlantic corridor, intermodal's disadvantage in trip times is a major deterrent to expanded useage. This problem is not only directly related to the trip time, but also train frequency. In many markets, frequencies are limited to one or two trains per day, which can result in a day-long delay if the origin cutt-off time is missed.

- *Railroad Plant Capacity*. Recent growth in rail traffic has effectively soaked up most surplus mainline and yard capacity throughout much of the industry. As a result, markets where the potential for intermodal service has been successfully demonstrated, have been left with insufficient capacity and, in some cases, a reduction in service. In the Atlantic corridor, 1993 traffic levels prevented the addition of more intermodal trains, even though trains were being operated at capacity. Even with substantial improvements in plant capacity, the proportion of truck-competitive freight volumes that could be shifted to rail may remain modest. Taking the Atlanta corridor again as an example, a doubling of intermodal volume would still only produce a market share of perhaps 5 to 10 percent of total intercity freight moving between the Mid-Atlantic region and Atlanta. A research initiative into what, if any, role government should play in enhancing railroad plant capacity should be considered.

- *Asset Management*. Beyond the integrated truck-load and parcel carriers, more than 50 percent of intermodal traffic is still managed by IMCs. In most cases, the IMCs only market and coordinate services, and do not bear any financial risk in managing the trailers and containers that are necessary to transport the fright. According to a recent Mercer Management study, intermodal trailers and containers are idle seventy percent of the time, a utilization rate that remains considerably below that for truckload carriers. Equipment costs, which form a significant component of overall costs for long-haul services, form a proportionally greater component for shorter hauls. Thus, equipment management practices that may be marginally economical for long-haul traffic are even less economical in short-haul corridors. Although methods for effective asset management are well known within the motor carrier industry, it appears that any effective solutions will require significant changes in the structure of the intermodal industry, including the IMC's roles.

5. INTERMODAL CAPACITY

Section 4 focuses on the role of infrastructure access and terminal location within the framework of a transportation corridor. Section 5 addresses similar issues from the perspective of terminal operations and location within the system. From this perspective, section 5 addresses a number of critical performance issues relating to terminal capacity, terminal access, terminal location, and an inventory of terminal best practices. This section underscores the unique role of the terminal in the viability of intermodal operations.

Terminal access issues fall into four categories:

- Terminal location and impact on capacity
- Railroad access limitations
- Highway access and drayage performance
- Operational access constraints

Any or all of these factors can *increase* door-to-door intermodal transportation costs or door-to-door transit times, or *decrease* door-to-door reliability. The emphasis on "door-to-door" is intentional and important. Terminal access issues primarily affect the links between:

- Shipper and origin terminal
- Destination terminal and consignee

While railroads establish rates and schedules for ramp-to-ramp line haul service, door-to-door rates vary by exact location and door-to-door schedules are not published. Despite the critical importance of door-to-door performance to intermodal customers, such performance—and the impact of terminal access issues—goes largely unmeasured and unrecorded.

The task of analyzing and assessing terminal capacity and access issues must, therefore, be approached through discussion of principles, examples, modeling, and the limited amount of data available. This section draws on all of these approaches, including use of the prototype terminal model developed as part of this study.

5.1 TERMINAL LOCATION AND IMPACT ON CAPACITY

5.1.1 Terminal Access Critical for Container Ports

While geographic location and the size of local markets continue to be prime drivers of vessel itineraries and hence cargo volumes, intermodal rail access is gaining importance in the routing of discretionary land-bridge cargo and in the choice between competing ports in the same region.

The relative locations of rail and marine intermodal terminals affect intermodal costs, port-area traffic conditions, and the competitive positions of ports. Other things being equal, on-dock container transfers are preferred to near-dock terminals, which in turn are preferred to distant off-dock terminals. The closer the terminal the less the drayage cost, and on-dock terminals eliminate gate costs in addition to replacing commercial drayage with in-terminal hostling. Yet shortage of marine terminal space, poor rail access, or problematic port configurations can make on-dock transfers impractical. There is a need for further investigation of near-dock approaches, including dedicated drayage access, electronic gates, and other potential innovations.

"On-dock" container transfer refers to transfer between marine and rail modes within the marine terminal or port. Its key distinguishing *feature* is that a commercial dray is *not* required. The key *advantages* of on-dock transfer are as follows:

- No separate drayage function exists and, therefore, no separate drayage charge. (This savings may be offset by internal transfer charges assessed by marine terminal operators or ports.)
- Gate functions and delays are eliminated at *both* marine and rail terminals.
- No need exists to provide a street-legal road chassis since containers are transferred with marine terminal equipment or yard chassis.
- Cargo security is increased by keeping containers off public streets. (This improvement can be offset when slow rail transit on port access routes makes containers vulnerable on the rail cars.)
- Ocean carriers perceive themselves to have greater control over container movements when the transfer takes place within the main terminal environment.
- An on-dock facility can be established with minimal fixed costs by borrowing lift equipment and personnel from the marine terminal.

- The burden on nearby rail terminals is reduced. (This is important where rapid growth of international container traffic may have strained rail terminal capacity.)
- Separate parking space is usually unnecessary because all parking, stacking, and storage takes place in the marine terminal.
- An on-dock facility may be accessible to multiple railroads, in some circumstances.

On-dock transfer also has some potential *disadvantages*:

- Marine terminal space is in short supply in many ports.
- The operation of on-dock terminals can raise serious labor jurisdiction disputes, and unionized longshore labor is generally considered to be more costly than rail union or teamster labor in off-dock alternatives.
- On-dock terminals are sometimes designed with short, stub-ended tracks to fit into tight spaces. (This entails extra switching.)
- Crowded marine terminals can no longer use rail terminals as staging or buffer storage for outbound containers that arrive well ahead of vessel loading.
- It may require lift equipment while the marine terminal is still handling the vessel. (This negates the ability to "borrow" lift equipment.)
- It may be suitable for only one ocean carrier/railroad combination at each port. (This surrenders long-term flexibility.)

At present, the following North American ports are known to have on-dock transfer capability of some kind:

New York-New Jersey
Seattle
Portland
St. Johns, New Brunswick
Long Beach
Los Angeles
San Francisco
Vancouver
Halifax
Montreal
Tacoma
Baltimore

No North American port regularly offers direct ship-to-rail container transfer without using marine terminal equipment as an intermediary. A few European ports do have such capability.

On-dock transfer is *not* practical at every port for the following reasons:

- Some ocean carriers do not tender sufficient rail intermodal volumes to justify a transfer facility.
- Some ports have marine terminals divided by waterways or non-terminal land uses that hinder transfer development and rail access.
- Some ocean carriers' terminals are not accessible to their chosen railroad.
- All ports have constraints on total marine terminal space. When ocean carriers want terminals of 100 acres or more to handle wheeled operations, conflicting demands are placed on the available space.

A review of the *advantages* of on-dock transfer suggests that most are contingent on institutional relationships--chiefly the ability to do without commercial drayage--rather than on its presence in the main terminal or distance per se. It may therefore be possible to obtain some of the *benefits* of on-dock transfer and avoid some of its potential *drawbacks* by establishing a "near-dock" transfer with some of the same institutional features.

One possibility is the creation of dedicated drayage lanes or roads that allow marine terminal personnel to transfer containers to a nearby rail facility without involving commercial drayage. Some ports (Oakland, San Francisco) have created corridors for overweight containers, a concept that might logically be extended to all marine/rail transfers. The South Intermodal Terminal at Tacoma is essentially a rail transfer facility connected to the marine terminal by a short, dedicated drayage road.

Electronic technologies such as Automatic Equipment Identification (AEI) may streamline gate procedures for near-dock facilities to the point where efficient commercial drayage is cost-competitive with internal marine terminal transfer charges. Such a development could approach the cost advantages of on-dock transfer, but would not yield the other benefits. Off-dock rail intermodal terminals serving ports have the same fundamental access issues as domestic inland terminals.

5.1.2 Domestic Terminal Location

The location of a domestic intermodal terminal determines the geographic market area that can be efficiently served. Generally speaking, drayage services can reach about 250 miles from a rail hub (the longest distance over which a round trip is possible in a 10-hour driving day). This does not guarantee, however, that intermodal service will be competitive for all traffic within a 250-mile radius.

The location of domestic terminals relative to potential customers can decisively affect geographic market access, especially in short-haul lanes. Intermodal carriers can be excluded from markets requiring long drays or drays "against the grain" because drayage is such a large part of door-to-door intermodal cost. Drayage costs become more prominent as line haul costs decline in short-haul corridors, foreclosing intermodal competition where terminal locations produce significant circuitry.

Comparisons of truck and intermodal costs over distance typically assume (albeit implicitly) that the two modes travel the same distance to serve the same customers. This is rarely the case, and the difference between intermodal and truck distances can range from trivial to decisive. Figure 5-1 demonstrates the potential impact of terminal location on the intermodal/truck distance disparity. The figure suggests that the variation can occur on the origin dray, on the line haul, or on the destination dray. In virtually every case, the intermodal distance is greater:

- The *smallest* variation occurs when drayage movements are aligned with the line haul direction, sometimes referred to as drayage "with the grain."
- The *largest* variation occurs when drayage movements are opposite the line haul direction, "against the grain."
- Most real patterns lie somewhere between the preceding extremes.

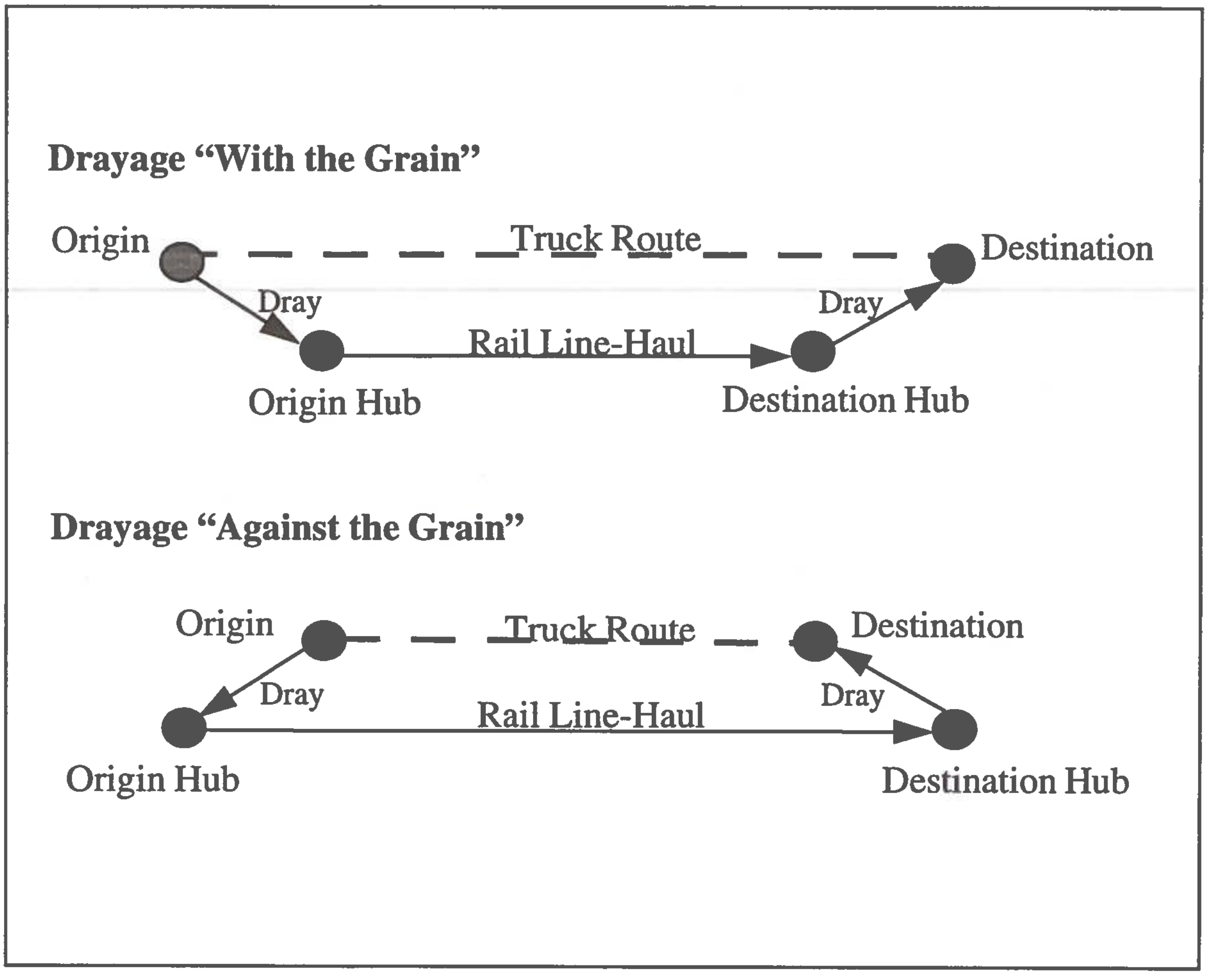


Figure 5-1. Drayage "With the Grain" and "Against the Grain"

5.1.3 Hub System Development

The reduction of over 2000 rail intermodal facilities into 200-300 mechanized hubs was a critical step in the development of modern truck-competitive intermodal service. By concentrating sufficient volume, such hubs justified both mechanization and frequent, dedicated train schedules. The presence of the hub system, in turn, made possible the introduction of mini- and micro-land bridge services and their maturation into the present double-stack network.

At one time, there were perhaps 2100 piggyback ramps in the U.S.; most of these were low-volume facilities adapted from local team tracks or freight stations. Until the introduction of mechanical lift equipment in the early 1960s, all were "circus ramps" (driving trailers on and off the ends of flatcars resembled the loading and unloading of circus wagons). While this proliferation of small and sometimes makeshift facilities provided tremendous geographic coverage in intermodal's formative years, loading methods were primitive and costly; low volumes also led to slow and infrequent service. Such a network could not have supported the efficient expansion of international container traffic for two related reasons:

- Without lift equipment, containers had to be moved on chassis--negating the advantages of COFC and making double-stacks impossible.
- Low-volume ramps could not economically support a chassis pool.

There are still some major cities (Indianapolis and Cincinnati) where the lack of chassis pools leads ocean carriers to move their containers routinely on chassis--TOFC rather than COFC.

Figure 5-2 shows the approximate potential geographic coverage of current intermodal hubs, using a 250-mile radius. This figure makes it clear that intermodal would have difficulty competing in some substantial geographic regions.

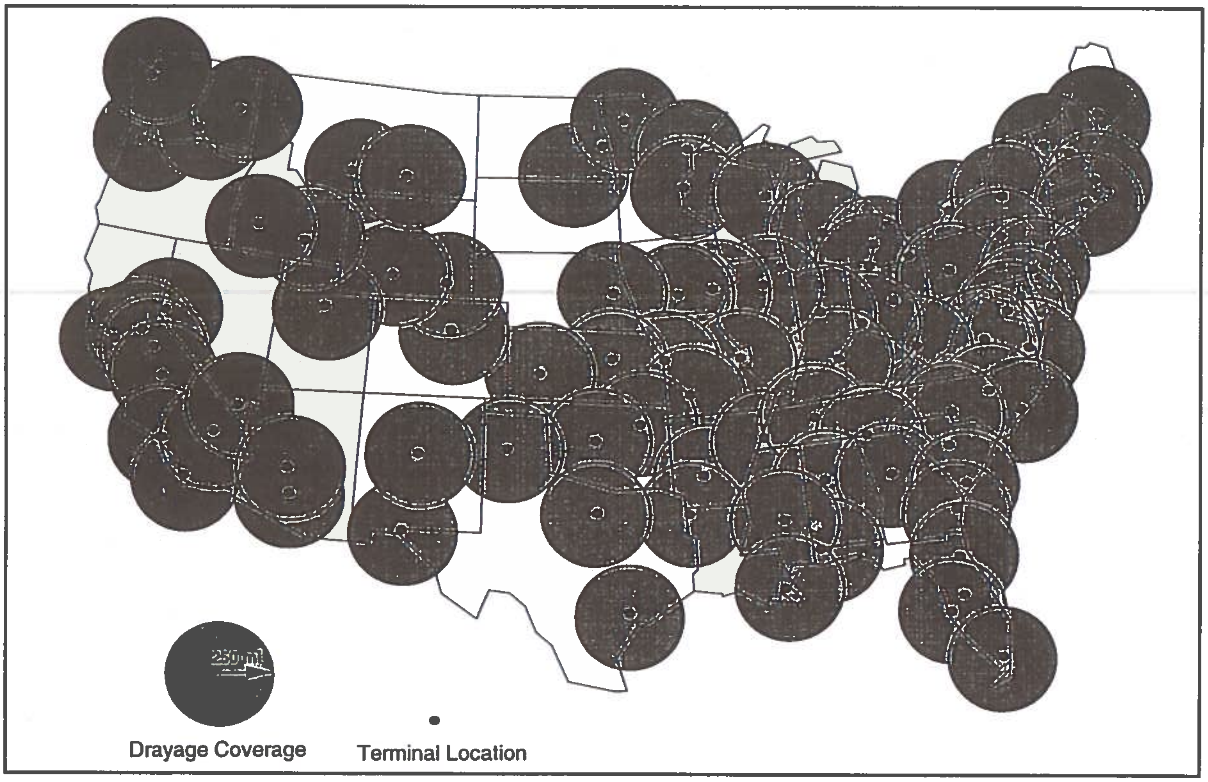


Figure 5-2. Geographic Coverage - 250 Mile Reach

The hub system is made possible by efficient drayage. As Figure 5-3 shows, geographic coverage would shrink if drayage were 50 percent slower or costlier (giving a 125 mile-reach instead of a 250-mile reach). The figure illustrates dramatically the symbiotic relationship between drayage efficiency, terminal location, geographic coverage, and terminal access. Terminal access limitations impair drayage efficiency, and either reduce geographic coverage or multiply the facilities required to cover the same geography.

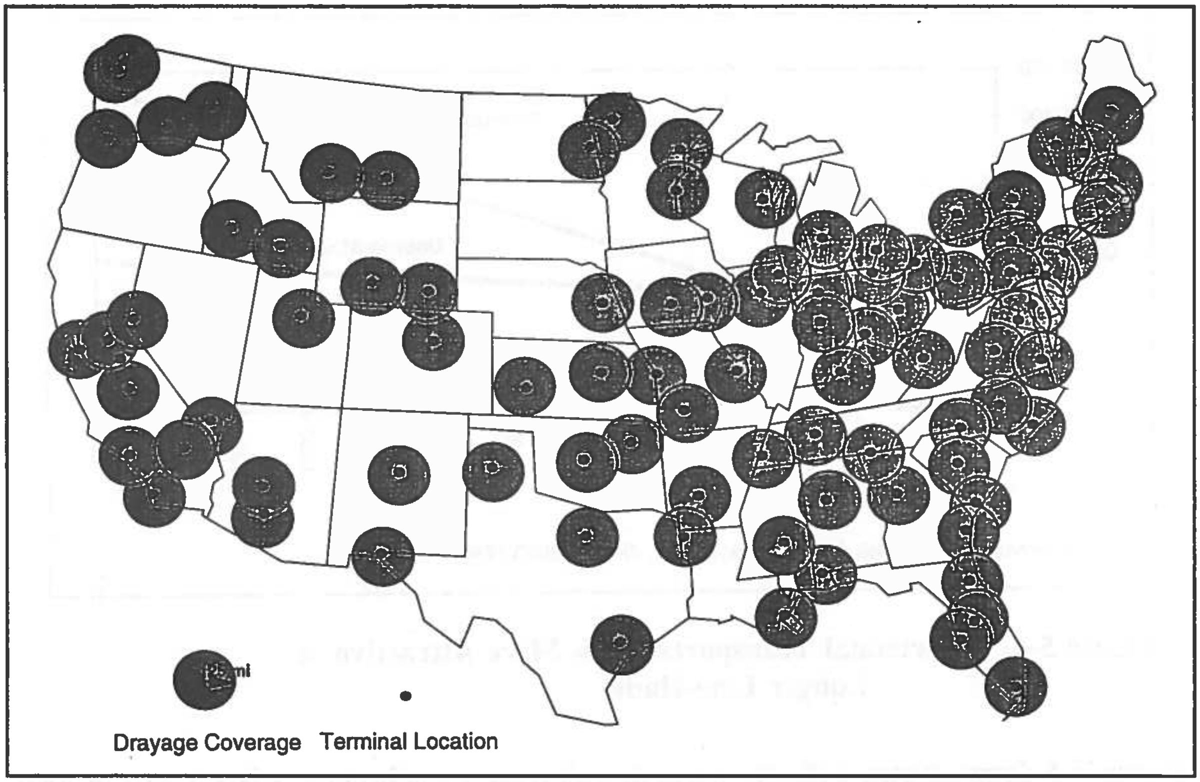
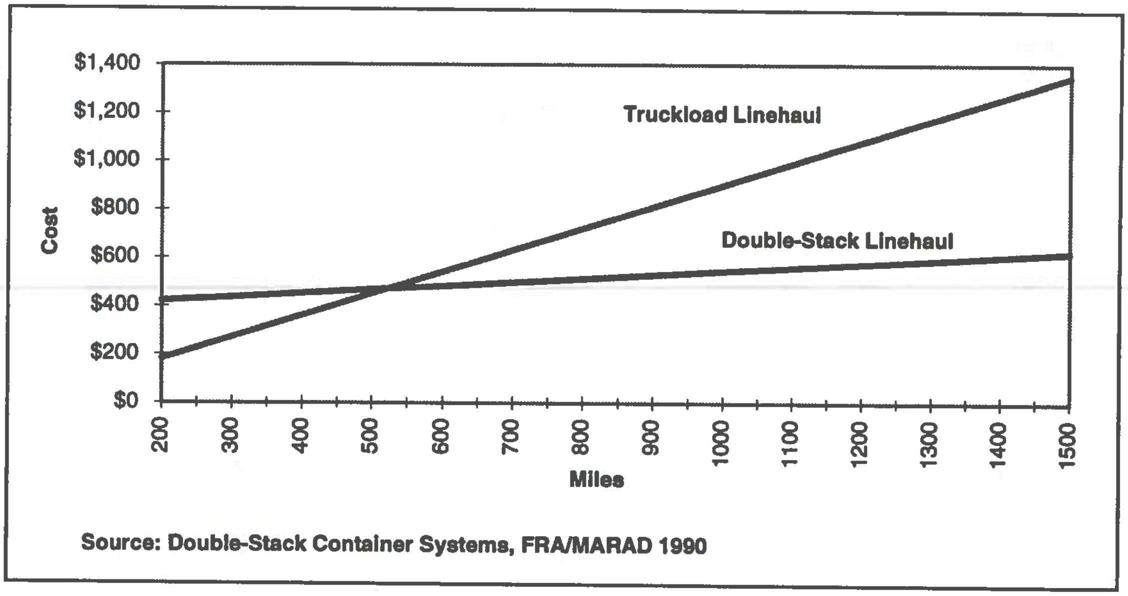


Figure 5-3. Geographic Coverage - 125 Mile Reach

5.1.4 Short-haul Market Competition

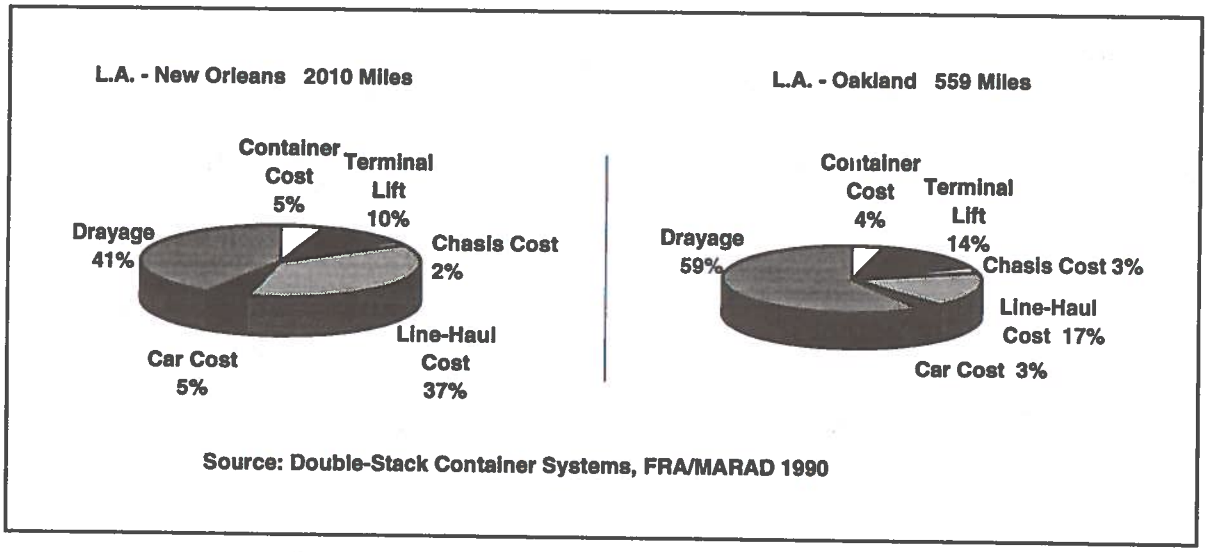
The commercial competitiveness of intermodal transportation is premised on the line haul advantages of rail over truck. As the length of haul *increases*, the line haul economics become move important, and intermodal transportation becomes more attractive relative to over-the-road trucking (see Figure 5-4). Conversely, as the length of haul *decreases*, it becomes harder for intermodal carriers to deliver either the economics or the service required to compete with trucks.



Source: Double-Stack Container Systems, FRA/MARAD 1990

Figure 5-4. Intermodal Transportation is More Attractive at Longer Line-Hauls

As Figure 5-5 demonstrates with two examples, drayage costs become a larger part of total costs as line-haul distance *decreases*. The influence that terminal access has on drayage cost gains in importance as well. Figure 5-6 shows that the same relationship holds for transit time in long and short hauls.



Source: Double-Stack Container Systems, FRA/MARAD 1990

Figure 5-5. Drayage Cost Share is Higher on Shorter Hauls

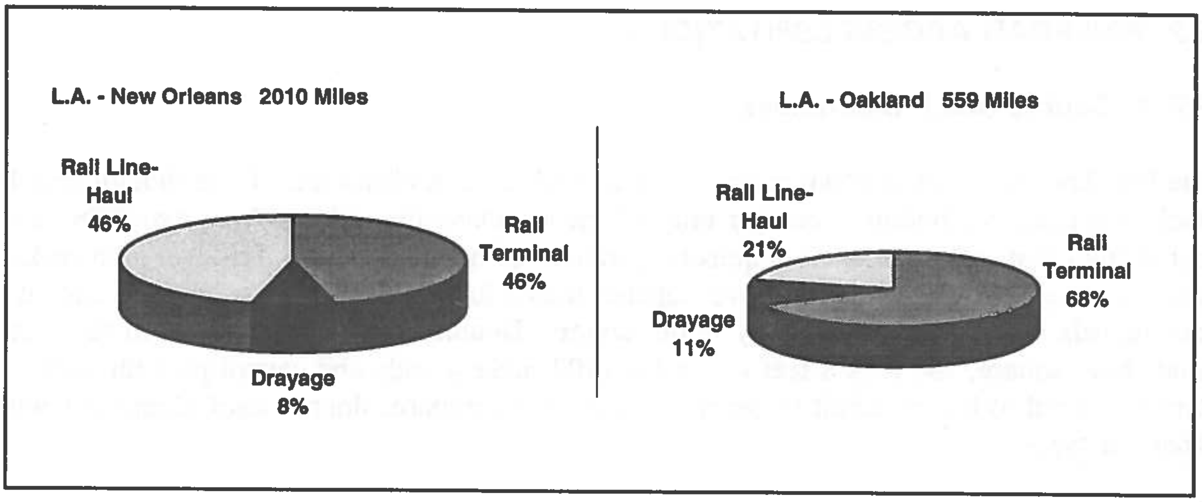
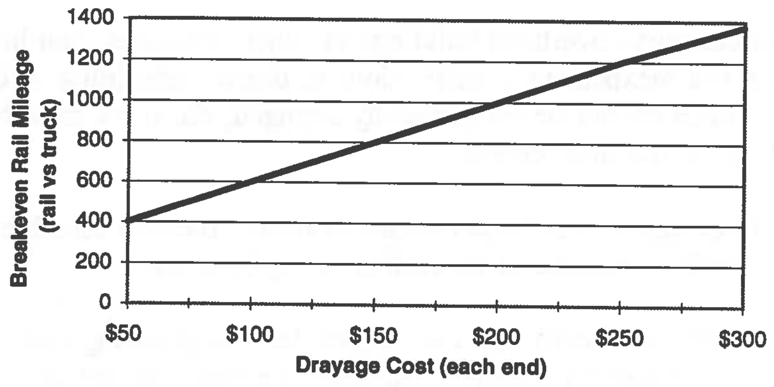


Figure 5-6. Drayage and Terminal Time are More Important on Shorter Hauls

These considerations suggest that the influence of terminal access on drayage costs is a determining factor in the ability of intermodal carriers to bring favorable economics to short-haul markets. Figure 5-7 makes this point explicitly: as drayage costs rise due to slow or circuitous terminal access, the break-even line-haul distance rises as well.



Source: Relationship from Double-Stack Container Systems, FRA/MARAD 1990

Figure 5-7. Breakeven Mileage for Double-Stacks as a Function of Drayage Cost

5.2 RAILROAD ACCESS LIMITATIONS

5.2.1 Double-Stack Clearances

The best known rail intermodal access issue is double-stack clearance. Even though double stack cars place the bottom container only 10 inches above the rail, stacking two 9 feet six inches high domestic containers requires clearances of nearly 20 feet. Tri-level auto racks (the previous clearance problem) have tapered tops allowing them to pass through curved roof tunnels with full clearance only in the center. Double-stacked containers, on the other hand, have square, flat tops 8 feet six inches (102 inches) wide and cannot pass through tunnels altered to barely admit tri-levels. Figure 5-8 compares double-stack clearances with other car types.

Clearance restrictions can include categories besides tunnels, such as:

- Overhead signal bridges, conduit, pipes, or walkways
- Station canopies or other structures impinging on side clearances
- Overhead buildings or other substantial structures
- Interior restrictions on truss bridges
- Overhead rail or highway bridges

The first two categories are relatively easily corrected--many involve railroad-owned or line-side equipment/stations that can often be altered inexpensively or demolished.

Correcting the third category, overhead buildings or other structures, can involve solutions ranging from simple and inexpensive modifications to drastic rebuilding or demolition. When overhead structures cannot be economically changed, the track must be lowered--often an expensive and time-consuming process.

Correcting the fourth category, restricted clearances from structural members on truss or other type bridges, involves substantial rebuilding or replacement.

Correcting the last category is costly and can require lengthy planning and implementation periods. Overhead rail or highway bridges can rarely be removed and options for mitigating the problem include:

- Raising the bridge and its approaches.
- Replacing the bridge with a type that gives greater clearances.
- Lowering the track.

Historically, railroads have maintained standard minimum clearances on each route, raising clearances only when the advent of new equipment and new traffic justified the expense. These occasions could be decades apart: such efforts were undertaken when dome cars were added to passenger trains in the late 1940's and again when tri-levels were introduced in the 1960's. As a result of these periodic efforts, a rail route may have multiple overhead clearances at the previous minimum and thus, multiple obstacles to the new requirements.

Clearance restrictions force railroads to do the following:

- Use circuitous routings.
- Restrict service to conventional flat cars or spine cars.
- Unload containers and dray them past clearance restrictions.
- Remove the upper rows of containers, sending double-stack cars through at half capacity.

All these practices increase costs and hurt service quality. Their impact must be weighed against the cost of clearance improvements. The crucial factors are the volume of traffic affected and its potential profitability. The decision is frequently portrayed as a "chicken and egg" problem:

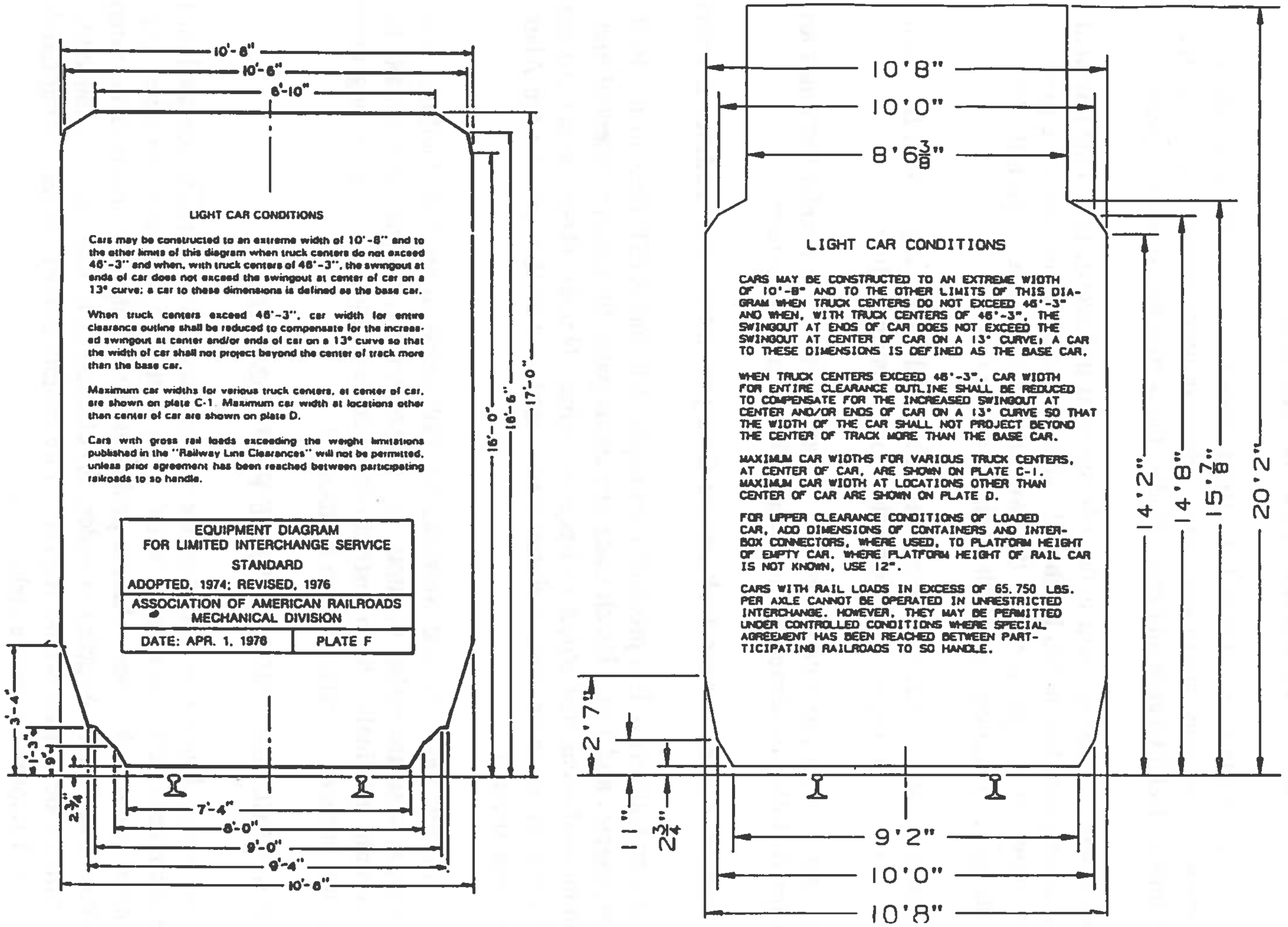
- If there were more--and more profitable--traffic, clearance improvements would be justified.
- If there were clearance improvements, traffic volume would grow and profitability would increase.

Railroads will invest in clearance improvements and resolve the dilemma, in situations where:

- Railroad market studies (formal or informal) demonstrate the traffic potential.
- Public sector resources can tip the scales in favor of improvements.
- Customers are willing to sign contracts or otherwise commit long-term traffic volumes and revenues.

Union Pacific's double-stack clearance improvements in the Feather River Canyon were supported by Union Pacific (the railroad), American President (the customer), and the Port of Oakland (the public sector). Ironically, the Budd LoPac 2000 cars used in the first double-stack trains were developed as low-clearance cars to bring piggyback trailers through eastern U.S. tunnels.

When rail access conditions limit the use of efficient equipment, hamper reliable train operations, or introduce switching costs and delays, intermodal competitiveness declines. Some of the these problems may be the legacy of intermodal as a secondary rail service and terminal priority, but they must be mitigated for intermodal to attain its full potential.



LIGHT CAR CONDITIONS

Cars may be constructed to an extreme width of 10'-8" and to the other limits of this diagram when truck centers do not exceed 46'-3" and when, with truck centers of 46'-3", the swingout at ends of car does not exceed the swingout at center of car on a 13° curve; a car to these dimensions is defined as the base car.

When truck centers exceed 46'-3", car width for entire clearance outline shall be reduced to compensate for the increased swingout at center and/or ends of car on a 13° curve so that the width of car shall not project beyond the center of track more than the base car.

Maximum car widths for various truck centers, at center of car, are shown on plate C-1. Maximum car width at locations other than center of car are shown on plate D.

Cars with gross rail loads exceeding the weight limitations published in the "Railway Line Clearances" will not be permitted, unless prior agreement has been reached between participating railroads to so handle.

EQUIPMENT DIAGRAM FOR LIMITED INTERCHANGE SERVICE STANDARD	
ADOPTED, 1974; REVISED, 1976	
ASSOCIATION OF AMERICAN RAILROADS MECHANICAL DIVISION	
DATE: APR. 1, 1976	PLATE F

LIGHT CAR CONDITIONS

CARS MAY BE CONSTRUCTED TO AN EXTREME WIDTH OF 10'-8" AND TO THE OTHER LIMITS OF THIS DIAGRAM WHEN TRUCK CENTERS DO NOT EXCEED 46'-3" AND WHEN, WITH TRUCK CENTERS OF 46'-3", THE SWINGOUT AT ENDS OF CAR DOES NOT EXCEED THE SWINGOUT AT CENTER OF CAR ON A 13° CURVE; A CAR TO THESE DIMENSIONS IS DEFINED AS THE BASE CAR.

WHEN TRUCK CENTERS EXCEED 46'-3", CAR WIDTH FOR ENTIRE CLEARANCE OUTLINE SHALL BE REDUCED TO COMPENSATE FOR THE INCREASED SWINGOUT AT CENTER AND/OR ENDS OF CAR ON A 13° CURVE SO THAT THE WIDTH OF THE CAR SHALL NOT PROJECT BEYOND THE CENTER OF TRACK MORE THAN THE BASE CAR.

MAXIMUM CAR WIDTHS FOR VARIOUS TRUCK CENTERS, AT CENTER OF CAR, ARE SHOWN ON PLATE C-1. MAXIMUM CAR WIDTH AT LOCATIONS OTHER THAN CENTER OF CAR ARE SHOWN ON PLATE D.

FOR UPPER CLEARANCE CONDITIONS OF LOADED CAR, ADD DIMENSIONS OF CONTAINERS AND INTERBOX CONNECTORS, WHERE USED, TO PLATFORM HEIGHT OF EMPTY CAR. WHERE PLATFORM HEIGHT OF RAIL CAR IS NOT KNOWN, USE 12".

CARS WITH RAIL LOADS IN EXCESS OF 65,750 LBS. PER AXLE CANNOT BE OPERATED IN UNRESTRICTED INTERCHANGE. HOWEVER, THEY MAY BE PERMITTED UNDER CONTROLLED CONDITIONS WHERE SPECIAL AGREEMENT HAS BEEN REACHED BETWEEN PARTICIPATING RAILROADS TO SO HANDLE.

Figure 5-8. Double Stack Car Clearance Diagrams

5.2.2 Access Configurations and Mainline Connections

The ideal rail intermodal terminal would have short, direct access to mainline trackage without interference from non-intermodal trains. Because many intermodal terminals were adapted from former freight yards and team tracks, the actual access varies greatly.

- One dramatic case in point is the BN terminal in Cicero, IL. This terminal is effectively divided in two by the BN mainline, which also hosts frequent commuter trains. As a result, the two halves cannot exchange rail cars, containers, or trailers for much of the working day.

- In another case, Conrail has three facilities south of Chicago--47th St., 51st St., and 63rd St.--arranged along both sides of a busy mainline.

Less dramatic, but perhaps more common, are instances where intermodal terminals are isolated from the mainline or served by awkward, circuitous connections.

In some port regions, access to near-dock and on-dock port intermodal facilities is restricted.

- Southern California is a prominent example: UP and ATSF lines to the Ports of Los Angeles and Long Beach trace circuitous paths thorough residential and commercial areas that object to frequent trains. Neighborhood objections have affected access to on-dock facilities and contributed to the need for the Alameda Corridor project.

- In San Francisco, CA, and Newark, NJ, rail access to on-dock facilities is by street trackage and either disrupts, or is disrupted by, drayage movements to and from main terminals. Such restrictions limit the frequency of switching moves and the number of cars that can be handled.

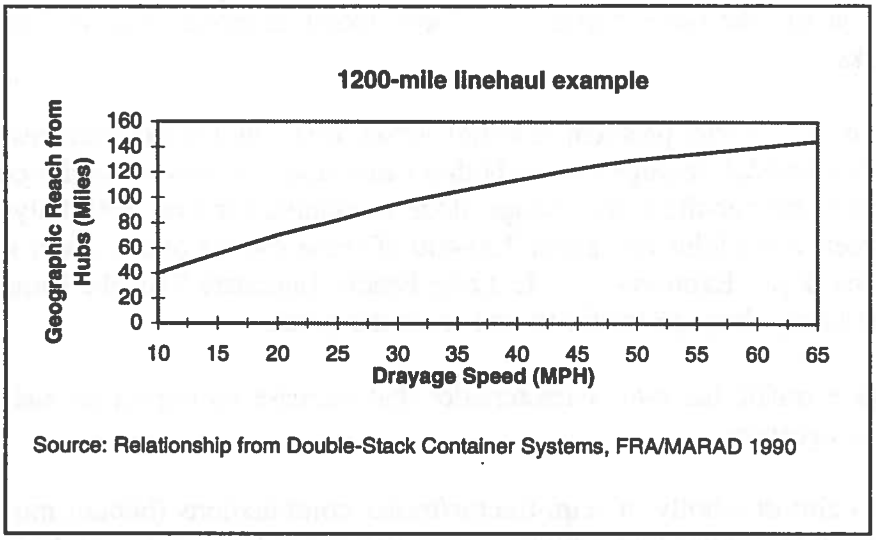
5.3 HIGHWAY ACCESS AND DRAYAGE PERFORMANCE

Highway or road access limitations can increase drayage time alone (traffic congestion) or both time and distance (circuitous access routes). In either case, drayage cost rises and intermodal competitiveness declines. Access problems can be highly idiosyncratic, ranging from traffic congestion in Los Angeles to underpass clearances in Chicago. A thorough assessment of nationwide impact would require a city-by-city survey; order-of-magnitude estimates would still require extensive field work.

Effective drayage speed affects door-to-door competitiveness. Drayage cost is primarily a function of time. Mercer's drayage study for the AAR[1] estimated the following cost function for drayage:

$25 per load + $.35 per mile + $20.59 per hour

With a cost function so dependent on time, average speed determines the distance over which drayage can be provided at a given competitive cost. From another perspective, a one-hour delay in accessing a terminal reduces the two-way competitive distance by a one-hour drive: perhaps 50 miles on open highway or 30 miles on urban roads and freeways. Figure 5-9 shows graphically that as average drayage speed drops, the geographic area that can be competitively covered from each terminal shrinks.



Source: Relationship from Double-Stack Container Systems, FRA/MARAD 1990

Figure 5-9. Drayage Speed and Geographic Reach

There are three reasons why average drayage speed may be restricted:

1. *Poor road, street, or highway conditions limiting safe speeds.* An example might be Doremus Avenue, which runs between the Port of Newark (Elizabeth marine terminal complex) and the CR (Kearny) and CP (Oak Island) intermodal ramps in New Jersey.

2. *Lack of limited-access freeways or high-speed arterials serving terminals.* Examples

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[1] Mercer Management Consulting, Inc., *Intermodal Terminal Capacity and Outlook* (Washington: Association of American Railroads, Intermodal Policy Division, January 1993).

abound in Chicago where ATSF's Corwith ramp (the nation's busiest) is accessed via crowded city streets and uncontrolled intersections. Another example is in California where freeway access to the Port of Oakland and nearby SP and UP ramps was disrupted by the Loma Prieta earthquake in 1989 and will remain poor until the freeway is rebuilt.

3. *Traffic congestion.* The most prominent example is Southern California where Rail Delivery Service (a major drayage firm) reports that many driving times have doubled in the last five years.

Poor highway conditions and lack of freeway or arterial access are prime candidates for public-private cooperation in identifying such bottlenecks and eliminating them, where justified. In some cases, intermodal facilities are among the major traffic generators in their areas and would justify the same traffic control and access improvements as shopping centers or industrial parks.

Traffic congestion is a thorny problem in major urban areas, and it has been resistant to low-cost solutions. Intermodal drayage can be both a cause and a victim of traffic congestion. By a 1991 estimate, rubber-tired interchange alone accounted for over 800 daily moves on Chicago-area streets and highways; about 200-400 of these moved over a short stretch of the Stevenson and Dan Ryan Expressways. In Long Beach, Interstate 710 (the Long Beach Freeway) carries heavy drayage traffic to and from the ports.

Intermodal drayage traffic has two characteristics that increase its impact on and vulnerability to urban traffic congestion:

1. It consists almost wholly of semi-tractor/trailer combinations (bobtail moves are inefficient) that require larger turning radii and more distance to accelerate and stop than smaller vehicles.

   Drayage equipment is effectively the same as that used by truckload carriers and is an integral part of intermodal service. The proliferation of 48-foot and 53-foot domestic containers, trailers, and Road/Railers is increasing maneuverability problems on city streets and older highways.

2. It is concentrated in the mornings (for inbound deliveries) and late afternoons (for outbound train cutoffs) and may coincide with local rush hours.

   The timing of intermodal peaks is driven by the same shipping and receiving preferences that drive other truck traffic during peak periods:

- Receivers prefer to take delivery in the morning, forcing drayage firms to begin work as soon as loads are available. (One drayage firm in Los Angeles reports that 80 percent of its deliveries are before noon.)
- Shippers prefer to ship in the late afternoon; outbound train cutoffs are therefore set for early evening

From time to time, it is suggested that intermodal customers might be offered incentives to ship and receive at off-peak hours. Since intermodal movements are typically only part of a customer's total traffic, the likely impact of affordable incentives is questionable.

5.3.1 Access Routing and Circuitry

Railroad lines and freight yards do not require special vehicular access. They are, moreover, often isolated from much of the highway network by geographic features or historic development patterns. Indeed, the problems of grade crossing or grade separations have led highway builders to avoid railroads where possible.

Since intermodal terminals were established within or in place of rail freight yards, vehicular access needs were initially modest and few improvements were justified.

As intermodal traffic and terminals have grown, many remain anchored to their original sites and have inherited decades-old access shortcomings. These include:

- Routes through commercial or residential areas
- Narrow streets
- Uncontrolled or poorly controlled intersections
- Rough surface conditions
- Circuitous routes

None of these are problems for the minimal vehicular traffic to and from freight classification yards or railroad shops; *all* are problems for efficient door-to-door intermodal service.

Physical clearance or weight restrictions are another source of circuitry in intermodal access. Such problems typically occur in cities with older highway, street, and rail infrastructures that are poorly adapted to modern traffic conditions.

These problems are most apparent in Chicago, the U.S. intermodal capital. Many surface routes to intermodal ramps have overhead clearance problems:

1. Clearances may be *accurately* posted *but* inadequate, posted *incorrectly*, or *not* posted at all and, therefore, *unsafe*.

2. Clearances change as streets are repaved and overpasses or underpasses are altered; *marginally acceptable* clearances can become marginally *unacceptable* overnight.

Ironically, many of the problem clearances are under the Conrail (Pennsylvania Railroad originally) viaduct running north-south through Chicago. The underpasses include access to Conrail's 47th Street and 63rd Street intermodal ramps. Those with clearance problems force draymen to take round-about, multi-block detours through surrounding neighborhoods.

In March of 1994, the City of Chicago Department of Consumer Services began using portable scales to enforce a 73,280-pound limit on selected Chicago streets. The 73,280-pound limit had been established some years prior for older Chicago streets, but had not been enforced. Since the 73,820-pound limit was substantially less than the 80,000-pound interstate limit, many intermodal loads were assessed fines of up to $1200 each. If permanently enforced, this local limit, would have been a serious barrier to direct drayage routing in Chicago. Fortunately, the limit was raised to 80,000 pounds.

5.4 OPERATIONAL ACCESS CONSTRAINTS

5.4.1 Traffic Peaking

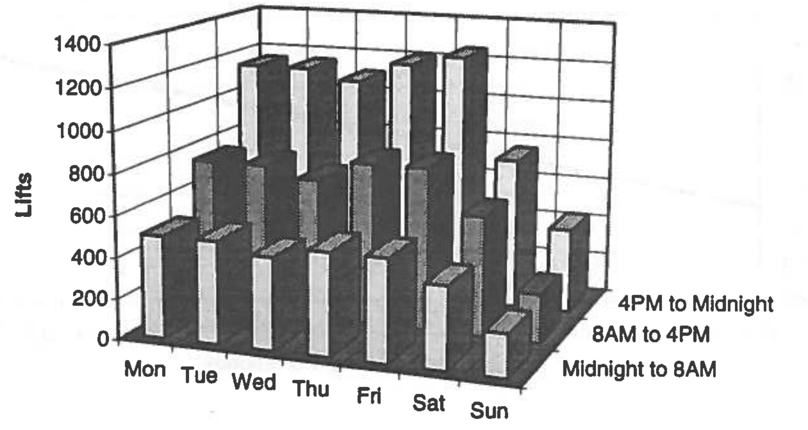
Traffic peaking can have impacts comparable to physical access constraints:

- Congested access routes
- Long gate queues
- Chaotic yard conditions

All of these can increase drayage costs and hurt service reliability in the same way as physical access problems. Peaking mitigation must therefore be matched with physical access solutions to solve the broader access problem.

Intermodal facilities experience three kinds of peaking: daily, weekly, and annual.

Daily peaking is determined by the preferences of customers for morning deliveries and afternoon shipments. Railroads, in turn, schedule train arrivals and departures to provide early morning inbound availability and evening outbound cutoffs. The result is a pattern of daily activity peaks such as that illustrated in Figure 5-10.



Source: Intermodal Terminal Capacity Outlook, AAR 1993

Figure 5-10. Typical Daily Terminal Activity Peaks

Because of the limited number of terminal gates, traffic peaks result in queues for entry or exit. Since drayage cost is a function of time, a delay at the terminal gate has the same effect as a similar delay due to physical access restrictions or traffic congestion. Mercer's drayage study for the AAR found that drayage firms reported gate queue delays of as much as an hour.[2] Figure 5-11 shows the relationship between gate time and drayage cost, and Figure 5-12 extends the relationship to competitive geographic coverage. Gate queues can thus affect the competitiveness of intermodal transportation as drastically as other access restrictions.

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[2] See previously cited Mercer.

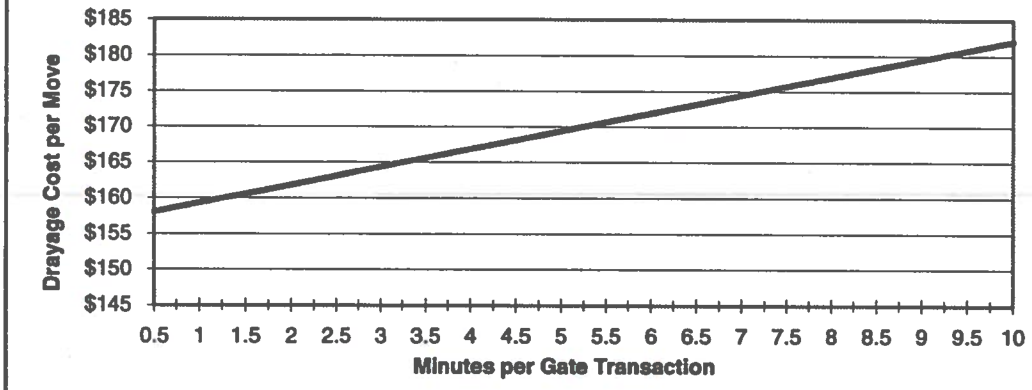
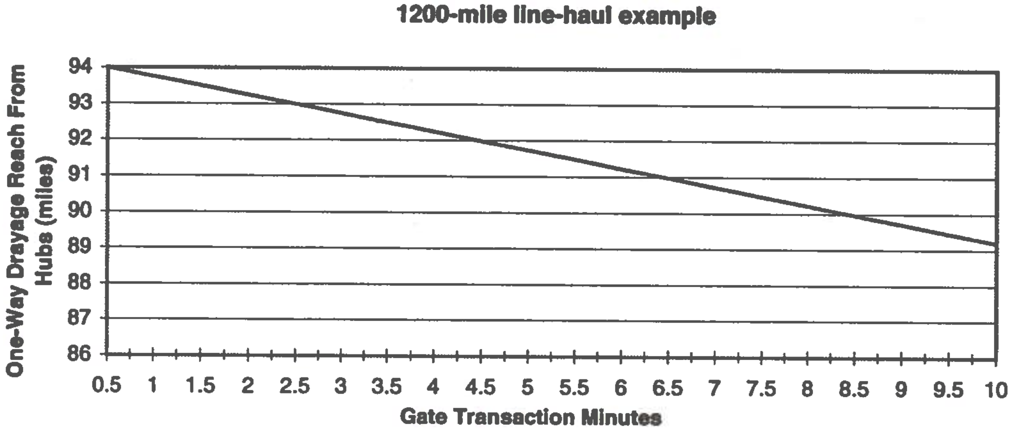


Figure 5-11. Gate Time and Drayage Cost



Source: Relationship from Double-Stack Container Systems, FRA/MARAD 1990

Figure 5-12. Gate Time and Geographic Reach

In visits to intermodal facilities, the author has frequently observed as many as 18 drivers in line at intermodal terminals. With each gate transaction taking 2-5 minutes, a queue of 18 drivers will impose a wait of 36 to 90 minutes on the last driver.

At marine terminals (or a few rail terminals) where containers are stacked ("grounded") rather than parked on chassis, traffic peaks can also result in queues for lift services within the terminal. In the busiest terminals, drayage firms report in-terminal delays of up to an hour. The effect of in-terminal delays on cost and competitiveness is the same as delays elsewhere in the system.

5.4.2 Restriction of Access by Gate Hours

Limits on terminal operations can reduce effective access, with consequences for drayage cost and door-to-door transit time. Operating interruptions or limited hours (primarily a problem at ports) can cause massive queues, driving up average drayage rates. When main or rail terminals have limited hours, the need to meet customer pick-up and delivery time preferences can add one or more days to overall transit time.

Many major rail intermodal terminals are open 24 hours per day, 7 days per week. Less-busy terminals may close at night and have reduced daytime hours on the weekend. Nighttime and weekend closures have little impact at rail facilities because gates stay open until cutoff times for the last evening departure. It is thus train frequency, rather than gate hours, that governs service at smaller hubs.

The situation is dramatically different at marine terminals. Labor agreements and operating practices at many major ports result in the following:

- 9 to 5 (or even 9 to 4) operating hours
- Weekend closures
- 10 to 15-minute coffee breaks at 10 a.m. and 3 p.m
- One-hour lunch break at noon

Because busy rail terminals in port cities are often open around the clock, the mismatched operating hours create queues at the marine terminal and prevent ocean carriers and their customers from taking full advantage of frequent train schedules. The practice of shutting down terminal gates for coffee breaks and lunch can likewise result in massive queues outside or inside the terminal (draymen in the terminal during breaks cannot leave).

5.5 TERMINAL BEST PRACTICES

5.5.1 Terminal Size and Configuration

Economies of Scale

Under current operating technologies, economies of scale are exhausted at relatively low volumes. Under-utilized terminals can exhibit apparent "scale economies" by easily handling marginal traffic increases. But neither scale economies or scale dis-economies are routinely seen in ever-larger terminals. Lift machine productivity peaks at roughly 40,000 to 50,000 annual lifts, and track space productivity does not necessarily increase with volume over 100,000 annual lifts.[3]

Terminal Location

Current thinking favors large "green field" sites away from urban centers with the goal of lowest delivered cost. The busiest terminals are presently established in the centers of large urban areas which in the past were easily accessible for both road and rail. Intermodal "ramps" were typically added on the fringes of carload freight yards and expanded as carload freight declined and intermodal freight increased. Many of these facilities were established decades ago and have grown incrementally rather than through planning. Not surprisingly, their configurations are seldom optimal.

As intermodal volume has exploded, these terminals are unable to acquire land for expansion at a reasonable cost. Where future traffic volumes cannot be handled by on-site operating or capital improvements, new facilities must often be located in more remote sites where land is available at a good price. While physical distance may add to drayage costs or reduce market coverage slightly, the disadvantage may be more than offset by the advantages of a "green field" site.

For example, Santa Fe's new intermodal facility next to Alliance Airport outside Dallas was built on a "green field" site; it has the following advantages:

- Replaces three separate Santa Fe yards in the Dallas area.
- Features three working tracks, each more than 6,000 feet with parking between.
- Enables trucks to queue up within the facility instead of spilling onto city streets.
- Laid out for maximum efficiency.

Southern Pacific's ICTF in Southern California, presently handling more containers than any other hub, was likewise built on a "green field" site.

As intermodal traffic has grown over time, the target markets have shifted. In the 1960s, the existence of some 2100 local ramps brought service close to most current customers. Today, consolidation into roughly 200 existing hubs has raised the issue of market access. Carriers have begun seeking locations that serve major markets at the lowest delivered cost.

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[3] Mercer Management Consulting, Inc., Intermodal Terminal Capacity and Outlook. (Washington: Association of American Railroads, Intermodal Policy Division, January 1993).

The goal of lowest delivered costs requires them to balance capital costs, terminal operating costs, and drayage costs and to minimize the total.

Design Approach

Best practice in terminal design stresses flexibility, access, and responsiveness.
A review of existing and planned yard configurations suggests that, beyond the basic common elements, intermodal terminal design is highly site-specific. Best design practice might therefore focus on the best design process and on the *principles* by which design is conducted. Vickerman•Zachary•Miller offers key principles for intermodal rail facility design. These principles provide criteria for judging a proposed design while allowing the flexibility and creativity needed in a growing, changing commercial and operating environment.

- *Responsiveness to the Overall System* - Design each individual piece while maintaining perspective on the overall picture. Focus primarily on value-added items.

- *Ability to Allow for Long-Term and Short-Term Expansion* - Plan for a full build-out scenario, then scale back to present needs. This will allow a facility to maintain the same overall footprint as it expands, thereby reducing expansion costs. Allowances should also be made for short-term expansion to meet annual peak period needs.

- *Adaptability to Allow for Current and Future Technological Advances* - Lay down the infrastructure permit installation of technical innovations as they become available. All such innovations do not need to be installed, but the infrastructure should allow future enhancements.

- *Flexibility for Alternative Equipment-Handling and Storage Modes* - Use the VZM Modular Grid Overlay System (MGOS) to allow expansion or changes in equipment without altering terminal operation. Essentially MGOS allows a terminal to grow as needed, while maintaining the operating methods best suited to current needs.

- *Accessibility for Both Rail and Road Movements* - Consider the types of rolling stock that will be used and their access into the terminal. Access and congestion problems are the most common reasons customers perceive a terminal as "flawed."

- *User-Friendliness for Operators and Customers* - Design the facility to operate as simply and logically as possible. When the system is automated, the design should always allow manual override, in case of outages.

- *Cost-Effectiveness and Space-Efficiency* - Be careful not to over-design the system. The solution must be fiscally practical as well as physically acceptable.[4]

Track and Parking Configuration

Current best practice favors long, train-length tracks and center-aisle parking. Train-length tracks minimize switching costs and delays and holdups in moving lift equipment--especially gantry cranes--between working tracks. Train-length tracks may be 6000 feet long or longer to accommodate fifty conventional flatcars or twenty double-stack or spine cars.

If tracks are much shorter, yard or train crews must "double over" the train between two or more tracks. Besides incurring switching costs and train delays, the added movement reduces the time available for loading and unloading and disrupts other yard activities. Gantry cranes, which are favored for high-volume loading and unloading, are easily moved up and down a single track, but are very slow to move sideways between tracks. A facility with fewer but longer tracks can leave gantry cranes assigned to a single track for long periods, thus minimizing the time lost in repositioning.

Center-aisle parking minimizes the distance between parking and trackside loading. To optimize center-aisle parking requires pre-planning track assignments and slot-number parking, rather than simply assigning parking lots by the last digit of the trailer number. Thus, optimization of center-aisle parking works best in conjunction with state-of-the-art terminal operating systems. Some facilities have found that they must place tracks in pairs to attain the desired track capacity, limiting the opportunity for center-aisle parking.

The most common parking systems seem to involve segregating parking lots by function (inbound vs. outbound, empties vs. loads, or containers vs. trailers) and then arranging each lot by "last digit": all units with serial numbers ending in "1" would be in the first rows and so on. This system has three basic shortcomings:

1. Draymen and hostlers must still search for each unit, even though the search is narrowed.

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[4] David Vandeveer, *Intermodal Rail Facility Designs for the Next Century*, Draft paper submitted for the TRB National Conference on the Intermodal Terminal of the Future (Vickerman•Zachary•Miller, 1994).

2. Some units have hard-to-read or non-uniform numbers and can more easily be misplaced or missed in a search.

3. In overflow situations, there is often no back-up system to place or locate a unit whose row is full.

As facilities expand and the number and size of parking lots grow as well, the search time for "last-digit" parking systems can increase substantially.

5.5.2 Private and Specialized Terminals

Common-user, Private, and On-dock Terminals

In the right situations, common-user, private, and on-dock terminals offer several advantages over conventional practice. Common-user terminals have been slow to develop, due to both operational and institutional complications. The "condominium" approach may be one way of overcoming these barriers: creating two or more independent terminal operations within a large facility and sharing key assets.

As the volume of intermodal traffic rises, the ability of a single major customer to support a highly specialized, efficient terminal becomes a real possibility. For example:

- CNW's Global One, originally envisioned as a multi-customer hub, now handles APL traffic almost exclusively. Chassis and drayage logistics are simplified, as are communications and management liaison. A single customer schedules all movements in and out.

- UPS's North Richmond facility, served by Santa Fe, handles only UPS piggyback traffic. Santa Fe can treat UPS as an industrial customer who loads intermodal flatcars, freeing itself of terminal management responsibilities.

- The new UPS/Santa Fe facility at Willow Springs (near Chicago) will likewise be primarily dedicated to UPS's intermodal traffic. The development of this facility will free Santa Fe's busy Corwith hub from a major traffic segment and concentrate UPS activity in one location.

"On-dock" terminals continue to proliferate as:

- Ports seek to deliver competitive service.
- Volume of traffic handled by each ocean carrier grows.
- Railroads face increasing pressure at near-dock facilities.

On-dock terminals can serve a single ocean carrier, several carriers calling at a given ocean terminal, or an entire port.

Trailer-only or Container-only Terminals

Container-only terminals can offer advantages if traffic volume attains minimum scale. There are very few trailer-only or container-only terminals. The few examples of container-only include:

- BN's Seattle Intermodal Gateway (SIG).
- SP's ICTF in Southern California.
- BN's Ogden Ave (Cicero) yard (the north half of the Cicero pair).
- CNW's Global One in Chicago.
- Conrail's North Jersey Intermodal Terminal at Croxton.

The very few remaining circus ramps are trailer-only in the sense that they can handle containers only on chassis (as if they were trailers).

There are a few potential advantages to container-only facilities:

- No need for dual-purpose spreader bars on lift equipment.
- Potential for stacking containers and chassis.
- Possible restrictions to track-efficient double-stack cars.

These or other advantages have not been enough to make container-only facilities common. Moreover, much of the "container-only" need has been met by on-dock facilities in ports.

5.5.3 Gate Configuration

Current best practices favor reversible gates, two-stage gates, and specialized gates where applicable.

Number of Gates and Directional Flexibility

Terminals are both increasing the number of gates and creating more "reversible" gates; the latter can be used for either inbound or outbound traffic as the peak flow shifts. Reversible gates are typically set in the center of an in-gate/out-gate complex and controlled by red and green signal lights to indicate the direction of use (similar to installations at some highway toll plazas). The flexibility provides more outbound gates during the typical morning rush of deliveries and more inbound gates during the afternoon peak of shipments.

Two-stage Gates

Most recent new facilities and gate improvements feature "two-stage" gate processing that uses "talk-back" installations (telephones or intercoms) to verify driver and shipment information before gate inspections. This allows terminals to turn away or segregate movements with inadequate documentation, or otherwise deal with problem cases before they clog the actual gates. Two-stage processing also allows systems to print a partially completed interchange document by the time the driver reaches the inspection gate, expediting handling there. Two-stage processing (like central queues in bank lobbies) also allows terminal operators to distribute workloads evenly over the active gates. In some cases, talk-backs have been supplemented with remote video cameras. Conrail is working on card-activated gates (similar to bank ATMs) that would allow drayman to enter required information and identifiers by inserting a card rather than using a talk-back. Two-stage gates are ideally positioned for conversion to AEI gates.

Specialized Gates

Terminals have set up specialized gates for some customers or traffic types. These gates abbreviate or eliminate inspections, or otherwise expedite processing. Examples include the following:

- CSX's Bedford Park facility - designates a separate gate for inbound mail movements during peak periods.
- ATSF's Corwith facility - maintains separate pass-through gates, manned by customer personnel, for UPS and J.B. Hunt traffic.
- Marine terminals at Elizabethport, New Jersey - have special gates for ILA-operated drayage moves.
- Many facilities - have "bobtail" gates for tractors without trailers or chassis.

Hand-held Input Devices

Hand-held input devices have been successfully applied to gate processing. By creating a paperless gate, they improve processing speed, accuracy, and availability of information for terminal management. The use of hand-held devices also makes gate personnel mobile, releasing them from the confines of a physical gatehouse and enabling them to create "virtual gates" as needed to accommodate traffic flow.

movements, exacerbated by the failure of infrastructure upgrades to accompany expanded intermodal loadings.

- Terminal operations often interfere with highway traffic and reduce effective access, with consequences for drayage cost and door-to-door transit times.

- Physical access constraints are often exacerbated by gate operations. Terminal gate operation inefficiencies result in congested access routes, long exit/entry gate queues, and in-terminal delays for lift services. These inefficiencies are caused by inadequate gate capacity, traffic peaking, and restricted gate hours. Congestion within the terminal affects the cycle time required for drayage and thus the cost of intermodal movements.

- Clearance problems in the Mid-Atlantic region precluded operation of double-stack trains. The ability to operate double-stack service is critical for single-track mainlines that are severely capacity constrained, or where track capacity cannot be expanded without extensive reconstruction.

- Poor access has caused deterioration of intermodal service times through recurrent delays, raising the cost of providing service. For the intermediate points in the Atlantic corridor, service times were twice as long for intermodal as the all-highway mode; and even longer in the Jacksonville corridor. Slow service times adversely affect mode choice as they raise transportation costs and entice shippers to avoid intermodal altogether or dray longer distances to terminals with better service.

- Improving highway access to terminals may enhance the competitiveness of intermodal services. A shipper survey identified several factors affecting terminal access and the cost of providing intermodal service: interstate highway access, roadway conditions, weight or commodity movement restrictions, and security.

- Truck access routes are a critical factor in mode choice. Access to intermodal terminals is often through local streets linking designated truck routes and the terminal. Conditions such as street paving, lane width, lighting, and signage often hinder access, compounded by the fact that if major highway or bridge repairs are required, direct alternate routes are not often available. A notable case in point is in Philadelphia when bridge reconstruction closed the primary intermodal terminal access route.

- Security is another area where the shippers clearly perceived a disadvantage for intermodal. Driving conditions and security along surface routes, in addition to terminal security, often discourage intermodal use. In locations such as Miami and Los Angeles, truck hijacking has become increasingly common.

- Weight restrictions on alternate routes, and also commodity and time-of-day turn restrictions, often pose access problems. These restrictions often require circuitous routes and add drayage time and cost.

Congestion Mitigation

- Congestion reduction benefits of intermodal movements within the corridor proved to be significant, as indicated by the circuity analysis of the intermodal rail movements. With an average drayage distance at each end-point ranging between 40 and 97 miles, the impact of intermodal operations on congestion can be demonstrated through the "avoided" VMT within the corridor. A typical intermodal move within the corridor generated only 21 percent of the VMT of the equivalent truck mode, representing a saving in VMT of 79 percent, or nearly 30 million vehicle miles. The average avoided truck VMT ranged from 440 to 880 miles.

- In the NJ/PA to Atlanta corridor, intermodal operations resulted in an 84 percent savings in highway VMT, corresponding to 13.7 million fewer vehicle miles of equivalent truck traffic. On the 863-mile long corridor from NJ/PA to Atlanta, shipping freight intermodally generated a total of 2.6 million vehicle miles of drayage, compared to 16.4 million vehicle miles for the all-highway alternative, thus generating only 16 percent of the VMT that would be generated by the truck mode.

- In 12 of the 16 cases, truck linehaul distances (ranging between 570 and 1060 miles) were shorter than the corresponding intermodal linehaul distance (the combined dray and rail linehaul ranging between 600 and 930 miles.) The intermodal-truck circuity index ranged from 0.99 to 1.28. In the worst case, intermodal distance was 182 miles longer than the equivalent truck movement.

- The impact on trucking congestion within the corridor can be illustrated through comparing the truck count with the equivalent intermodal count. In the Baltimore segment of I-95, for instance, the average daily truck count was 4,568, compared to an estimated 146 intermodal container moves, representing an intermodal mode share of 3.2 percent. The highway segment within the corridor which showed the greatest intermodal mode share was the I-95 segment in Jacksonville with 6.6 percent market share (8.5 percent if counting the empty backhaul of intermodal containers.)

6.1.2 Terminal Facilities

Capacity

- Capacity constraints in terminal facilities are a major impediment to improved intermodal performance, as the recent rail traffic growth has effectively absorbed much of the earlier surplus mainline and yard capacity. Also contributing to terminal capacity problems is traffic diverted from closed terminals.

- Insufficient capacity or reduction in service in less profitable markets has undermined efforts to expand operations in markets where the potential for intermodal service has been successfully demonstrated. Improvements in capacity and service levels, information systems, terminal mechanization, and coordination with major shippers are critical to improved operations.

Level of Service

- The level of service a terminal offers impacts mode choice as it influences the shipper's willingness to use the terminal. Terminal delays are a major factor in service levels and have a direct bearing on the shipper costs. Slow service times lead some shippers to dray longer distances to terminals with better service or avoid intermodal altogether.

- Terminal mechanization impacts lift times and service levels by influencing the minimum cutoff times when a shipper has to deliver a load. Also, availability of yard storage affects level of service as it impacts the speed of operations and terminal congestion, and imposes additional handling requirements as the boxes have to be moved to a secondary storage location for later pickup.

- Location of terminals within the drayage range influences the service level as it affects the relative costs of truck versus intermodal shipments. Locating terminals such that they are readily accessible by large trucks minimizes disruption to other traffic and reduces drayage cycle times and the breakeven distance for intermodal movements.

Gate Practices

- Terminal gate practices influence operational efficiencies. Current gate configurations favor streamlining gate procedures by the use of reversible gates, two-stage gates, and specialized gates. Increasing the number of gates or use of bi-directional gates ease gate delays and offer the flexibility of efficiently handling traffic peaks.

- Innovations in gate-processing techniques have proven successful. Two-stage gate processing has allowed pre-screening of movements before they clog the actual gates and allows for advance documents to be generated while drivers wait for inspection. Specialized gates allow for expedition of processing for specific traffic. Paperless gates improve processing speed and accuracy. Hand-held input devices have been used to mobilize gate personnel allowing them to create "virtual gates" as needed to accommodate traffic flow.

- Terminal delays have been reduced through the use of specialized terminal equipment and track configurations, coordination of pickup and delivery operations, and information systems for expediting terminal processing. Application of these terminal innovations has been beneficial in combatting gate queues and terminal congestion, and improving terminal processing times, train schedules, transfer and interchange connections, and notification of shipment arrival.

Interchange Operations

- One of the major impediments to efficient terminal operations is rail interchange practices. Interline transfers at rail terminals are fraught with inefficiencies, long delays and unnecessary switching, partly due to the fragmented rail infrastructure ownership and operation. The absence of a nationwide network that allows railroads to share lines, equipment, or resources impedes further growth of a highway competitive intermodal system. Successful run-through services and train switching operations are critical factors for eliminating the redundant handling of steel-wheel and rubber-tire interchanges. The growth of intermodal freight depends on inter-company cooperation to extend rail haul length and avoid delays.

- Well-managed mechanized interchange operations boost labor and equipment productivity. Handling techniques, specialized equipment, and track configuration provide greater speed and efficiency in areas such as train assembly/disassembly. In-terminal track configuration practices include train-length tracks which minimize switching costs and delays, and easily allow for high volume loading and unloading without crane repositioning. Center-aisle parking practices minimize the distance between parking and trackside loading as well as unit search time.

Capacity Utilization

- Productivity of terminal operations is impacted by advances in operations and service delivery through the improvements in processes, equipment, and information system technologies. Process improvement strategies increase the efficiency and customer appeal of intermodal transfer at junction points.

- Intermodal utilization rates are considerably below those for truckload carriers. Equipment costs, a significant component of overall costs for long-haul services, form a proportionately greater component for shorter hauls. Thus, equipment management practices, marginally economical for long-haul traffic, are even less economical in short-haul corridors.

- Asset ownership affects capacity given the major role played by non-asset owning IMCs. Equipment standardization, neutral chassis and container pools, and harnessing available technology to track, trace, and maintain equipment are some of the approaches taken to improve asset management and equipment utilization.

- Many new rail technologies are designed to reduce weight, fuel, and handling requirements and increase capacity. Intermodal linehaul cost advantages have increased through the adoption of new technologies such as RoadRailer vehicles and double-stack trains.

- Computers and automation have helped unify intermodal operations through the entire process using information technologies such as EDI and AEI. These systems can improve route optimization, equipment (railcar, trailer, container) tracking, electronic transfer of intermodal documents, order processing, damage claims processing, and rate information.

Drayage

- Drayage accounts for a large share of the total intermodal door-to-door costs and is a major factor in service quality as perceived by shippers. High drayage costs affect the profitability of intermodal service, and limit the markets in which it can compete with intercity trucking. This is especially true in shorter intermodal corridors, where an expensive dray at either end of the trip is likely to result in a price higher than a comparable truck rate.

- Drayage length is a critical factor in intermodal cost competitiveness. Corridor drayage distances ranged from 12 to 230 miles. As a rule, intermodal is cost-effective when the drays are kept to a short distance, or the break-even distance for intermodal is long enough for the per-mile linehaul savings to offset the added costs for terminals and drayage. Drayage costs are minimized when the length of the rail portion increases, and when there are no reverse-direction drayage moves. Where drays were under 32 miles, intermodal costs were always lower than truck rates. Where drays were greater than 90 miles, intermodal was cost competitive in only 3 out of 8 cases.

6.1.3 Linehaul Operations and Performance

Mode Share

- The intermodal market share remains below 5 percent. In the corridor analysis, the mode share ranged between 1.9 percent and 8.5 percent of the total freight volume. The overall intermodal mode share in the U.S. is substantial in long-haul intermodal corridors but rather small in the medium and short haul markets.

Mode Choice and Performance

- Mode choice decisions are based primarily on price and service. On these criteria, intermodal service competes directly with over-the-road trucking, and its attractiveness depends on the extent to which intermodal cost advantages are outweighed by factors such as terminal location, access difficulty and the geographic pattern of shipper distribution around the terminal.

- Larger companies which ship longer distances and are cost sensitive are more likely to choose intermodal over truck. In some cases, imbalanced traffic levels will favor intermodal if no backhaul is available, even though it is more expensive in one direction. Intermodal may also be selected instead of truck if there are driver shortages along the route.

- As measured by service times, intermodal performance could be considered below par. Shipper's perception of performance often depends on qualitative aspects such as terminal security. Which may dominate choices when the price and service of truck and intermodal are generally similar. In particular, if the intermodal terminal is located in an unattractive area with perceived security problems, intermodal may not be used.

6.2 CONCLUSIONS

6.2.1 Intermodal Freight Generates Significant Benefits

The current and potential benefits from intermodal freight operations have been quantified in a variety of ways, though most benefits remain to be estimated more precisely. These benefits have significant implications for the overall efficiency and performance of the transportation system, and include the following:

- ***Congestion Reduction***. The impact on highway congestion of a continuing shift of freight traffic away from highway to intermodal can be significant. Currently more than 9 million container and trailer loads move the nation's domestic freight. The findings of a corridor study conducted for this report [see Section 4] suggest that for each 10 containers that are carried on intermodal rail, a minimum of 7 trucks are taken off the highways.

- ***Lower Emissions***. Intermodal operations have the potential to help achieve the desired national air quality standards. The ratio of hydrocarbons per billion ton- miles for rail is lower than truck by a factor of five; for nitrogen oxides and carbon monoxides, the ratio for rail is lower than truck by a factor of two.

- ***Higher Fuel Efficiency***. Rail linehaul operations are more fuel efficient than trucking. In 1989, freight railroads in the U.S. consumed 79 billion barrels of fuel to carry more than one trillion ton-miles of freight. In comparison, commercial trucks consumed 407 billion barrels of fuel to carry 700 billion ton- miles of freight. On a per-unit basis, this translates to 300 ton-miles per gallon for rail and 90 ton-miles per gallon for trucks.

- ***Greater Safety***. Rail operations are considerably safer than truck operations. Rail fatalities are roughly one per billion ton-miles, while trucking fatalities are four per billion ton-miles.

- ***Cost Savings.*** Average rail linehaul prices are significantly lower than the equivalent all-highway mode, accounting for a more efficient use of resources. Average revenue for rail freight is less than 3 cents per ton-mile, compared to more than 23 cents per ton-mile for the equivalent truck mode.

- ***Reduced Highway Deterioration.*** Reducing the number of trucks on the nation's highways will help slow the rate of pavement deterioration and the accelerating costs of highway maintenance.

- ***Greater System Efficiency.*** Improved use of the multimodal freight connections corresponds to more efficient resource use, as the existing rail and waterways networks are placed in optimal use. The synergies from the joint use of interchanging modes will benefit the users and service provider through lower prices, higher service quality, and expanded global markets.

6.2.2 Intermodal Freight Faces Challenges

Challenges to intermodal performance range from inadequate infrastructure and network access, to constrained terminal capacity and door-to-door service delivery problems. These impediments affect industry costs, service quality, and overall performance by interfering with the smooth flow of goods and information over the multimodal network. Figure ES-6 illustrates the components of the intermodal system consisting of the layers of physical infrastructure, terminal facilities, and linehaul operations. These components need to fit together to form a fully integrated, seamless system.

The study findings summarized above indicate that inadequate clearance and access links, the failure to make needed investment in support infrastructure, capacity constraints, equipment shortages, and performance problems have hampered efficient port and terminal operations. The findings also indicate that terminal capacity shortages and rail interchange and service delivery practices create operational and performance problems. Identifying these impediments will help develop strategies that remove the barriers and allow the smooth movement of freight within a seamless transportation system.

Challenges to seamless intermodal operations fall into five general categories:

- ***Institutional and Regulatory Barriers.*** Although there is relative consensus on the need to remove infrastructure access bottlenecks, there are several institutional and funding obstacles that slow down implementation of the improvements. These impediments range from jurisdictional restrictions on funding and constructing port access, to difficulties in funding improvement projects that directly concern private rail terminal operations. The stymied efforts by the Santa Fe Railroad to acquire the needed permits to build access to its Corwith terminal in Chicago illustrate such barriers. Regulatory restrictions that involve specific design requirements for terminal construction are another example. The industry views design specifications as impediments to operational improvements, and favors performance standards which leave the choice of technology or design to the operators. The efforts of the industry advocates to use the promise of the ISTEA funding flexibility to expedite construction of access projects that enhance rail-truck operations have so far been only partially successful. Also included in the institutional barriers are problems related to union labor rules and restricted work hours at container ports.

- ***Operational Impediments.*** The complexity of intermodal operations is at the core of many challenges faced by the industry, including an array of problems relating to terminal, linehaul, and drayage operations. Peaking pressures at terminals are a major source of service problems as they lead to severe capacity shortages and delays. Gate inspection practices, particularly container damage inspection and liability assignment are another source of terminal delay. Rail interchange practices also pose an obstacle to efficient operations as interline transfer involving steel-wheel and rubber-tired interchange are fraught with long delays, high costs, and unnecessary switching. Drayage inefficiencies are another source of operational problem, often hampering efforts to offer cost effective service in shorter haul markets. The outcome of operational problems is the poor level of service offered by some terminals, which impacts mode choice and drives away shippers requiring better service.

- ***Structural Problems.*** These problems relate to the structure of the intermodal industry and are inherent in the highly complex nature of the industry. The fragmentation of the industry is a major manifestation of such structural problems, and stems from dependence on multiple linehaul and drayage carriers, third parties, terminal operators, and equipment owners and lessors. Fragmentation has hurt the industry goal of achieving greater intermodal mode share because of 1) the divergent incentives that provide pricing, customer service, and liability rules that while benefiting a small segment of the industry, undermine the overall efficiency of the operations; 2) diffused control and accountability that undermines the industry performance and prevents carriers from providing efficient door-to-door service; and 3) communication disconnect causing service unreliability, as manifested through missed train connections, delayed drayage service, and management failure.

The traditional wholesale perspective adopted by the railroads has been another deterrent to providing the level of service shippers demand. The wholesaling mindset is often manifested in cost-service tradeoffs that might result in cost savings in the short run, but are detrimental to the industry profitability and market share in the long-run. Cost cutting measures adopted through such tradeoffs are driven by budgetary objectives that ignore the overall performance and result in service shortfalls and paradoxical outcomes for the profit margins.

The structure of asset ownership in the industry is also detrimental to adequate service levels, as illustrated by the extent to which non asset-owning IMCs contribute to equipment availability problems and supply shortage.

- ***Technological and Supply-Related Impediments.*** Inefficient equipment utilization is at the core of equipment shortage that plagues the industry. Incompatible communication systems and EDI standards have also hampered the industry efforts to provide a seamless flow of containers across modes. Though EDI is available to all major rail and marine carriers and IMCs, only some 50 percent of all intermodal transactions are EDI-based. Lack of access to EDI by small operators, incompatible systems, and the multitude of software programs in use also contribute to the technological impediments in the industry. The problem of compatibility will gain increasing prominence as communication technologies such as AVI and WIM penetrate the market and necessitate EDI interface. Another standardization issue arises with the *Intermodal Safe Container Act of 1991* that will go into effect in September 1996, and the need to incorporate the requirements of this Act into the existing EDI bill of lading.

- ***Demand-Driven Impediments.*** A major demand-driven impediment to better service and market share is the geographic distribution of the U.S. freight markets. More that two-thirds of all freight in the U.S. move over distances shorter than 500 miles. The average length of haul for truckload shipments has declined from 258 miles in 1980 to 228 miles in 1991, posing a potential threat to the viability of rail service. The nation's mid-sized markets are severely underserved, as most service improvements have concentrated on long-haul double-stack markets. Whereas the *scale economies* from operating long-haul markets have resulted in major cost reduction and service benefits, the short-haul market share has not increased significantly, notwithstanding the success of new technologies such as RoadRailer.

One of the obstacles to profitable short-haul service has been the lack of demand density in such markets due to the absence of an extensive intermodal hub-&-spoke system. The corollary of the lack of demand density is the failure of intermodal rail to develop *economies of scale* that would effectively compete with the elaborate trucking network and create a nationwide network of linehaul service and regional distribution and consolidation centers.

Compounding the effect of sparse demand and an absence of an intermodal freight hub-&-spoke system are JIT practices that have resulted in smaller shipment size and increased outsourcing to clusters of interdependent suppliers within short trucking distances. Also adding to the effect of fragmented markets has been the inability of the intermodal industry to form regional alliances for freight pooling, fleet sharing, and joint terminal operations.

6.3 RECOMMENDATIONS

The study findings identify an array of policy alternatives that demand strategic investment and action on the part of the public and private sector stakeholders. The strategies are geared to improving the overall efficiency and performance of intermodal operations, and ultimately help the industry to gain mode share.

6.3.1 Access Improvements

Access strategies target the improvements required to remove physical infrastructure access impediments. Removing these impediments is critical for improving the flow of intermodal traffic through the network:

- Provide adequate clearance on bridges, tunnels, viaducts, and highway overpasses required by drayage trucks and rail double-stack service.
- Remove or update restrictions on weight, time-of-day, and commodity movements on highways and bridges at key access points to ports and terminals.
- Construct the needed arterial and interstate connectors and access links to terminals to reduce circuity; and provide adequate lane capacity and terminal access for truck routes leading to intermodal terminals to reduce drayage costs and improve cycle time.

- Enhance highway security and accessibility by ensuring adequate lane width, lighting, signage, and overall safety to assuage the shipper concerns over the security of intermodal access roads.

- Construct needed on-dock rail facilities, and ensure adequate access to ports, airports, rail and truck terminals, tank farms.

6.3.2 Institutional Improvements

These strategies target the institutional, regulatory, and interagency impediments that prevent smooth operations of intermodal interchange:

- Remove funding barriers to investing on improvement projects involving multimodal and multi-jurisdictional operations, and common-user terminals; and help realize the provisions in the ISTEA for funding flexibility for such projects.

- Remove the barriers to a more efficient interline interchange operations by improving communication among railroads; and initiating "run-through" agreements for interline transfers.

- Work with the industry advocates to have uniform weight restrictions and incorporate the requirements of the *Intermodal Safe Container Act of 1991* in the existing EDI protocol.

- Standardize communication protocols and EDI formats to ensure interoperability of all data transmission mechanisms and compatibility of all software and operating systems.

- Remove the institutional barriers to formation of regional alliances, freight pooling, track sharing, and joint terminal use to help build a more efficient hub-and-spoke system and achieve market density.

6.3.3 Technology-Oriented Improvements

Ensuring efficient port and terminal operations and expanding capacity for existing facilities are made feasible by using supply-oriented solutions that include adoption of new technologies and streamlined operations, including:

- Increase capacity by effectively matching the equipment, terminal, and linehaul schedule capacity; adopting new methods of charging for container use; and modernizing container handling equipment.

- Improve terminal throughput and cycle time and reduce terminal delays through techniques such as drayage-by appointment, coordinated pickup and delivery operations, automated gate processing, in-terminal track configurations that include train-length tracks that minimize switching costs and delays and crane repositioning, and center-aisle parking practices that minimize the unit search time and the distance between parking and trackside loading.

- Enhance equipment utilization and terminal productivity by adopting automated inventory techniques and information processing systems; rationalizing gate operations and container damage inspection; streamlining container use, storage policies, and terminal inspection processes; mechanizing terminal handling equipment and interchange operations; and providing greater speed in areas such as train assembly/disassembly.

- Ensure cargo security through installing specialized sensors, fences, gates, and video monitors.

- Apply ITS/CVO technologies such as AEI, AVI, and AVL to expedite container processing; streamline gate procedures by the use of "smart gates", reversible gates, and two-stage and bi-directional gates that pre-screen the loads before they clog the actual gates and generate; pre-clear vehicles by generating advance documents for drivers waiting for inspection, and using paperless gates and EDI transfer of documents for order processing, damage claim processing, and rate information; and use hand-held input devices to mobilize gate personnel allowing them to create "virtual gates" as needed to accommodate traffic flow.

6.3.4 Market-Oriented Improvements

This set of recommendations is geared to increasing the profitability and market share of intermodal freight operations by expanding the scope and density of the markets, improving service quality, and reducing operating costs.

- Improve quality of service and customer satisfaction by offering more reliable door-to-door delivery satisfying the shippers' service needs, streamlining train schedules, developing on-line tracing systems, and automating order-processing.

- Increase economies of scale and hence market share by generating networks of distribution hubs and load consolidation centers, and by negotiating customized service and volume discounts in exchange for volume guarantees and streamlined contracts.

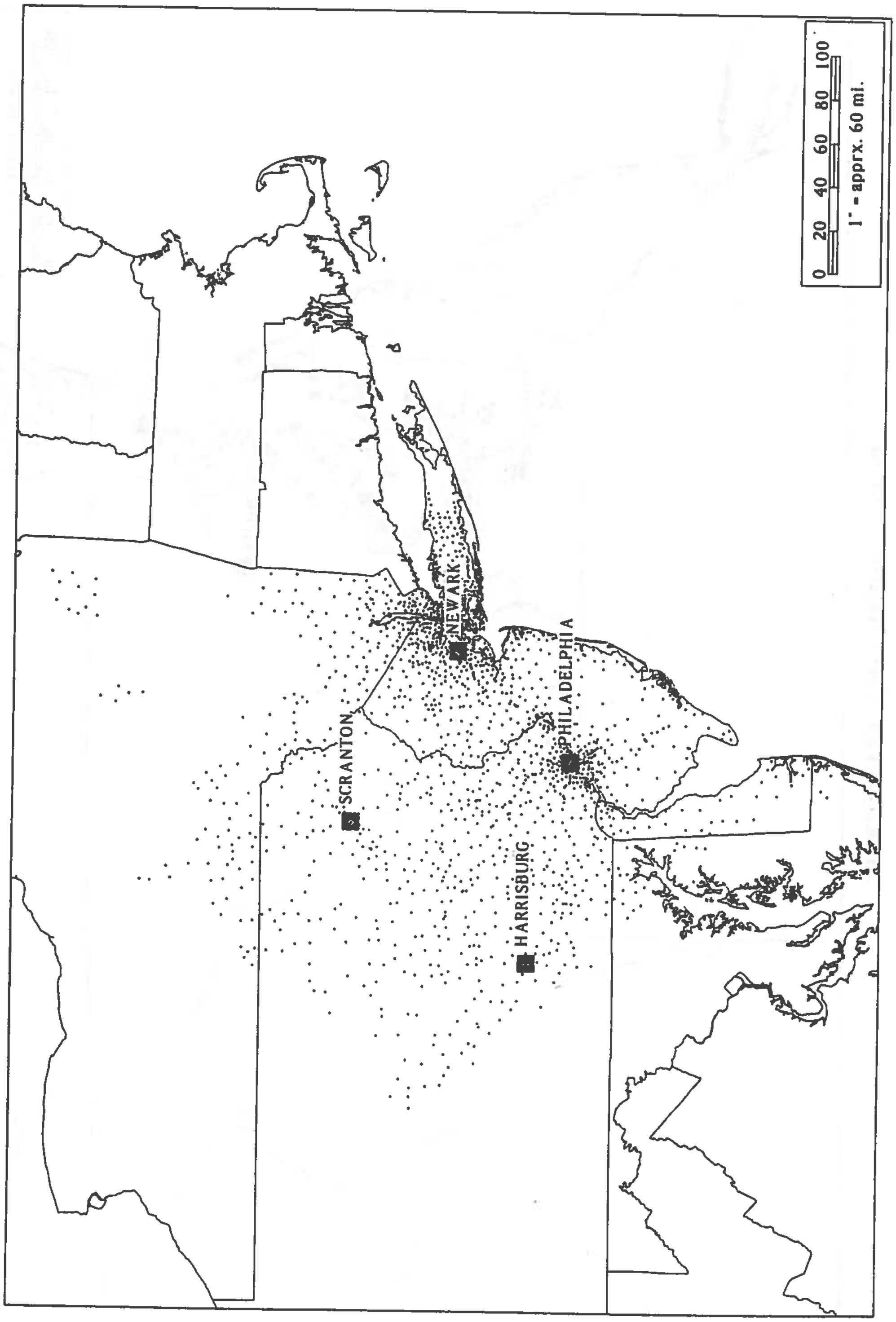
- Maximize terminal location benefits by siting terminals at key locations throughout each metropolitan area; and designing terminals to be collocated with major customers and truck distribution centers, and within easy access to areas of economic activity.

- Enhance demand and mode share by reducing the shipper's inventory carrying costs by meeting shippers' JIT requirements, offering faster and more reliable delivery, more frequent and regularly scheduled train departures, and shorter transit times.

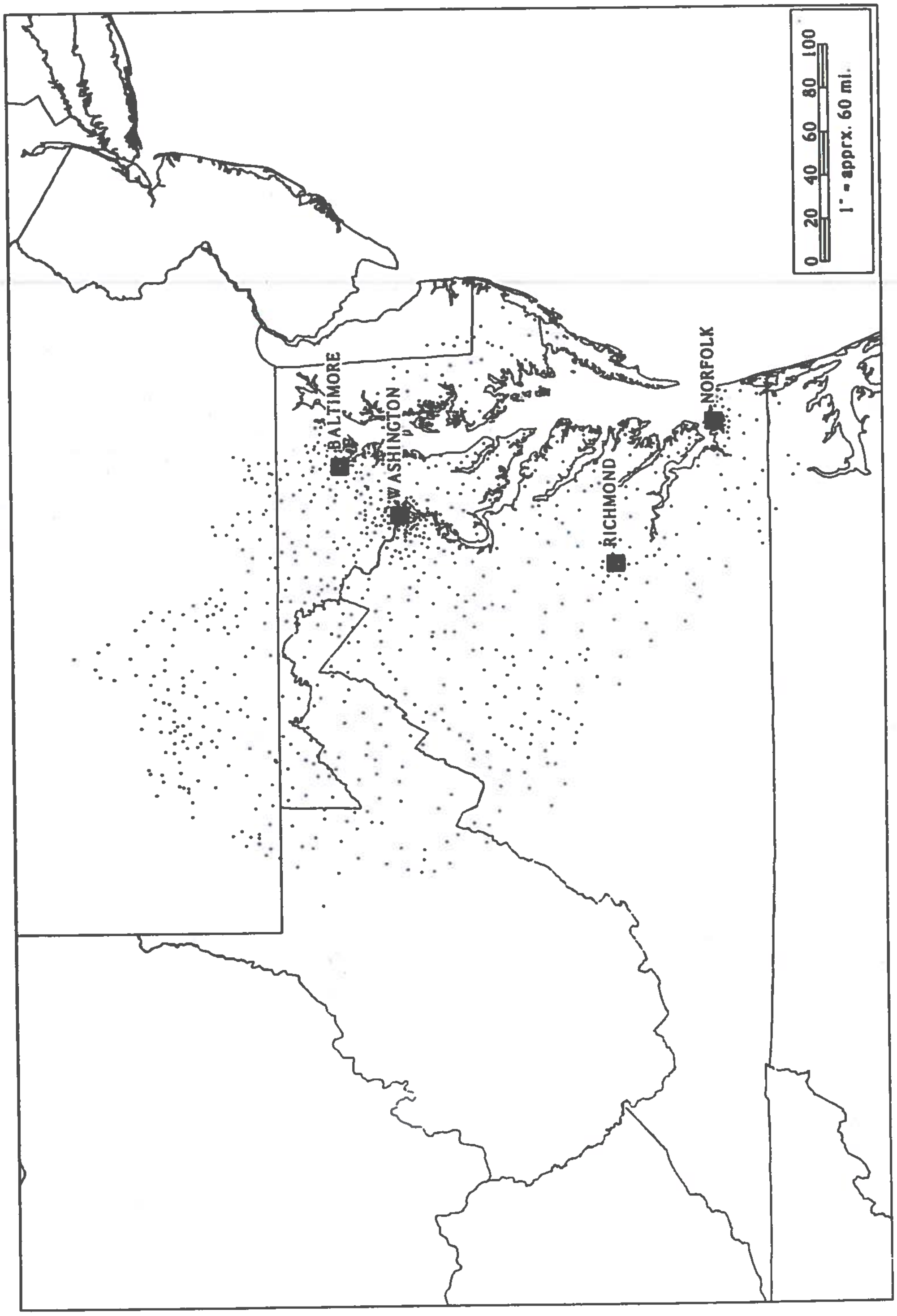
- Expand the industry's market scope by further reducing drayage and terminal operating costs and investing in such technologies as Iron Highway, RoadRailer, and other bimodal vehicles that reduce the breakeven distance in short-haul lanes.

APPENDIX A - TERMINAL SERVICE AREA MAPS & DRAYAGE DISTRIBUTION

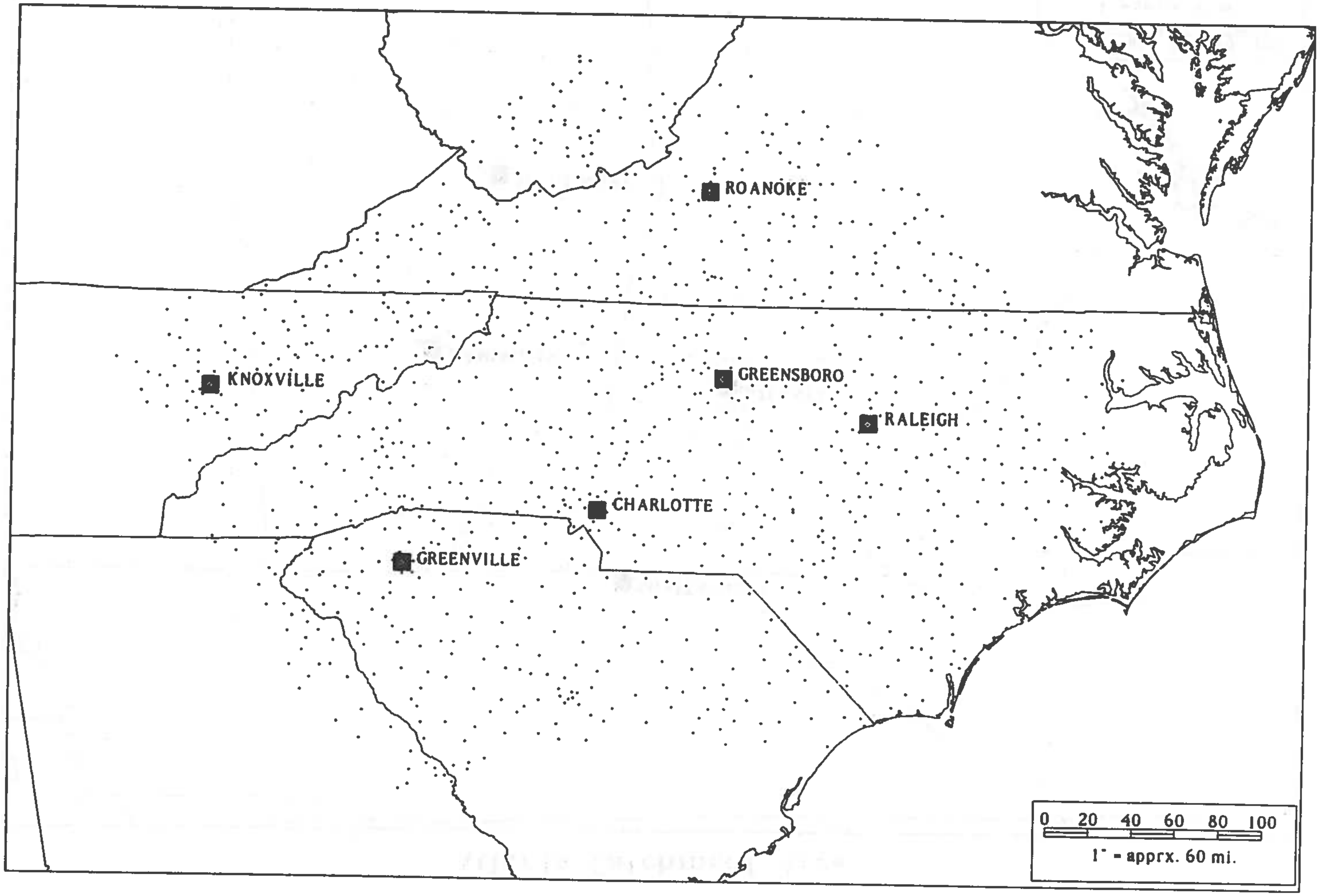
New Jersey–Pennsylvania Catchment Area



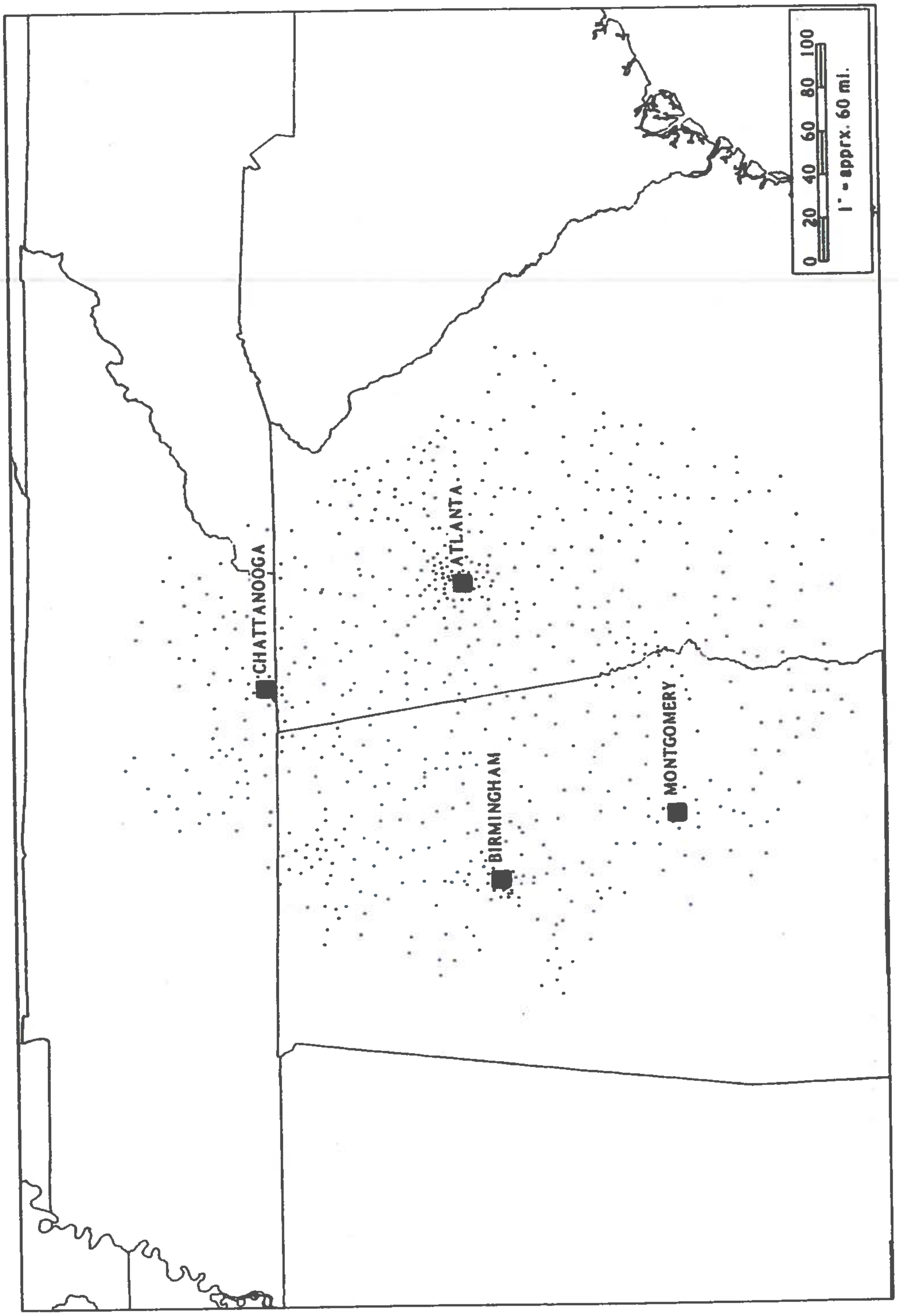
Alexandria Catchment Area



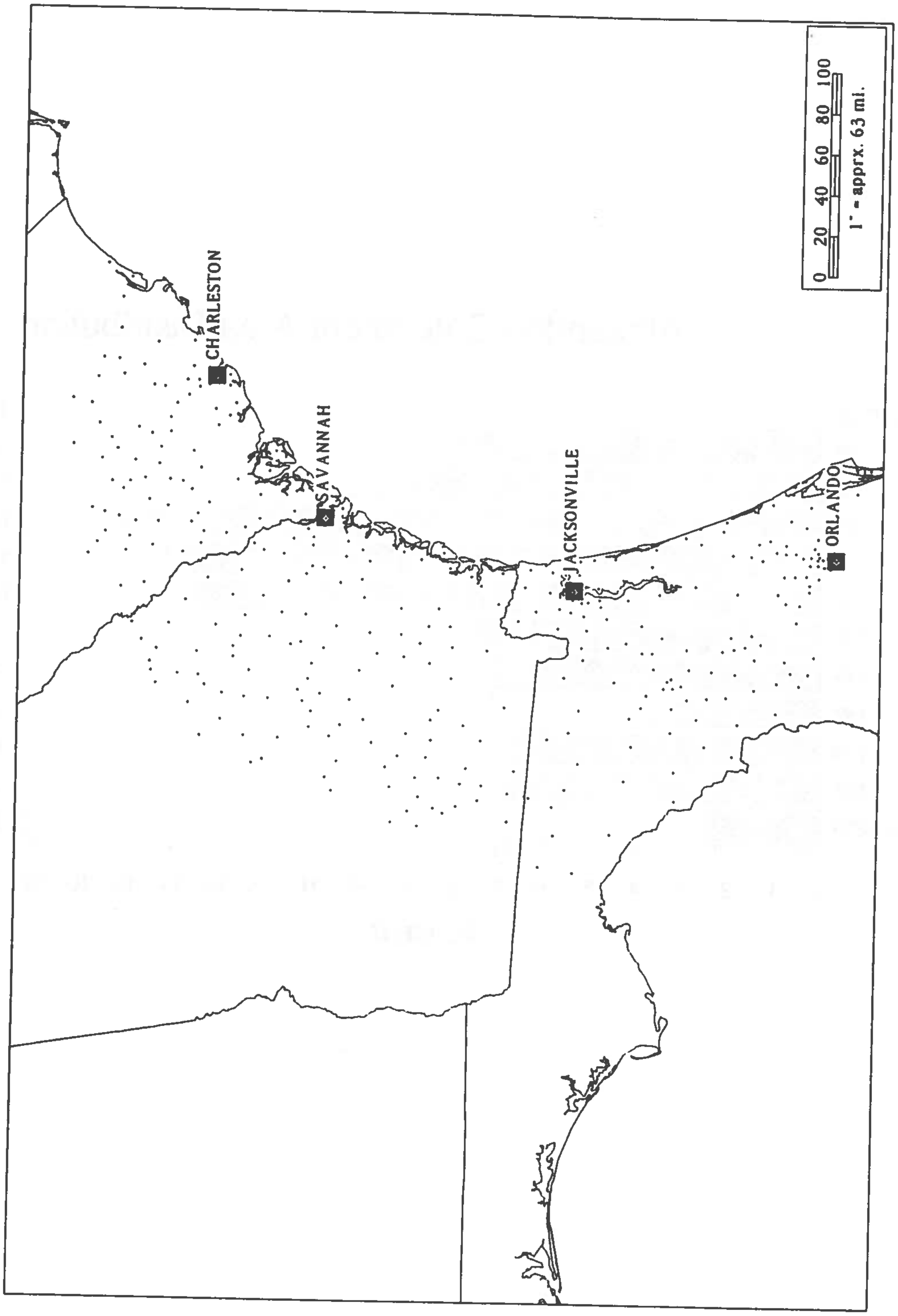
North and South Carolina Combined Catchment Area



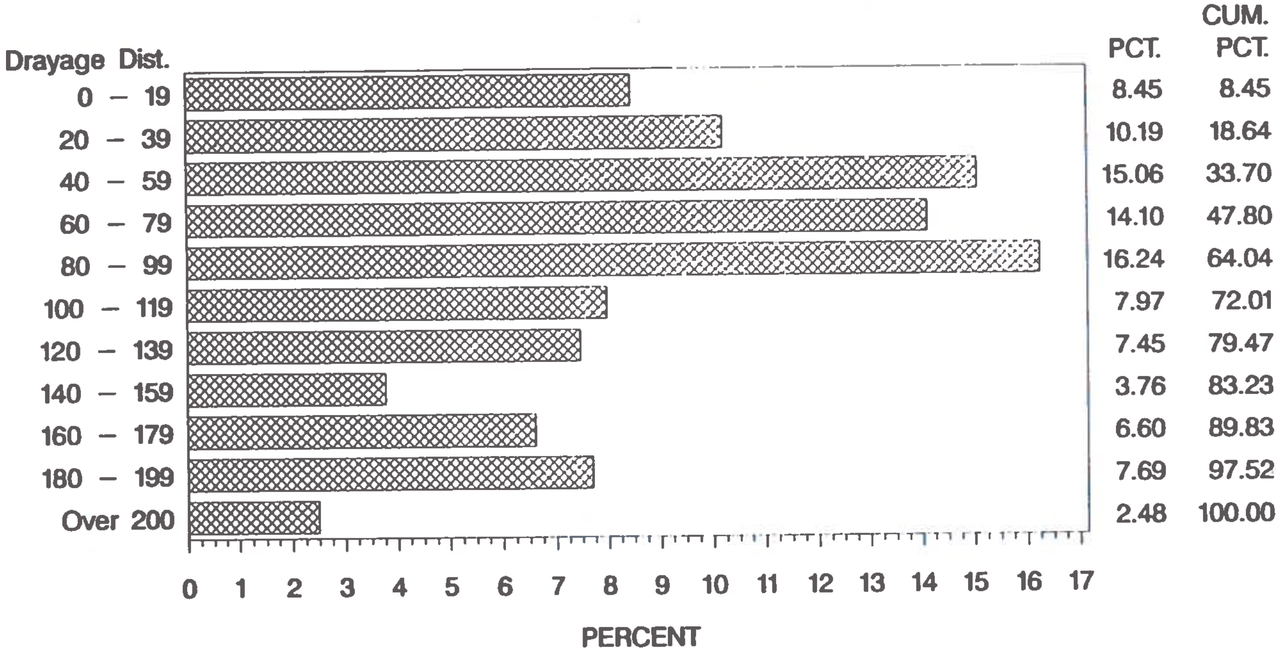
Atlanta Catchment Area



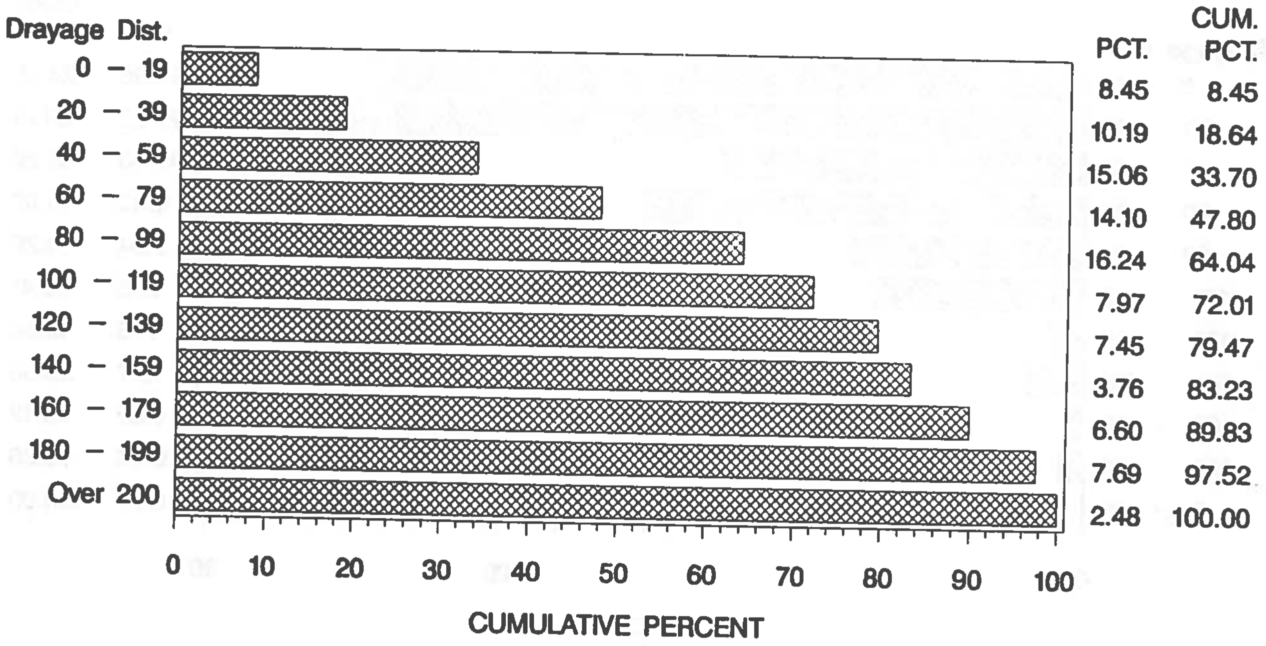
Jacksonville Catchment Area

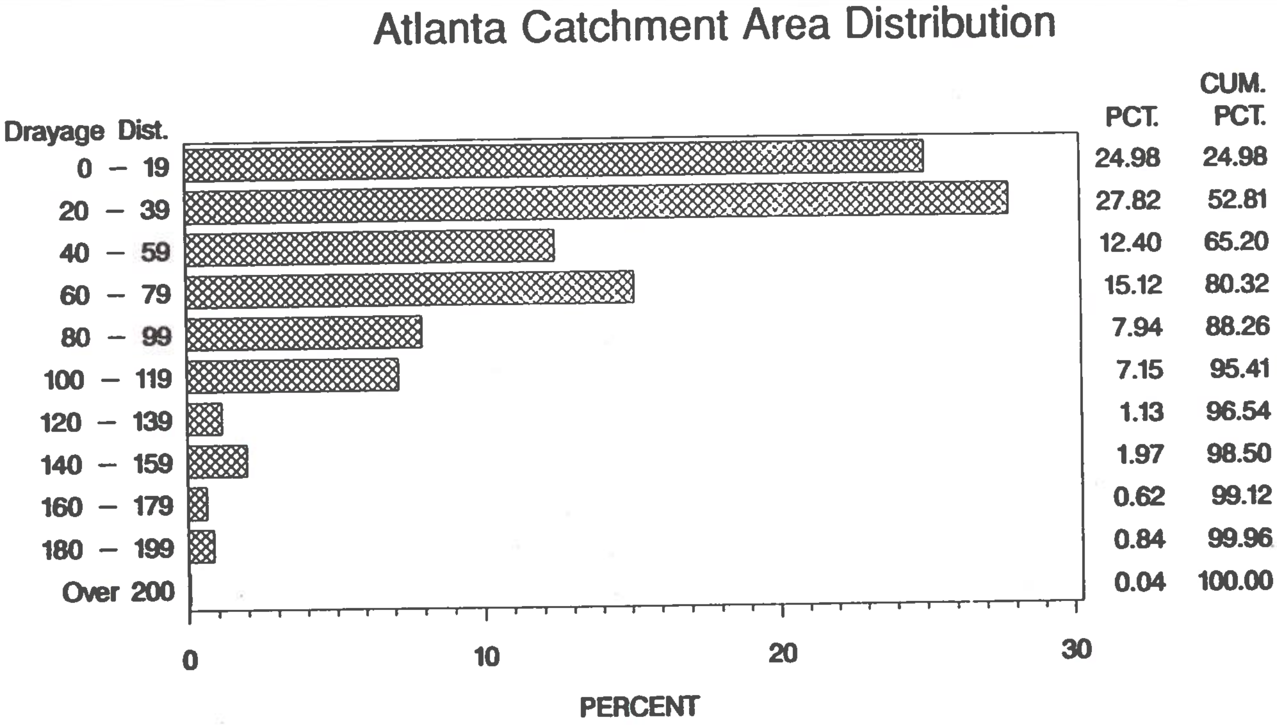


Alexandria Catchment Area Distribution

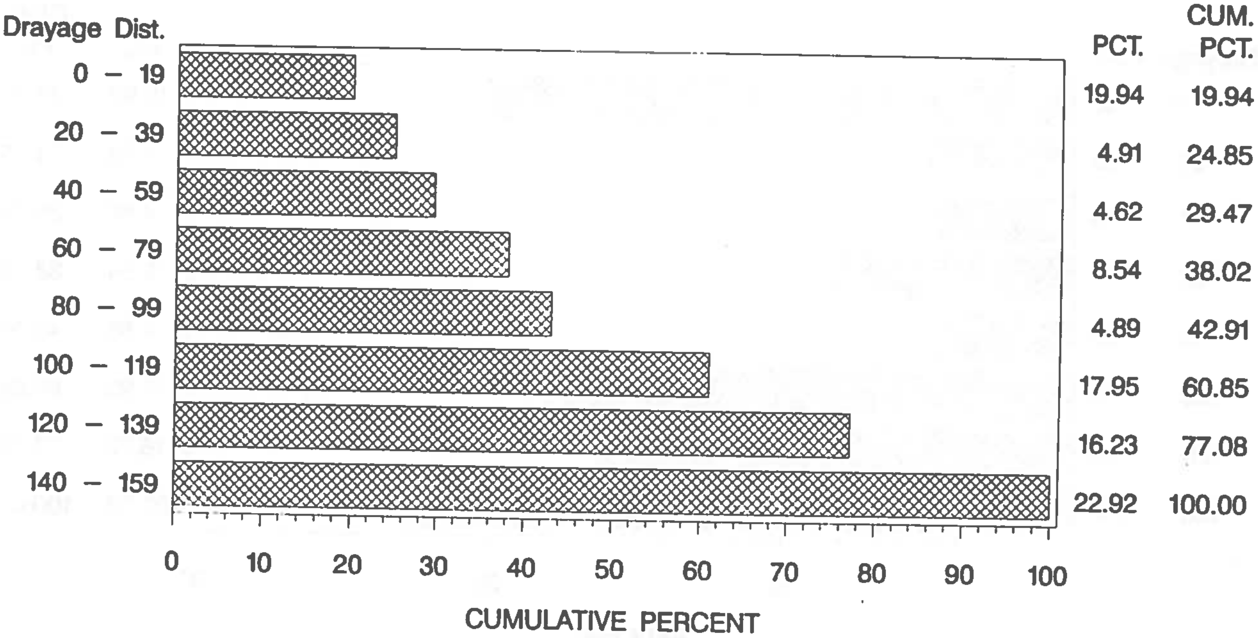


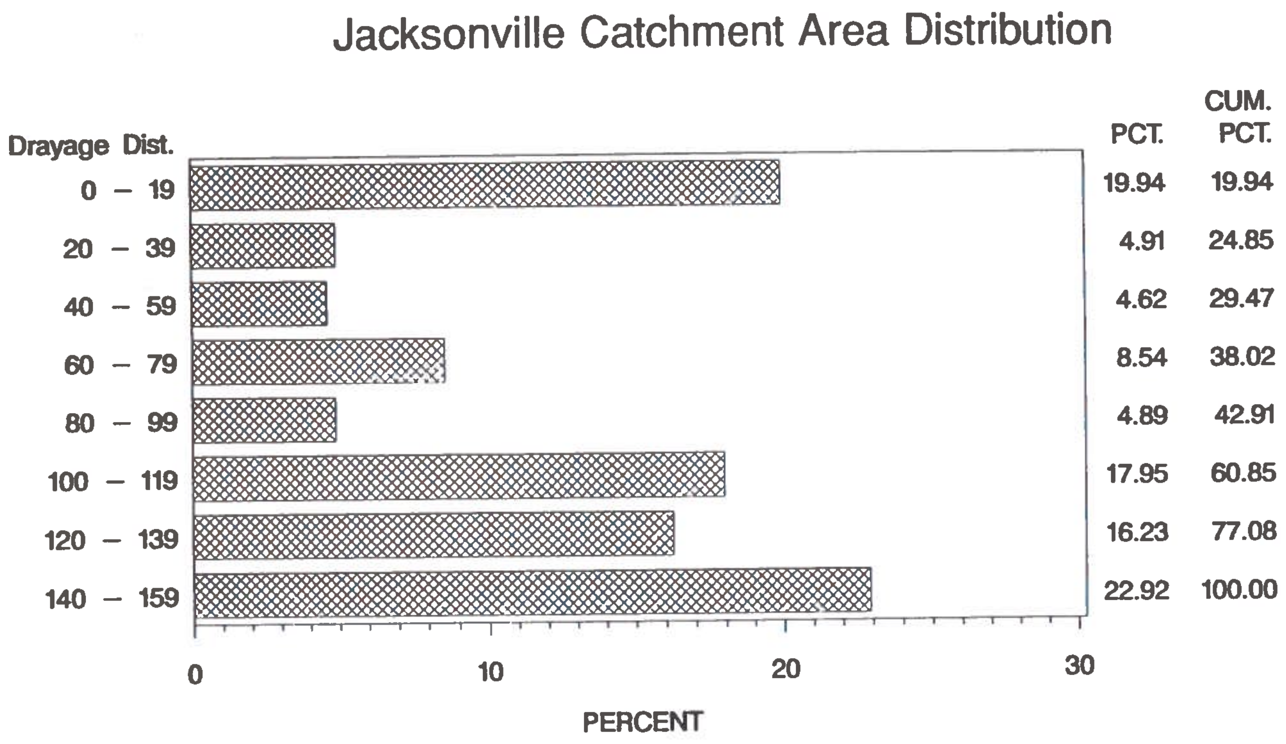
Alexandria Catchment Area Cumulative Distribution

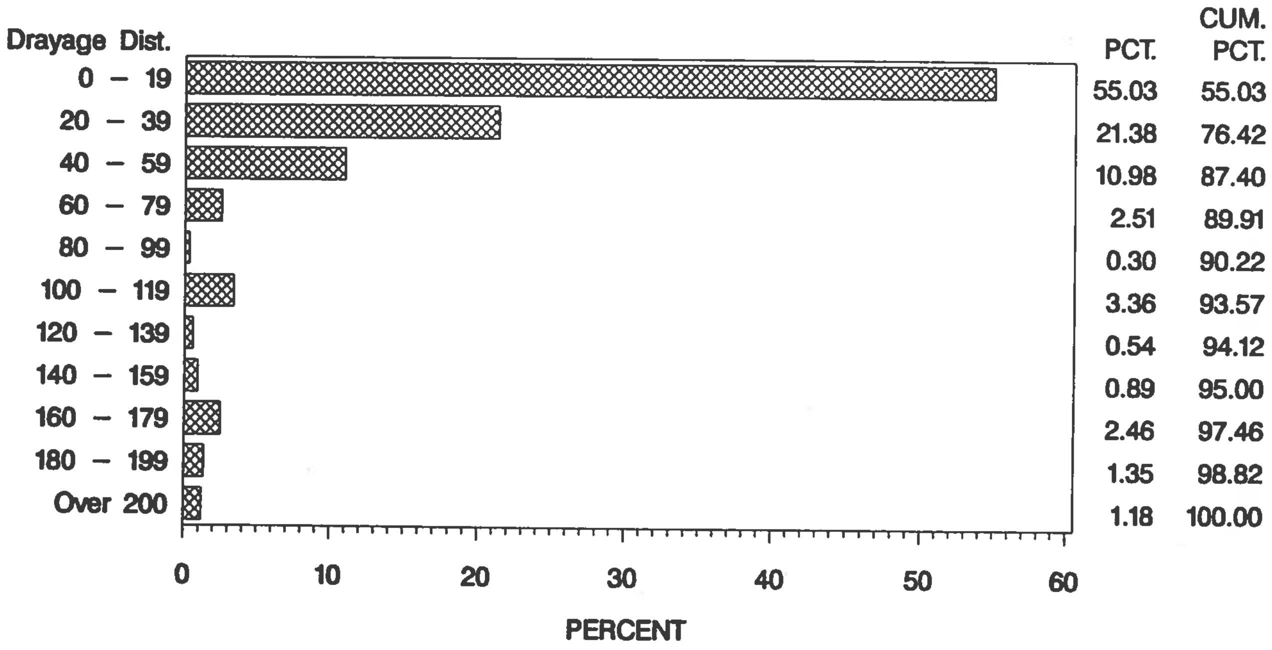



Atlanta Catchment Area Distribution
Drayage Dist.
PCT.
CUM. PCT.
0 – 19	24.98	24.98
20 – 39	27.82	52.81
40 – 59	12.40	65.20
60 – 79	15.12	80.32
80 – 99	7.94	88.26
100 – 119	7.15	95.41
120 – 139	1.13	96.54
140 – 159	1.97	98.50
160 – 179	0.62	99.12
180 – 199	0.84	99.96
Over 200	0.04	100.00
0
10
20
30
PERCENT

Jacksonville Catchment Area Cumulative Distribution




Jacksonville Catchment Area Distribution
Drayage Dist.
0 – 19
20 – 39
40 – 59
60 – 79
80 – 99
100 – 119
120 – 139
140 – 159
PCT.
CUM. PCT.
19.94 19.94
4.91 24.85
4.62 29.47
8.54 38.02
4.89 42.91
17.95 60.85
16.23 77.08
22.92 100.00
0
10
20
30
PERCENT



NY/Northeastern NJ Catchment Area Distribution

APPENDIX B - CIRCUITY MODEL DESCRIPTION

1.0 INTRODUCTION

The intent of the models developed for this corridor study are: 1) to allocate existing rail intermodal terminal truck traffic to origins and destinations, and 2) to determine end-to-end substitute truck routes from each origin to each destination. In order to allocate terminal shipments to origins and destinations, terminal service areas are defined and the likelihood of draying to or from any given location within the service area is estimated. Truck shipments for drayage to an intermodal terminal or *substitute* point-to-point truck shipments can be assigned to a highway network by finding the least cost route. Using the estimated shipment levels at each origin and each destination, the shipment level from each origin or destination can be assigned as a flow on the network.

1.1 Partition the Network into Intermodal Terminal Service Areas

Each intermodal terminal serves a particular area, within reasonable driving distance for drayage. The most important intermodal terminals are generally located closest to major concentrations of shippers and consignees, usually in major metropolitan areas. Such areas are generally served by more than one railroad. Some of the most important terminals located in the study area do not account for major north-south flows corridor flows, but instead specialize in shipments in other corridors.[1] Less important terminals with lower volumes exist either where the area is not in proximity to a large enough pool of potential users to justify the high levels of service or where the length of haul in the corridor is too short to be competitive with truck. Smaller markets are often served by only one carrier for reasons such as proximity to their main line.

The network consists of highway links[2] and nodes (intersections) with ZIP code centroids connected to the network at the closest intersection. Each intermodal terminal, ***i***, served by one or more railroads, was also attached to the network. Each railroad, ***r***, serves a set of terminals ***R***. The network was partitioned for each railroad into intermodal terminal service

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[1] Terminals such as Norfolk, Charleston, and Savannah primarily serve east-west commodity flows and port traffic.

[2] Each highway link has a distance and travel time attribute for least cost path calculation.

areas by assigning each ZIP centroid, k, to a terminal, $i \in R$. The terminal with the lowest drayage cost[3], D_{ik}, is selected, setting the indicator variable, δ_{ikr} to 1; otherwise δ_{ikr} is set to 0[4].

$$\delta_{ikr} = \begin{cases} 1, \text{ if } D_{ik} = \underset{i \in R}{\mathrm{MIN}}(D_{ik}) \\ 0, \text{ otherwise} \end{cases} \tag{1}$$

1.2 Allocate Intermodal Truck Traffic

The manufacturing employment level for each ZIP code, obtained from the *Census of Manufactures*, is specified by E_k. Each rail shipment is defined as one intermodal unit, representing a trailer or a container. The probability of drayage to or from a specific ZIP code within the terminal service area is

$$P(IMU_{ikr}) = \frac{E_k}{\sum_k E_k \delta_{ikr}} \bullet \delta_{ikr} \tag{2}$$

The number of intermodal units shipped to and from ZIP code, k, from terminal j is a fraction of the total traffic (IMU_{ij}) between intermodal terminals i and j. It is expressed as

$$IMU_{ijkr} = IMU_{ijr} \bullet P(IMU_{ikr}) \tag{3}$$

In effect, this allocation method assigns traffic to each ZIP code, subject to service from a terminal, on the basis of the ZIP code share of manufacturing employment. For example, a ZIP code with a 2 percent share of the service area employment would originate and terminate 2% of the intermodal terminal traffic.

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[3] The drayage cost was calculated as \$.56 per kilometer (\$.90 per mile) and \$30 per hour.

[4] In case of a tie, only one terminal is selected.

1.3 Traffic Allocation With Attenuation

In reality, not all of these drayage moves, given above, will occur. For some shipments, a drayage move to an intermodal terminal would be in the "wrong" direction. The tendency not to dray in the "wrong" or out-of-the-way direction to a terminal may be accounted for by performing an attenuation analysis based on the relative cost of a complete intermodal shipment compared to an all-highway alternative. The origin-destination ZIP pairs which have a high intermodal cost relative to other ZIP pairs are less likely to ship intermodally, especially if the cost is high relative to the all-highway cost.

The intermodal terminal cost model used in the analysis consists of the following variables:

D_{oi} - Origin drayage cost for ZIP o to terminal i
D_{dj} - Destination drayage cost for ZIP d from terminal j
R_{ij} - Intermodal rail cost for terminal i to terminal j
T_{od} - Substitute truck cost from origin o to destination d

The relationship

$$\alpha T_{od} > D_{oi} + R_{ij} + D_{jd} \tag{4}$$

must be true if intermodal rail movements are to be selected at all. A scale factor α, less than one, may be specified to account for a possible bias in favor of the shorter travel time in the all-truck alternative. Let A_{od} be the set of all shipments for which the condition (4) is true.

If the origin ZIP code, o, is in the set I of ZIP codes served by terminal i and railroad r, and the destination ZIP code, d, is in the set J of ZIP codes served by terminal j, then f_{odr} is the fraction of destinations $d \in J$ which can be reached from the origin $o \in I$ using railroad r

$$f_{odr} = \sum_{IMU_{odr} \in A} \mathrm{P}(IMU_{jd}) \tag{5}$$

and the share of traffic which could possibly originate from origin o is

$$F_{oi} = \sum_{d \in J} P(IMU_{odr}) \cdot f_{odr} \tag{6}$$

Traffic from terminal ***i***, served by railroad ***r***.to terminal ***j***, is reallocated within the service area ***I***

$$IMU_{odr} = \frac{IMU_{oir} \cdot F_{oi}}{\sum_{o \in I} F_{oi}} \tag{7}$$

This normalizes drayage levels to account for the possibility that not all destinations in ***J*** are likely to be served from all origins in ***I***.

The relative attraction of traffic between an origin ZIP and a destination ZIP is inversely related to these factors. That is, the lower the drayage cost, and the more direct the route, the higher the proportion of traffic that would use this route. The cost formulation increases in significance when the intermodal haul is short and the terminal catchment areas area large.

The fraction of shipments which remain is multiplied by the employment percentage for each ZIP and then the terminal area factors are re-normalized to sum to one. For example, if a ZIP in Atlanta which has 2% of the employment can reach only half of the ZIPs in the Alexandria terminal catchment area, the probability of a shipment to or from the ZIP becomes ***.02 * .5 = .01***. This insures that if a shipment from an origin ZIP code must travel in a direction away from its final destination to reach an intermodal terminal, the additional drayage distance will add cost while the corresponding highway shipment cost will be reduced.

As a practical matter, rather than using a distance-based continuous cost function, a discrete function that projects the number of drayage shipments per day to a given ZIP centroid was used instead. This is consistent with the nature of intermodal terminal drayage, where a substantial non-divisible portion of every move is spent at terminals and modest differences in drayage distance do not have a significant bearing on cost or attractiveness of the service. A ZIP code that can be drayed three times in a given day is more attractive than one that can only be drayed twice. In addition, intermodal moves to a ZIP code that required a dray in excess of one day were excluded.

APPENDIX C - MODEL APPROACH

1.0 APPROACH DATA

1.1 Data

The analysis depended most heavily on data from the *Census of Manufactures* and the *Interstate Commerce Commission Waybill Sample*. From the rail carriers, intermodal service schedules were used to evaluate service levels at terminals. In addition to intermodal traffic volumes, vehicle counts for selected segments along the corridor which would be used for the alternative all-highway move were compared, when available. Such data was obtained from the Highway Performance Monitoring System (HPMS) database.[1]

The *Carload Waybill Statistics*, usually known as the ICC Waybill Sample, is a statistically selected sample of all class I railroad waybills. VNTSC extracted all of the waybills from the 1991 waybill sample flagged as intermodal.[2] The sample includes the origin railroad (SCAC), the origin terminal standard point location code (SPLC), origin freight station accounting code (FSAC), destination SCAC, destination terminal SPLC and FSAC, and the number of intermodal units (IMUs). This data does not include information regarding the actual location of the shipper or consignee. Hence, the drayage portions of the move are not specified.

The enhanced *Oak Ridge United States Highway Network*, supplied with TransCAD, was the basis for the Southeast truck network used in this analysis. The network was reduced to a 13-state and District of Columbia highway system stretching from southern New York state to Florida and included West Virginia, Tennessee, and Alabama.

The reduced network consisted of 14,834 links and 9,439 intersection nodes. The highway layer link attributes specifying distance and travel time were used in the analysis. Additional link attributes included highway route designations, status, and location. Node attributes in the intersection layer included state and nearest place.

Data from the *1987 Economic Censuses* (specifically, the Census of Manufactures), collected as part of the U.S. Economic Census was used for manufacturing employment. This data includes the number of manufacturing employees at the ZIP code level. While this data is

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[1] See Appendix D for a more detailed discussion of the data sources used for this analysis.

[2] The selection consisted of all records with the TOFC plan field set to a non-zero value. At the time of writing, it is not clear that all RoadRailer service is marked as TOFC. Some may be classed as boxcar traffic. A TOFC question flag exists in the waybill sample, but was not used in the initial selection.

available at the 3-digit Standard Industrial Classification Code level, resource constraints precluded detailed analysis of the commodities manufactured. Data for ZIP codes in the 13 states and the District of Columbia was extracted from the database, and the employment by size category data were summed to calculate employment level for each ZIP code.

This step entailed building a table of relevant manufacturing and "other" employment data by ZIP code using the 1987 Census of Manufactures. Although manufacturing employment appears to predominate in the production of intercity truck shipments (discussed in a recent San Francisco Bay Area truck shipment generation study), "other" employment may also be significant. Employment data describing other relevant activities, particularly warehousing, were aggregated by "place" rather than ZIP, making it much less useful for estimating truck shipments. Because the balance between consumption and manufacturing may vary from region to region, the ratio of manufacturing employment to total truck and intermodal shipments may differ at the corridor ends even if all other factors such as geographic dispersion and intermodal service levels were the same. One would, however, continue to expect the spatial *distribution* of shipments to correlate with the spatial employment distribution. Zero and low employment ZIPs were removed, since very small manufacturing operations are much less likely to handle goods in truckload volumes.

The location of the relevant intermodal terminals was determined by consulting with railroad managers and confirmed using the *Official Railway Guide*. These terminals were identified from origin-destination data as generating significant traffic within the corridor. It was necessary to expand the number of terminals beyond those in the study area in order to determine if traffic would go to a terminal within the study area or one outside. (For example, shipments in South Carolina would be more likely to be trucked to Greenville rather than Atlanta and then backhauled north.) The corridor area terminals were manually located by address and confirmed in conversation with terminal managers and staff. In this analysis the ZIP code centroid coordinates were used to locate some terminals. Major terminal locations were checked visually for location in TransCAD.

Finally, the *Highway Performance Monitoring System* (HPMS) is a database of highway characteristics maintained by the Federal Highway Administration (FHWA) using data collected by individual states. Commercial vehicle percentages of 24-hour traffic volumes are estimated from sample sections with similar characteristics. Although heavy truck volumes are not specified, the percentages of heavy trucks in the sample can be estimated based on the characteristics of the highway section.

Alternative truck movements between terminal service areas may not always follow the optimum route which would be identified by a model. In this study a small number of nearly equivalent highway routes were identified which under a given set of weather and traffic conditions may be the preferred route for shipments. Highway network data available to the modeler does not account for differences in "link quality" which may affect choice of route. To some extent, better routes can be selected by raising per hour operating costs and lowering per kilometer operating costs slightly. This removes bias in favor of shorter but slower highway routes which may have lower actual speeds than the maximum speed because of traffic signals, curves, grades, and other factors.

1.2.1 Intermodal Waybill Origin-Destination Database

The ICC waybill sample was aggregated by origin-destination railroad, SPLC and freight station accounting code (FSAC) to define a terminal. In certain cases aggregation of FSAC or "similar" SPLCs referring to the same terminal for a railroad was required. Missing SPLC records and inconsistencies between the waybill and the SPLC data, primarily related to the merger of Southern Railway and Norfolk and Western Railway into Norfolk Southern during the waybill sample period, were resolved as part of the aggregation process. The result of this phase was the creation of an intermodal origin-destination matrix for the railroad-SPLC-FSAC combinations relevant to the study.

Origin-destination pairs serving the corridor were then selected from the origin-destination matrix. Low traffic level terminals were also identified and eliminated from consideration. In addition, locations where traffic volumes could not be estimated from employment data were identified. Such locations include on-dock ramps and ramps captive to a specific shipper such as United Parcel Service. Discussions with the carriers indicated that in 1991 there were no such terminals within the study corridors.

Each waybill record was expanded using the expansion factor provided to determine the number of trailers or containers, referred to as intermodal units (IMUs) represented by each waybill. Waybills were sorted according to origin SCAC, origin SPLC, origin FSAC, destination SCAC, destination SPLC and destination FSAC and aggregated. An origin-destination table for each unique SCAC/SPLC/FSAC pair was created. The waybill sample was found to contain no reported errors with the exception that intermodal equipment for which no UMLER[3] equivalent existed was flagged.

The geocoded SPLC file supplied by VNTSC was matched with each waybill record and the

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[3] The only error flags in the waybill extract were "UMLER record not found" or "no TC UMLER record found" for the rail car. Such errors are possible because of equipment renumbering, acquisitions, or retirements.

SCAC/SPLC/FSAC combinations in the Waybill Sample were merged with the SPLC database to attach place names and geographic information to the Waybill origin-destination data. Because of the merger of Norfolk and Western and Southern Railway into Norfolk Southern during the period of the waybill sample, aggregation of Southern Railway FSACs with Norfolk & Western FSACs and conversion to Norfolk Southern FSACs was required.

Origin-destination pairs within the corridor were extracted and ranked by volume. Low volume pairs, generally one waybill record, were removed. The origin-destination volumes for competing railroads and smaller regional terminals were consolidated for reporting purposes.

1.2.2 Application of Geographic Information System

The ZIP code employment data and intermodal terminal locations were integrated into the TransCAD US highway database to build a truck network which connected ZIP centroids and intermodal terminals with the highway network.

The Oak Ridge highway network from TransCAD was used for the base network. Intermodal terminals and approximately 7000 geocoded ZIP centroids were added, and links with truck restrictions were removed from the network. Intermodal terminals were located by geocoded Standard Point Location Code (SPLC) data provided by the Volpe National Transportation Systems Center. The location of each terminal, necessary for determining the appropriate highway off-ramp(s) and local street access to a terminal, was obtained from the Official Railway Guide and railroad marketing sources.

A TransCAD layer was built with employment data, calculated employment, and number of establishments. The ZIP database was geocoded using the "ZIPMATCH" procedure in TransCAD. Errors in the Census of Manufactures database were highlighted by a failure to geocode a small number of ZIP codes.[4] The ZIP code database was reduced to the set of centroids located within areas which would be served[5] by the intermodal terminals within the corridor.

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[4] ZIP codes not listed in the 1993 US Post Office ZIP code list were merged by name or dropped from the study. A group of ZIPs in Florida appeared to have been numbered incorrectly.

[5] The maximum distance from any corridor terminal was initially set to 355 kilometers (220 miles). Not all ZIP centroids within 355 kilometers (220 miles) of Kearny, NJ, were included because the service area could conceivably extend into Southern New England.

The node layer in the highway database was expanded to include columns for the ZIP code, and columns for each terminal and highway partition. Each partition required columns to define the terminal or highway node, cost, and distance. Nodes and links corresponding to each ZIP were created in the highway database using the "PT2LINE" module to locate ZIP centroids in the highway layer and attach them to the spatially closest intersection. There were 6725 ZIP codes included in the final network, located in 13 states and the District of Columbia. ZIPs not located within the reduced highway network were dropped. The ZIP code was copied from the ZIP centroid layer to the highway intersection layer using the "COLUMN TAG" operation to identify the nearest ZIP code to the ZIP centroid. The ZIP code level employment and establishment count were moved into the highway intersection layer using the "COLUMN AGGREGATE" operation to sum co-located ZIP employment and establishment counts. Some aggregated employment and establishment counts which were duplicated in the network (because the coordinates were duplicated) were removed manually in TransCAD and the remaining ones were removed in SAS.[6]

A TransCAD layer was added to locate the terminals used in the analysis. The terminals were added to the highway network using the "PT2LINE" module to add nodes to the highway network corresponding to the terminal locations. The terminals used in the analysis are shown in Table C-1.

1.2.3 Network Partition

For each railroad, each ZIP code was assigned to the "closest" intermodal terminal, defined in terms of least cost.[7] (In most cases this was also the shortest distance route.) This insured that ZIP codes which are served by terminals outside the corridor boundaries were not unwittingly brought into the corridor. For example, traffic from Southern Alabama will generally travel to Mobile rather than Atlanta to move to Alexandria. This process is known as partitioning the network. After this step was completed, ZIP centroids served by terminals outside the study area were removed from further consideration. Also, based on information gained from our discussions with the carriers, ZIP centroids for which drayage costs exceeded a maximum were dropped from the analysis.

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[6] Not all ZIP code centroids are geographically distinct and about 700 (10%) are co-located with another ZIP, primarily in larger post offices. The resulting extra TransCAD records were removed in SAS to prevent double counting.

[7] A truck cost of $.56 per kilometer ($.90 per mile) and $30.00 per hour as shortest path parameters in the network partition was used. Total costs were consistent with Lawrence and Shugart.

Table C-1. Terminals Included in the Analysis

Carrier	Location	Comments
Conrail		
	Kearny, NJ	New Jersey, New York end point for CSX and NS traffic
CSX		
	Alexandria	Relocated service to Baltimore after 1991
	Atlanta	
	Baltimore	CSX alternate corridor end point
	Charlotte	
	Jacksonville	CSX corridor end point
	Memphis	Limit Atlanta service area
	Philadelphia	
Florida East Coast		
	Miami	South Florida end point for CSX and NS traffic
Norfolk Southern		
	Alexandria	NS corridor end point
	Atlanta	Triple Crown at separate location
	Greensboro	
	Greenville, SC	
	Jacksonville	
	Memphis	Limit Atlanta service area
	Savannah	

The partition of the ZIP centroids to the least cost terminal for each railroad did not account for differences in observed levels of traffic or known differences in levels of service. (An intermodal load may be drayed to a more remote terminal if the level of service is substantially better.) In some cases high volume terminals were removed from consideration prior to the partition when the amount of traffic along the corridor was not significant. For the remaining terminals, only a few terminals had significant corridor traffic, suggesting that service levels are important and that significant volumes are required.

It was not possible to use "SHORTEST PATH" procedures in TransCAD to designate flows using distance rather than cost was used to approximate the distance on the least cost routes.[8] Truck kilometers traveled calculations were based on the distance to each ZIP centroid and the percentage of traffic allocated to it rather than the equivalent sum of the link distance and the percentage of traffic assigned to the link using an "all or nothing" traffic assignment.[9]

An "all or nothing" traffic assignment using minimum cost was used to assign truck traffic levels to links. The links with traffic were selected in TransCAD and used to generate a network. A network partition on the reduced network using minimum distance was used to establish VKT on the selected routes.

1.2.4 Shipment Allocation

To estimate the ultimate destinations of the shipments, manufacturing employment by ZIP code was used as a proxy for relative trip generation levels. This is consistent with prior goods movement studies, which generally found that the level of employment is the best single predictor for goods movement trips.[10] Using manufacturing employment as a proxy for goods movement trip generation, it becomes possible to estimate the kilometers from each zone of employment to the intermodal terminal and to a cordon[11] line across the corridor. That process is discussed in the following section. It was assumed that a shipper uses the terminal with the lowest cost once a railroad has been selected to move the shipment. No attenuation of flow because of distance or proximity to a competing carrier's terminal was assumed. Instead, it was assumed that some shipments would go to the closest terminal and that other shipments would go to the closest major terminal (as defined in the Waybill Sample).

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[8] The shortest distance allocation may underestimate highway mileage, a conservative assumption, particularly for long distance truck trips.

[9] Alternatively, an all or nothing traffic assignment can be performed using minimum cost and the links in the network with flow can be selected. The selected links are used to build a network which can then in turn be used to do a distance-based network partition or traffic assignment confined to the least cost routes. The network partition generates terminal to end-point costs which can be used to calculate VMT on an individual end-point basis. A traffic assignment can be used to calculate VMT on a per link basis, allowing computation of total or sub-area VMT using a spatial select operation in TransCAD.

[10] Previous goods movement studies are reviewed in Ogden (1992).

[11] The Virginia-North Carolina border was defined as the cordon line in the study corridor. The major crossing points were I-95, I-85, US-29, I-77, and I-81. All highway shipments between northern and southern points in the study corridor were assumed to cross the cordon line at one of these points.

The level of service at different terminals for the same railroad was found to be quite different[12] and corresponding traffic volumes much lower, suggesting that some shipments would be drayed to a terminal with better service or would have been shipped entirely by highway. A network partition with only major terminals was tested and compared with a partition including all the terminals.[13]

For each ZIP code served by a railroad intermodal terminal, the ratio of manufacturing employment in that ZIP code to total employment in the terminal service area was calculated. This ratio (which sums to one for all the ZIP codes served by a terminal) was used to allocate traffic to each node. The product of the relative traffic and the node distance summed over all nodes is the average trip length from the intermodal terminal.[14]

With large terminal service areas and a relatively short rail distance between terminals, such as the two corridors that were the subject of this study, drayage forms a substantial part of a move. As a result, the likelihood of a potential shipment travelling intermodally will increase if it is drayed towards the final destination, while it will decrease if it must be drayed away (in the "wrong" direction) from the final destination. This "directionality" effect is discussed further in section 5.1.2.

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[12] The major terminals in this corridor had second-day service between the end points. Some secondary terminals without much corridor traffic generally required one or two extra days, the result of enroute switching or reloading at a major hub, such as Atlanta, during the course of the shipment.

[13] An upper cost limit of $330 to drayage was imposed to limit the size of the service area.

[14] Alternatively, if a traffic assignment is used to assign the relative terminal traffic to each service area link, then VMT can be calculated within subareas. This will determine the relative truck VMT impacts on links used for intermodal terminal access. The average truck distance travelled within the service area is the sum of the products of the link distances and the relative truck traffic for all links in the corridor. For example, a 6.4 kilometer (4 mile) link which handles 25 percent of the traffic would add 1.6 kilometer (1 mile) to the average truck distance.

APPENDIX D - INTERMODAL TERMINAL DATABASES

1.0 INTRODUCTION

Research into freight movements is useful for a better understanding of intermodal facility access and the impacts of intermodal operations on the transportation network. Terminal location information is essential for understanding the efficiency of intermodal operations. Locating current or future freight-related economic activity is a prerequisite to planning new intermodal terminal sites. Collection of data for planning intermodal networks requires integration of data from a variety of sources, where compatibility is by no means assured and access may be difficult because of ownership issues.

Geographic data sources for intermodal research are derived from various U.S. government sources including the Bureau of the Census, the U.S. Geological Survey and agencies of the Department of Transportation, state departments of transportation, and MPOs. Although trucks enter and exit from intermodal terminals every day, precise locations consistent with geographic data used for highway analysis are not always available. Addressing the specific needs of intermodal transportation planning, especially freight, requires consistent sources of geographic data.

The railroad waybill sample gives a comprehensive view of rail traffic flows but is not easily related to existing truck volume data. This memo describes selected data fields in the waybill sample and how they can be related to highway network and truck flows in order to compare intermodal traffic with truck traffic.

2.0 DATA SOURCES OVERVIEW

Data sources include the *Interstate Commerce Commission Waybill Sample* and the *Census of Manufactures*. The *Highway Performance Monitoring System* (HPMS) database is the source for estimates of highway truck flows. The *Oak Ridge United States Highway Network*, supplied with TransCAD, and the *Federal Railroad Administration Rail Network* are the basis for networks to relate goods movements to routes and terminals.

The *Carload Waybill Statistics*, known as the ICC Waybill Sample, is a statistically selected sample of all class I railroad waybills. Each sample waybill represents the end to end movement of a carload or intermodal shipment between an origin and destination with routing information. Intermodal waybills show only the rail portion of the shipment and do not specify the drayage portions of the move from the shipper to the intermodal terminal and from the intermodal terminal to the consignee.

The 1987 *US Census of Manufactures* provides detailed manufacturing employment data to the ZIP code level and warehousing employment to the "place" level with some commodity specific information. Manufacturing employment can be used to allocate freight shipment demand within a region, such as an intermodal terminal service area.

The *Highway Performance Monitoring System* data contain detailed vehicle type and link flows for a small sample of highway links and provide less detailed flow for all other highway links in the sample. Truck flow volumes on any given link can, in principle, be estimated from the actual flow and the link type using the sample flow percentages.

The *Oak Ridge Highway Network* provides major highway route attributes such as mileage and minimum travel time useful to selecting long distance truck routes. Additional link attributes include highway route designations and nearest place. The FRA rail database specifies railroad location, mileage, and ownership.

The process of integrating the data (exhibit 1) includes the following steps: 1) convert the waybill sample to rail origin-destination flows, 2) attach intermodal terminals and shipment origins or destinations to the highway network, 3) assign rail-related drayage or substitute truck trips to the highway network, and 4) locate HPMS truck flows at selected network locations for comparison. The remainder of this memo will focus on the task of extracting useful data from the ICC Waybill Sample and describe the information required to interpret fields necessary to convert waybills to origin-destination flows. The process of appending the intermodal rail shipment data to the highway network using a Geographic Information System (GIS) to spatially represent the flows is briefly described.

3.0 RAILROAD WAYBILL DATA

The ICC Waybill Sample is a weighted, approximately two percent, sample of Class I railroad waybills. It contains data for an entire year and is available in at least three forms: an ICC version, an AAR version and a Public Use version.[1] The Association of American Railroads (AAR) publishes a User Guide which provides an essential introduction and overview to the use of the Waybill Sample.

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[1] The public use Waybill Sample masks proprietary data, including railroad, routing, and revenue. The shipment origin and destination is each masked to one of the 192 Business Economic Area (BEA) zones.

3.1 Identifying Intermodal Shipments

Fields in the waybill sample define the origin, destination, the commodity, the type of equipment, the number of cars, tonnage, etc. Rail routing, detailed equipment information and error information fields are also included in the sample. Intermodal waybills are identified by a nonzero value in the TOFC or Container plan field, **TOF1.**[2] Possible additional intermodal waybills have a nonzero value in **FLAG1.**[3]

The *Universal Machine Language Equipment Register* (UMLER) file, maintained by the AAR, describes most freight cars, trailers, and containers used in interchange or commercial service. Some intermodal records may contain rail car information which was not found to have an UMLER[4] equivalent and are flagged in **ERR1**, error codes. Such records are considered to be valid.

3.2 Expanding Waybill Sample Data

Factored waybill data, the sample data expanded by the inverse of the sampling rate, can be used to estimate origin-destination flows. The expansion factor, **EXPN**, field in each waybill may be used to expand **UCAR**, the number of carloads and **NTRI**, the number of trailers or containers. Other fields such as **UTON**, the billed weight in tons,[5] or **UREV** may also be expanded. The AAR waybill sample, unlike the ICC sample, includes expanded fields to save the analyst the step of calculating factored values. Most intermodal waybill records will contain an expansion factor of 40, which is the standard for single car moves. The number of trailers per flat car will vary depending on the equipment. Standard "spine" cars may carry only one container or trailer. Articulated five-section double stack cars, on the other hand, may carry as many as ten 40-foot containers.

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[2] The TOFC plan describes the billing arrangement, railroad, third party, etc., for the shipment. If the arrangements at the destination are different than the origin, TOF2 will contain a value other than blank or zero.

[3] The intermodal equipment flag is set if definitive intermodal fields are missing values. It is set to *1* if the equipment used was intermodal and the weight of the shipment was in a consistent range or to *2* if the equipment was a RoadRailer (a trailer which can operate as a truck trailer or as a rail car).

[4] The only error flags in the waybill extract for the rail car were: *08, UMLER record not found*, or *13, no TC UMLER record found*. Such errors are possible because of equipment renumbering, acquisitions, or retirements.

[5] The **WGHT** field is the billed weight of the commodity is in hundredweight (CWT).

3.3 Finding the Waybill Origin and Destination

The six-digit Standard Point Location Code (SPLC) defines the origin and destination of the shipment. The first two digits of the SPLC define a state or province in the U.S., Canada or Mexico. Each origin and destination also specifies a three-digit railroad number (the AAR code) and a Freight Station Accounting Code (FSAC) specified by the railroad. The FSAC is the most precise indicator of the rail origin and destination of a shipment.

The origin and termination SPLC fields are **OSPL** and **TSPL**, respectively. The origin railroad, **ORR**, and the origin FSAC or station, **OSTA**, define the origin of the shipment and the termination railroad, **TRR**, and the termination FSAC or station, **TSTA**, specifies the destination. The SPLC, which specifies a place or a location, may not be specific to a railroad. For example, the SPLC location **380000**, Chicago, refers to a "place," while the SPLC, **380012**, that refers to Chicago, 63rd Street, is much more specific.

3.4 Waybill Commodities

The seven-digit commodity code (STCC) is specified in the **CMD** and **STCC** field. The STCC code in the waybill sample generally corresponds to the equivalent Standard Industrial Classification Code (SIC) at the (high order) two- or three-digit level. The high order two digits of manufacturing SIC codes are in the range 20 to 39 where detail is available, (or 0 in the census if not disaggregated). Railroad STCC codes range from 1 to 50 with the 20 to 39 range for manufactured goods. Hazardous materials are coded as STCC 49 in the **CMD** field but are described with the actual STCC in the **STCC** field. Unfortunately, about half the intermodal waybills are classified as STCC 46, miscellaneous mixed shipments or "freight, all kinds", making commodity tracking more difficult.

3.5 Intermodal Terminals and SPLC Database

The Standard Point Location Code (SPLC) database contains the name of the location, the FIPS code, and the state for each SPLC, making it possible to name the origins and destinations in the waybill sample. It also contains one or more FSAC and SCAC combination (rail station and railroad initials) associated with each SPLC. Each SPLC record also the contains the AAR numeric code (used in the Waybill Sample) corresponding to the SCAC. A list of these codes can be found in the *Official Railway Guide* or the *Official Railway Equipment Register*. The SCAC and FSAC codes may change from year to year as railroads open and close stations and change their networks. In the 1991 sample year, Southern Railway (SOU) and Norfolk Western (NW) were officially merged into

Norfolk Southern (NS), and the FSAC codes for most of the Southern Railway stations were changed.

Not all of the intermodal waybill origins or destinations as defined by a SPLC-SCAC-FSAC combination should be expected to match the corresponding entry in SPLC database. In addition to possible SCAC-FSAC changes, the SPLC may be "similar" or may refer to a nearby but different location. For example the waybill origin, Norfolk, may be coded as 261000 "Norfolk" or as 261001 "Norfolk FGN" (Norfolk International Terminal), which may indicate the existence of multiple ramps, particularly on dock ramps. If no SPLC matches the waybill sample, the place name from a nearby SPLC should be used or the terminal should be explicitly identified.

3.6 Intermodal Origin-Destination Database

The ICC waybill sample can be aggregated by origin-destination SPLC-SCAC-FSAC pairs. In certain cases aggregation of terminal SPLC-SCAC combinations for a railroad or combination of SCAC-FSAC combinations may be desirable. Disaggregation by STCC is also a possibility. Traffic may be aggregated by origin terminal or destination terminal, or origin-destination matrix combinations relevant to a particular study may be created.

Origin-destination pairs within a corridor may be extracted and ranked by volume. Low volume pairs, sometimes only one waybill record, should be discarded, for statistical reasons. The origin-destination volumes for competing railroads and smaller regional terminals may be consolidated for analysis purposes or to mask proprietary information.

4.0 TRUCK DATA

4.1 Highway Performance Monitoring System

The Highway Performance Monitoring System (HPMS) is a database of highway characteristics maintained by the Federal Highway Administration (FHWA) using data collected by individual states. Commercial vehicle percentages of 24-hour traffic volumes are estimated from sample sections with similar characteristics. Although heavy truck volumes are not specified, the percentages of heavy trucks in the sample can be estimated based on the characteristics of the highway section.

Alternative truck movements between terminal service areas may not always follow the optimum route which would be identified by a model. In this study a small number of nearly equivalent highway routes were identified which, under a given set of weather and traffic conditions, may be the preferred route for shipments. Highway network data available to the modeler do not account for differences in "link quality" which may affect choice of route. To some extent, better routes can be selected by raising per hour operating costs and lowering per mile operating costs slightly. This removes bias in favor of shorter but slower highway routes which may have lower actual speeds than the maximum speed because of traffic signals, curves, grades, and other factors.

5.0 TRANSPORTATION NETWORK DATABASES

The Oak Ridge U.S. Highway Network was the primary source for the Highway Network used in the analysis. The relevant fields included distance, speed (limit), the route name and facility type. The network is tiled by state with nodes wherever links (highways) cross state lines. Fields were added to the database in TransCAD to store results.

6.0 ECONOMIC DATA

6.1 1987 Census of Manufactures

The *1987 Economic Censuses* (specifically, the Census of Manufactures) contain employment data at various levels of aggregation by employment category and by SIC. The most disaggregated data are manufacturing employment by ZIP code and establishment size. Employment levels are given as ranges which may be used to estimate total employment by ZIP code. Employment in warehousing is aggregated to place level, making it difficult to allocate truck trips to such establishments.

6.2 ZIP Code List and ZIP Centroids

The ZIPNAME database from the 1987 Economic Census was used to supply place names, state and 2-digit FIPS code for the for the manufacturing employment data. It contains columns for ZIP code, with place name, state abbreviation and the two-digit state FIPS code.

7.0 INTEGRATION OF TRANSPORTATION AND ECONOMIC DATA INTO A GIS

The ZIP code employment data and intermodal terminal locations must be appended to the US highway database to build a truck network which connects ZIP centroids to intermodal terminals using the highway network. Links with truck restrictions may be identified and removed from the network.

Intermodal terminals were identified from the waybill sample. The matching SPLC, railroad, and FSAC entries were selected from the geocoded SPLC table and joined to the terminal traffic table. The street address of each terminal, helpful for locating the appropriate highway off-ramp(s) and local street access routes to the terminal, was obtained from the Official Railway Guide or railroad marketing sources.

Once the necessary terminal and traffic generators are attached to the highway network, it is possible to use the GIS to find least cost routes between the origin and the destination or from the origin to the loading intermodal terminal and to the destination from the unloading intermodal terminal. Locations served by a network of intermodal terminals may be modeled by selecting a set of traffic generators for each terminal. The waybill intermodal traffic at each terminal may be allocated to drayage locations assigned to the terminal using some measure of economic activity such as manufacturing employment. One means of allocating locations to intermodal terminals is to partition the network into service areas where each location is assigned to the terminal with the lowest access cost. The HPMS link volumes may be compared with truck volumes estimated from whichever model is applied to allocate truck trips.

APPENDIX E - PROTOTYPE INTERMODAL TERMINAL MODEL/SENSITIVITY ANALYSIS

1.0 INTRODUCTION

The prototype terminal model developed in Task I of this study was designed to permit testing of alternative terminal scenarios and analyze the sensitivity of terminal capacity to key variables.

The following graphs analyze the impact of intermodal practices using sensitivity analysis on the spreadsheet model of a prototype intermodal terminal. Three main groups of input variables were tested,, corresponding to the three groups of inputs on the spreadsheet model (Terminal Characteristics, Traffic Mix, and a full range of possibilities of one input, all other input variables were assumed to remain constant at their given default values. (Only one input, i.e., was changed at a time.)

The effects of changing each input variable were shown on different outputs. For example, the effects of changing Total Working Track Length in Feet were shown on the Average Track Capacity, Lifts Per Year, Overall Average Capacity Limit, Lifts Per Shift and the Peak Track Capacity, Lifts Per Shift outputs, while the effects of changing Peak Shift % of Average Shift Volume were shown only on the Peak Lift Capacity Utilization output. At the beginning of each of the three groups of inputs, a table of contents indicates what outputs are shown in conjunction with the variable input that affects them.

Inputs Tested:

Terminal Characteristics

	Default Values	Range of Graphs
Total Working Track Length In Feet	16,000 Feet	10,000-30,000 Feet
Lift Machines	6 Machines	1-20 Machines
Lifts Per Machine-Hour	20 Lifts	15-30 Lifts
Equipment Load Factor As A % of Capacity	95%	70%-100%
Switching Time Per Track Turnover In Hours	1 Hour	0-2 Hours
Avg Dwell Time In Hours	48 Hours	12-96 Hours
Operating Hours Per Week	168 Hours	40-168 Hours
Working Hours Per 8-Hour Shift	7 Hours	4-8 Hours
Avg Gate Time In Minutes	3 Minutes	.5-10 Minutes
Avg Gate Queue Length In Units	4 Units	0-20 Units
Peak Shift % of Avg Shift Volume	170%	100%-250%

Traffic Mix

	Default Values	Range of Graphs
% Traffic In Double-Stacks[*]	45%	0%-100%
% Traffic In Conventional Flat Cars[*]	45%	100%-0%

Drayage Factors

	Default Values	Range of Graphs
City Miles	30 Miles	5-50 Miles
City Speed In MPH	30 MPH	10-50 MPH
Hwy Speed In MPH	45 MPH	30-60 MPH
Avg Dray Yard Time In Minutes Per Move	30 Minutes	15-90 Minutes
Avg Dray Length In Miles	50 Miles	10-250 Miles
Dray Repositioning Allowance In %	25%	0%-100%

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[*] For the purposes of the graphs, it was assumed that % Traffic In Double-Stacks + % Traffic In Conventional Flat Cars = 100%. In other words, % Traffic In Spine Cars + % Traffic In Other = 0%.

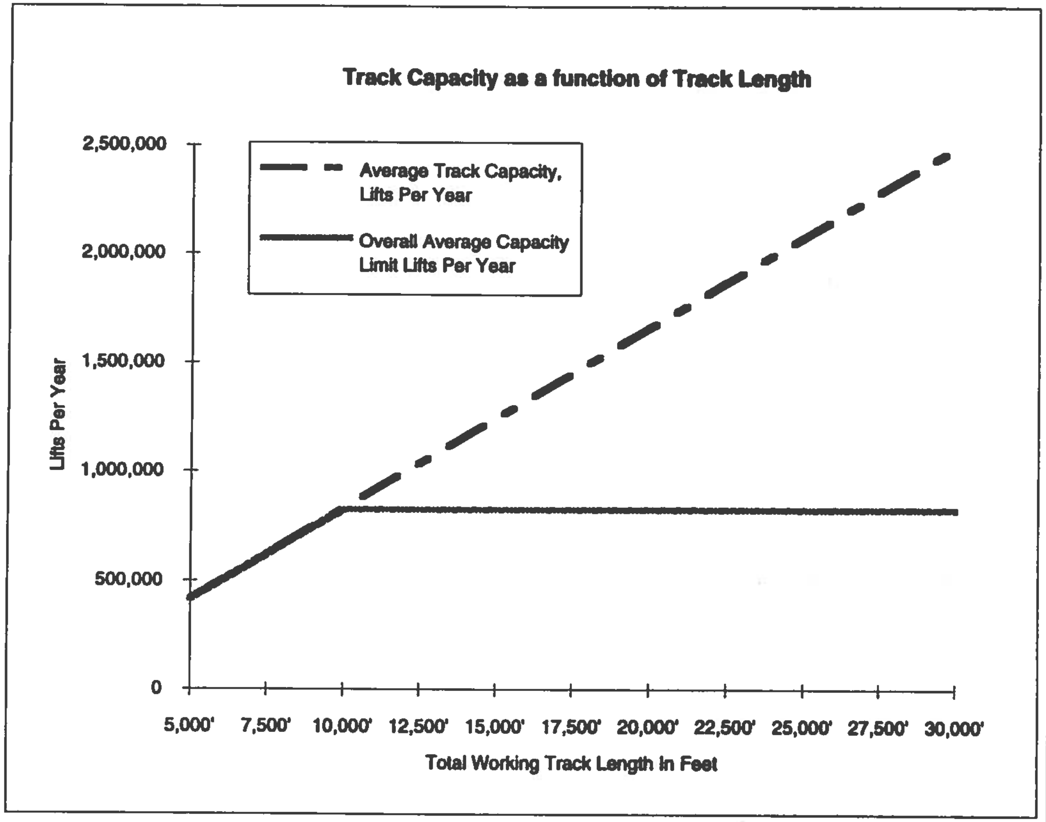
Terminal Characteristics:

	Range of Graphs
Total Working Track Length In Feet	10,000-30,000 Feet
affecting Average Track Capacity, Lifts Per Year	
and Overall Average Capacity Limit, Lifts Per Year	
affecting Peak Track Capacity, Lifts Per Shift	
Lift Machines	1-20 Machines
affecting Average Track Capacity, Lifts Per Year	
and Overall Average Capacity Limit, Lifts Per Year	
affecting Peak Track Capacity, Lifts Per Shift	
Lifts Per Machine-Hour	15-30 Lifts
affecting Overall Average Capacity Limit, Lifts Per Year	
affecting Peak Track Capacity, Lifts Per Shift	
Equipment Load Factor As A % of Capacity	70%-100%
affecting Average Track Capacity, Lifts Per Year	
and Overall Average Capacity Limit, Lifts Per Year	
affecting Peak Track Capacity, Lifts Per Shift	
Switching Time Per Track Turnover In Hours	0-2 Hours
affecting Average Track Capacity, Lifts Per Year	
and Overall Average Capacity Limit, Lifts Per Year	
affecting Peak Track Capacity, Lifts Per Shift	
Avg Dwell Time In Hours	12-96 Hours
affecting Parking Capacity	
affecting Parking Capacity Utilization	
Operating Hours Per Week	40-168 Hours
affecting Overall Average Capacity Limit, Lifts Per Year	
Working Hours Per 8-Hour Shift	4-8 Hours
affecting Average Track Capacity, Lifts Per Year	
and Overall Average Capacity Limit, Lifts Per Year	
affecting Peak Track Capacity, Lifts Per Shift	
Avg Gate Time In Minutes	.5-10 Minutes
affecting Average Dray Cost Per Move	
affecting Total Annual Dray Cost	
Avg Gate Queue Length In Units	0-20 Units
affecting Average Dray Cost Per Move	
affecting Total Annual Dray Cost	
Peak Shift % of Avg Shift Volume	100%-250%
affecting Peak Lift Capacity Utilization	

Track Capacity as a function of Track Length

As Exhibit 1 clearly shows, the Overall Capacity Limit almost doubles from about 400,000 Lifts Per Year to over 800,000 Lifts Per Year as the Total Working Track Length doubles from 5,000 Feet to 10,000 Feet. However, after 10,000 Feet, the Overall Capacity Limit levels off, for Track Capacity is no longer the limiting factor of Overall Capacity, rather Lift Capacity limits the Overall Capacity. Therefore, to take advantage of increased Track Capacity gained by the Total Working Track Length being over 10,000 Feet, Lift Capacity must also be raised to comparable levels.

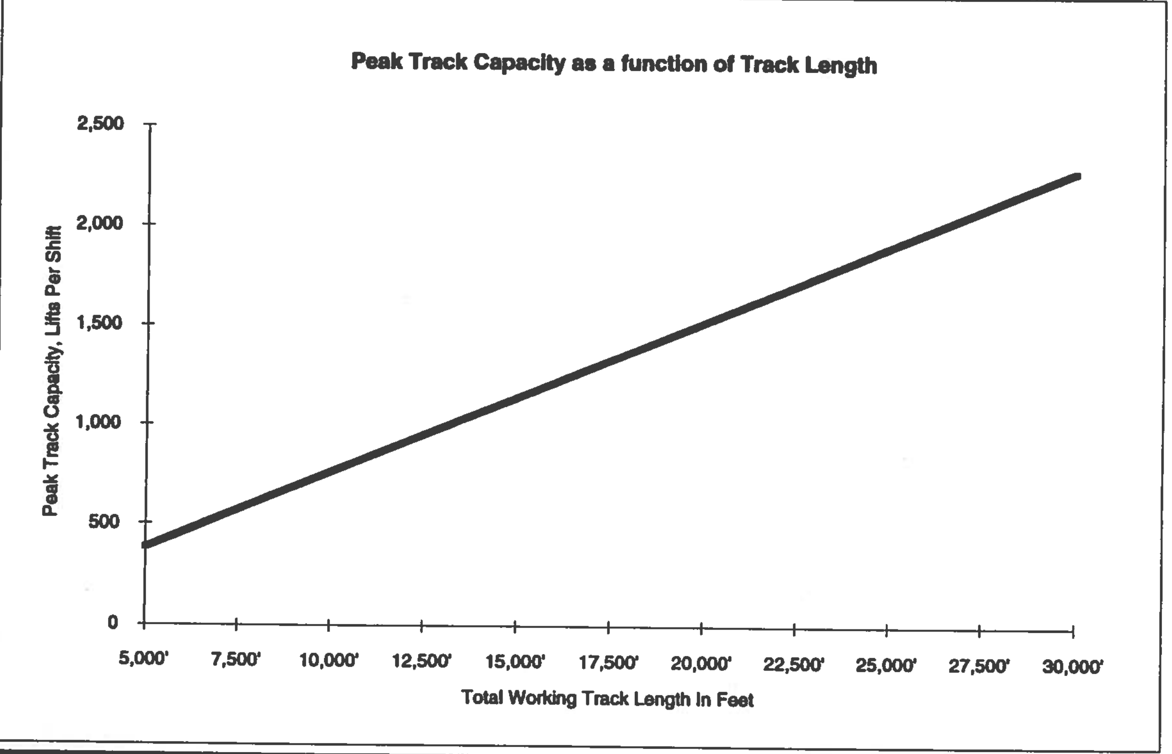
Total Working Track Length In Feet	Average Track Capacity, Lifts Per Year	Overall Average Capacity Limit Lifts Per Year
5,000'	414,856	414,856
7,500'	622,284	622,284
10,000'	829,712	825,552
12,500'	1,037,140	825,552
15,000'	1,244,568	825,552
17,500'	1,451,996	825,552
20,000'	1,659,424	825,552
22,500'	1,866,852	825,552
25,000'	2,074,280	825,552
27,500'	2,281,708	825,552
30,000'	2,489,136	825,552


Track Capacity as a function of Track Length

Peak Track Capacity as a function of Track Length

As Exhibit 2 illustrates, there is a direct relationship between the Peak Track Capacity and the Total Working Track Length. As Track Length doubles, so does Peak Track Capacity.

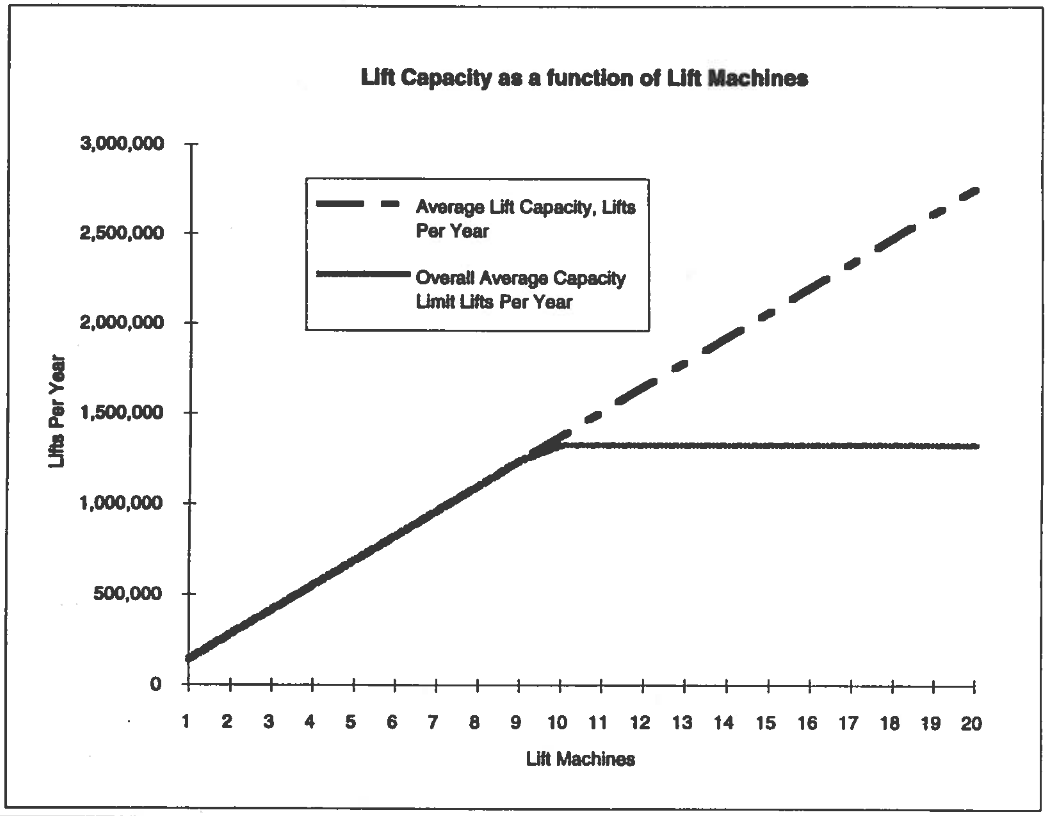
Total Working Track Length In Feet	Peak Track Capacity, Lifts Per Shift
5,000'	380
7,500'	570
10,000'	760
12,500'	950
15,000'	1,140
17,500'	1,330
20,000'	1,520
22,500'	1,710
25,000'	1,900
27,500'	2,089
30,000'	2,279


Peak Track Capacity as a function of Track Length

Lift Capacity as a function of Lift Machines

As Exhibit 3 illustrates, the Overall Capacity Limit is directly related to the number of Lift Machines up to 11 machines. However, after 11 Lift Machines are used, the Overall Capacity Limit levels off, for the Lift Capacity is no loner the limiting factor of Overall Capacity, rather Track Capacity limits Overall Capacity. Therefore, to take advantage of increased Lift Capacity gained by running more than 11 Lift Machines, Track Capacity must also be raised to comparable levels.

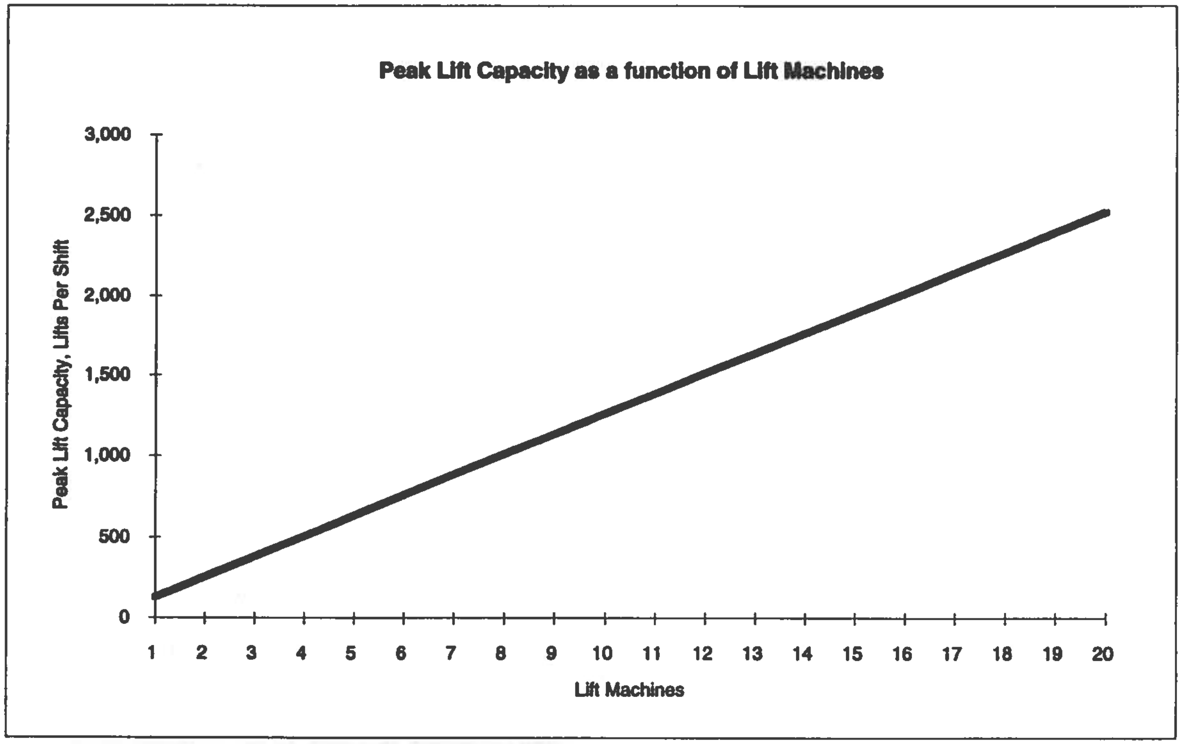
Lift Machines	Average Lift Capacity, Lifts Per Year	Overall Average Capacity Limit Lifts Per Year
1	137,592	137,592
2	275,184	275,184
3	412,776	412,776
4	550,368	550,368
5	687,960	687,960
6	825,552	825,552
7	963,144	963,144
8	1,100,736	1,100,736
9	1,238,328	1,238,328
10	1,375,920	1,327,539
11	1,513,512	1,327,539
12	1,651,104	1,327,539
13	1,788,696	1,327,539
14	1,926,288	1,327,539
15	2,063,880	1,327,539
16	2,201,472	1,327,539
17	2,339,064	1,327,539
18	2,476,656	1,327,539
19	2,614,248	1,327,539
20	2,751,840	1,327,539



Lift Capacity as a function of Lift Machines

As Exhibit 4 illustrates, there is a direct relationship between the Peak Lift Capacity and the Lift Machines. As the number of Lift Machines doubles, so does the Peak Lift Capacity.

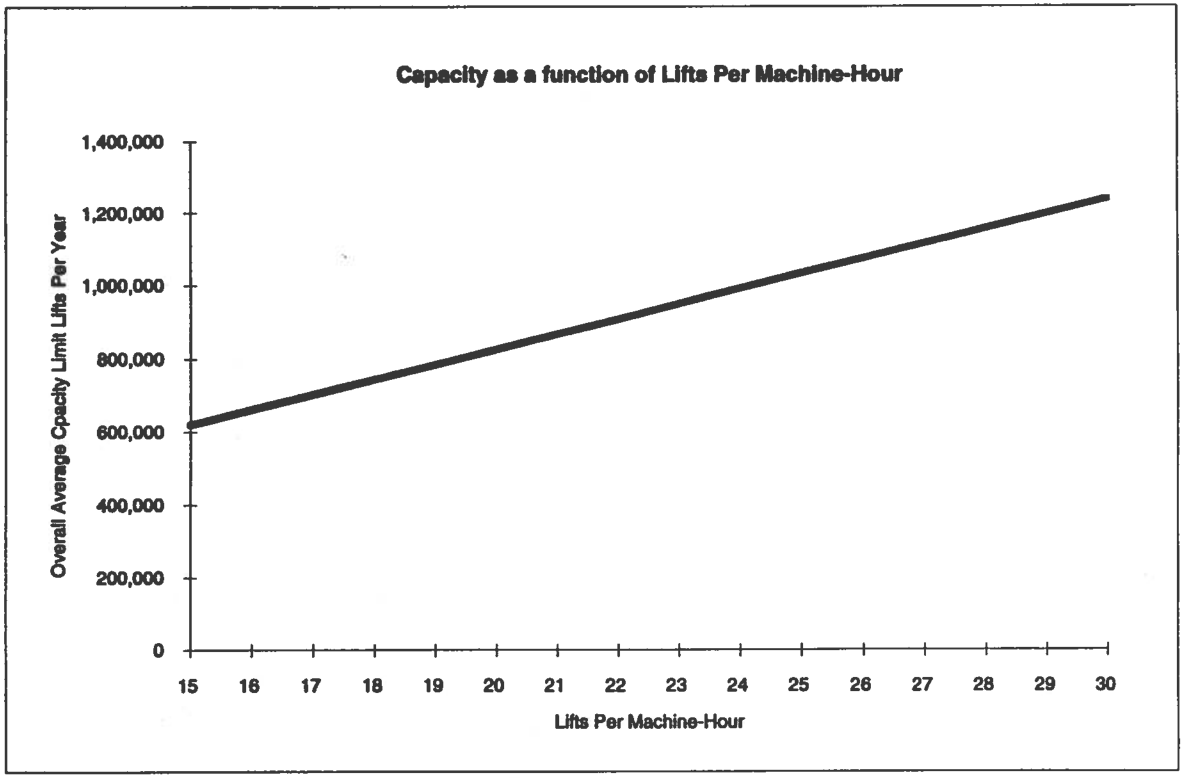
Lift Machines	Peak Lift Capacity, Lifts Per Shift
1	126
2	252
3	378
4	504
5	630
6	756
7	882
8	1,008
9	1,134
10	1,260
11	1,386
12	1,512
13	1,638
14	1,764
15	1,890
16	2,016
17	2,142
18	2,268
19	2,394
20	2,520



Capacity as a function of Lifts Per Machine-Hour

As Exhibit 5 illustrates, there is a direct relationship between Lifts Per Machine-Hour and the Overall Capacity Limit for the range of 15-30 Lifts Per Machine-Hour. As Lifts Per Machine-Hour doubles, so does the Overall Capacity Limit. This direct relationship holds for Lift Capacity is the limiting factor of Overall Capacity for all values generated for the range of 15-30 Lifts Per Machine-Hour.

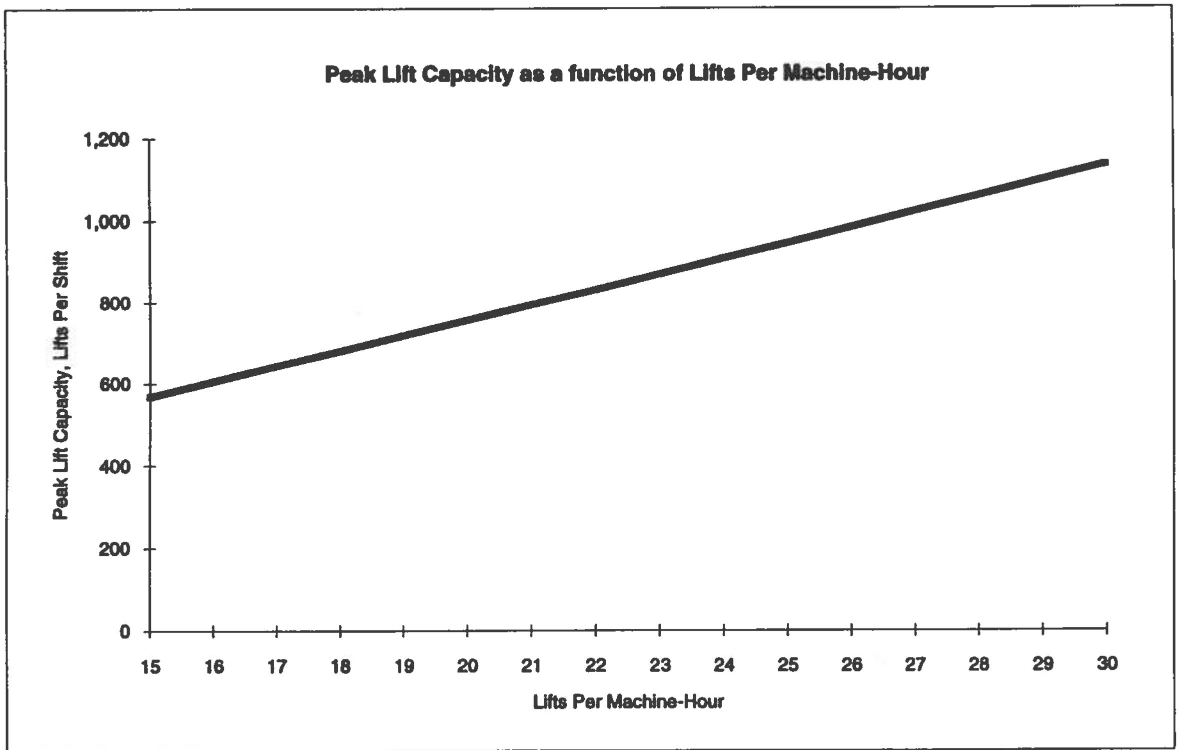
Lifts Per Machine-Hour	Overall Average Capacity Limit Lifts Per Year
15	619,164
16	660,442
17	701,719
18	742,997
19	784,274
20	825,552
21	866,830
22	908,107
23	949,385
24	990,662
25	1,031,940
26	1,073,218
27	1,114,495
28	1,155,773
29	1,197,050
30	1,238,328


Capacity as a function of Lifts Per Machine-Hour

Peak Lift Capacity as a function of Lifts Per Machine-Hour

As Exhibit 6 shows, there is a direct relationship between Lifts Per Machine-Hour and the Peak Lift Capacity. As Lifts Per Machine-Hour doubles, so does the Peak Lift Capacity.

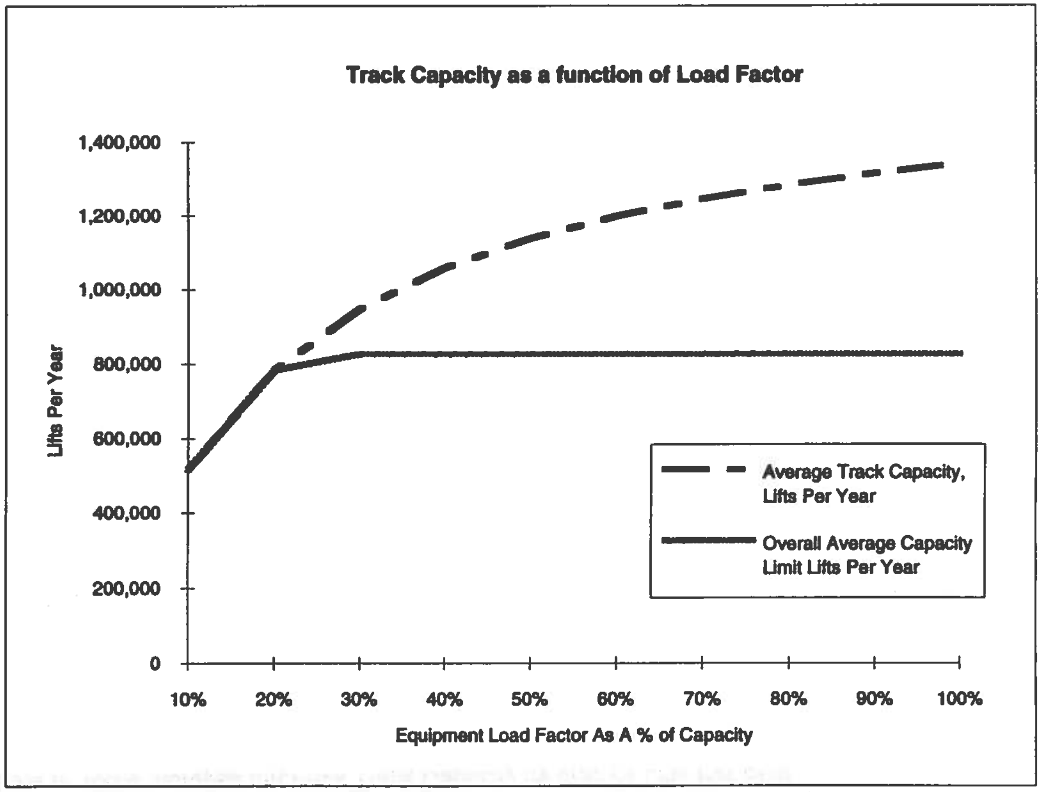
Lifts Per Machine-Hour	Peak Lift Capacity, Lifts Per Shift
15	567
16	605
17	643
18	680
19	718
20	756
21	794
22	832
23	869
24	907
25	945
26	983
27	1,021
28	1,058
29	1,096
30	1,134


Peak Lift Capacity as a function of Lifts Per Machine-Hour

Track Capacity as a function of Load Factor

As Exhibit 7 illustrates, the Overall Capacity Limit is directly related to the Equipment Load Factor up to about 20%. However, after 20%, the Overall Capacity Limit levels off, for Track Capacity is no longer the limiting factor of Overall Capacity, rather Lift Capacity limits the Overall Capacity. Therefore, to take advantage of increased Track Capacity gained by the Equipment Load Factor being higher than 20%, Lift Capacity must also be raised to comparable levels.

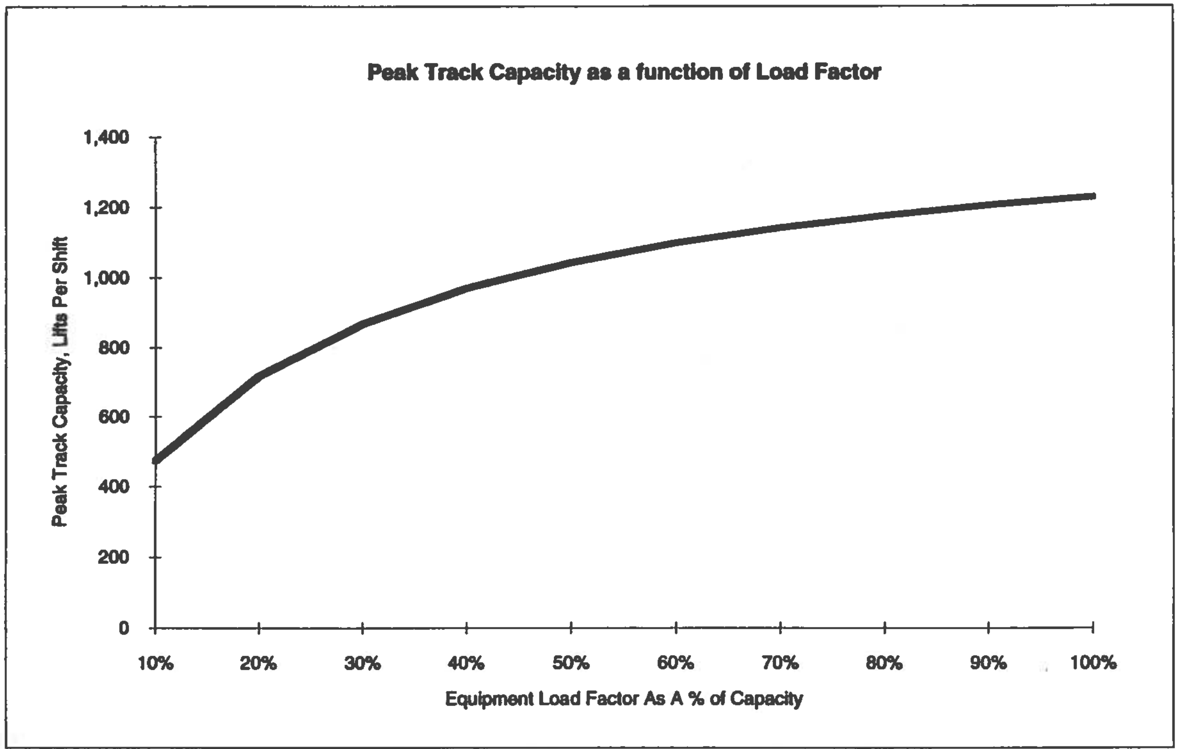
Equipment Load Factor As A % of Capacity	Average Track Capacity, Lifts Per Year	Overall Average Capacity Limit Lifts Per Year
10%	514,489	514,489
20%	782,197	782,197
30%	946,334	825,552
40%	1,057,263	825,552
50%	1,137,248	825,552
60%	1,197,651	825,552
70%	1,244,880	825,552
80%	1,282,821	825,552
90%	1,313,968	825,552
100%	1,339,996	825,552



Peak Track Capacity as a function of Load Factor

As Exhibit 8 shows, as the Equipment Load Factor increases, so does the Peak Track Capacity; however, it is not a direct relationship; it is a relationship of diminishing returns. As the Equipment Load Factor increases from 10% to 20% of Capacity, the Peak Track Capacity increases by 245 Lifts Per Shift. However, that same 10% increase in Load Factor from 90% to 100% increase the Peak Track Capacity by only 24 Lifts Per Shift.

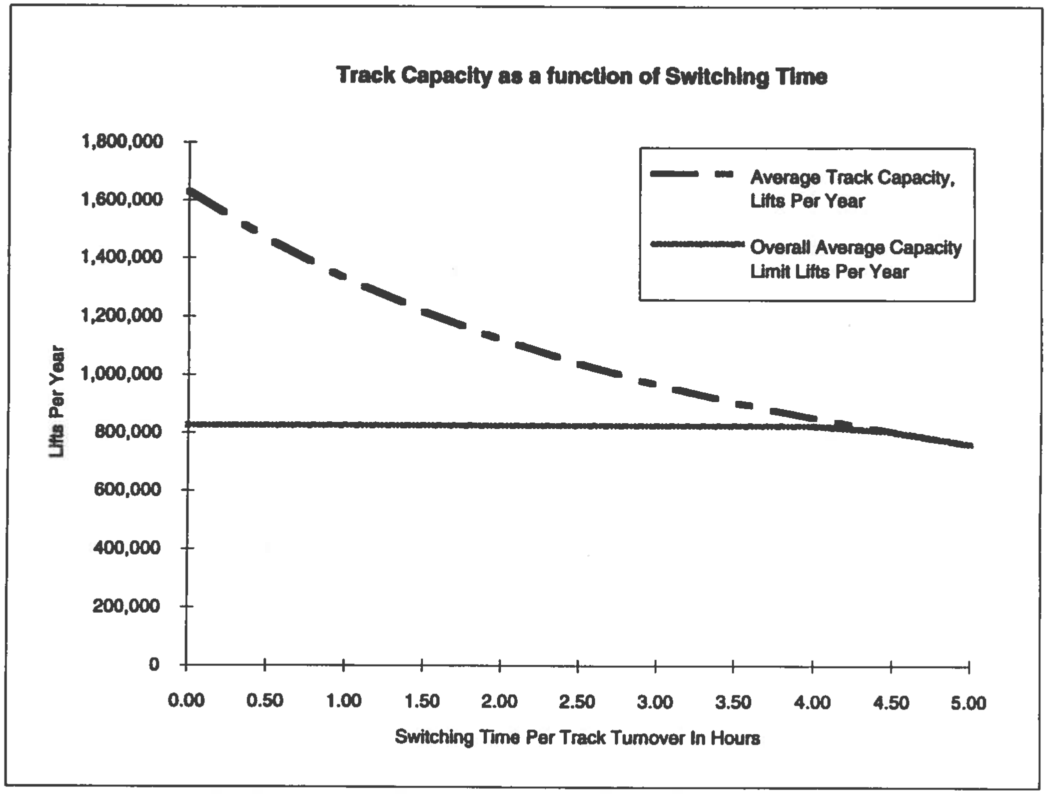
Equipment Load Factor As A % of Capacity	Peak Track Capacity, Lifts Per Shift
10%	471
20%	716
30%	867
40%	968
50%	1,041
60%	1,097
70%	1,140
80%	1,175
90%	1,203
100%	1,227


Peak Track Capacity as a function of Load Factor

Track Capacity as a function of Switching Time

As Exhibit 9 illustrates, the Overall Capacity Limit is unchanged for all Switching Times under about 4.25 hours. For all times less than this, the Track Capacity goes steadily downward as more Switching Time is needed; however, since Lift Capacity, not Track Capacity is the limiting factor of Overall Capacity until 4.25 hours of Switching Time, this lessening of Track Capacity does not affect Overall Capacity until 4.25 hours of Switching Time is needed.

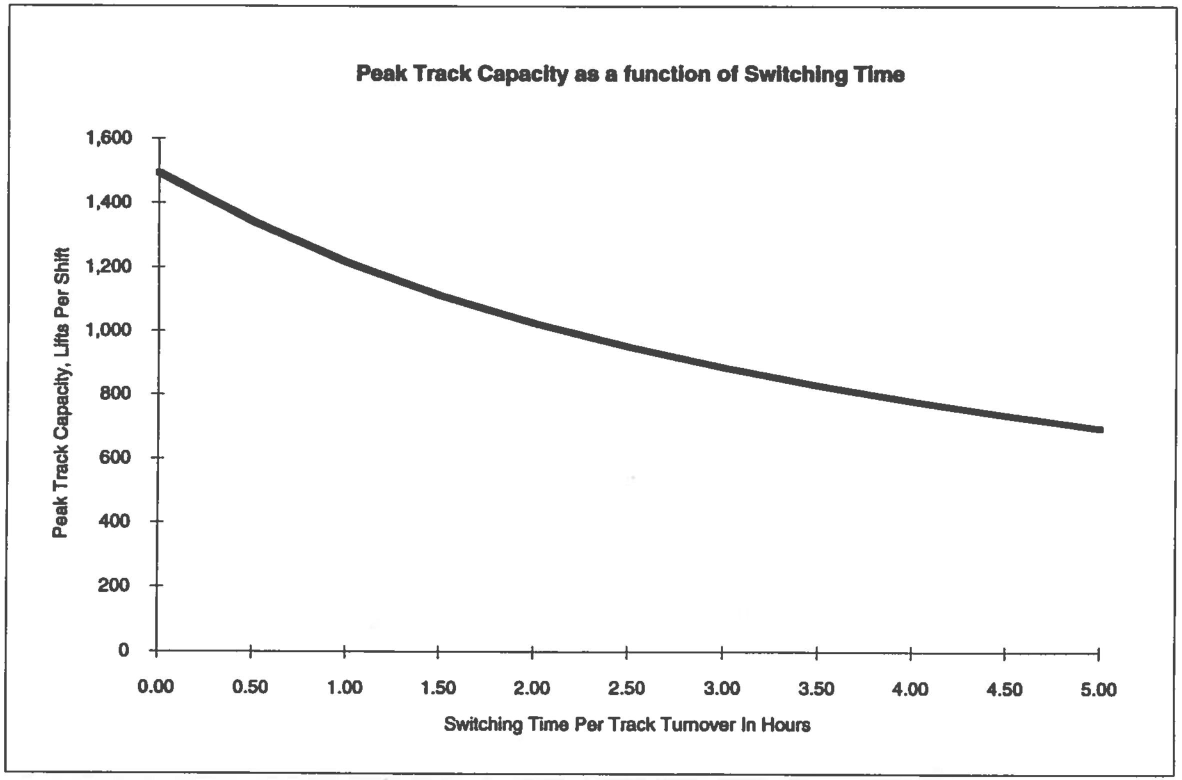
Switching Time Per Track Turnover In Hours	Average Track Capacity, Lifts Per Year	Overall Average Capacity Limit Lifts Per Year
0.00	1,630,720	825,552
0.50	1,463,594	825,552
1.00	1,327,539	825,552
1.50	1,214,628	825,552
2.00	1,119,419	825,552
2.50	1,038,050	825,552
3.00	967,709	825,552
3.50	906,296	825,552
4.00	852,213	825,552
4.50	804,221	804,221
5.00	761,346	761,346



Peak Track Capacity as a function of Switching Time

As Exhibit 10 illustrates, as the Switching Time increases, the Peak Track Capacity decreases; however, it is not a direct relationship; it is a relationship of diminishing losses. As the Switching Time increases from 0 hours to 1/2 an hour, the Peak Track Capacity decreases 153 Lifts Per Shift; however, that same increase of 1/2 an hour in Switching Time from 4.5 to 5 hours results in a decrease of only 39 Lifts Per Shift.

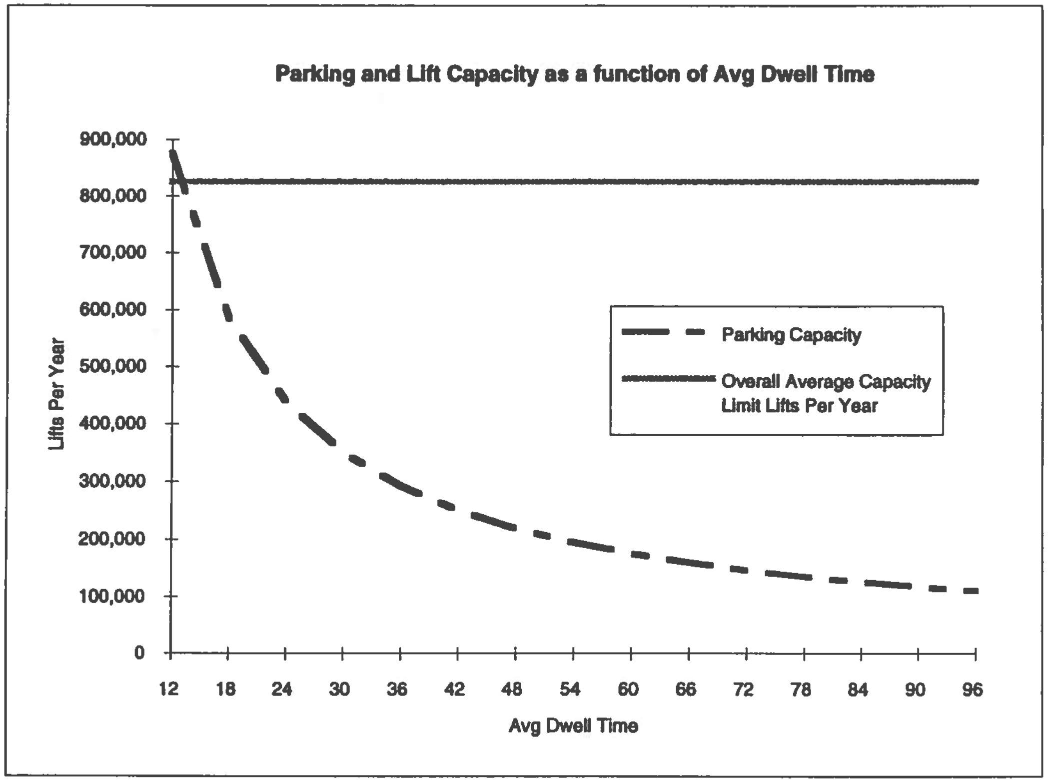
Switching Time Per Track Turnover In Hours	Peak Track Capacity, Lifts Per Shift
0.00	1,493
0.50	1,340
1.00	1,216
1.50	1,112
2.00	1,025
2.50	951
3.00	886
3.50	830
4.00	780
4.50	736
5.00	697



Parking and Lift Capacity as a function of Dwell Time

As Exhibit 11 shows, effective Parking Capacity declines dramatically as Dwell Time rises. The prototype terminal considered in these examples has 1200 parking spaces and 48 hours dwell time, yielding an effective parking capacity of 219,000 annual units. With a current volume of 200,000 units, the facility is utilizing 91% of its parking capacity, but only 24% of its theoretical Overall Lift Capacity. As traffic grows, such a facility will experience parking congestion before reaching other capacity limits unless dwell time can be reduced.

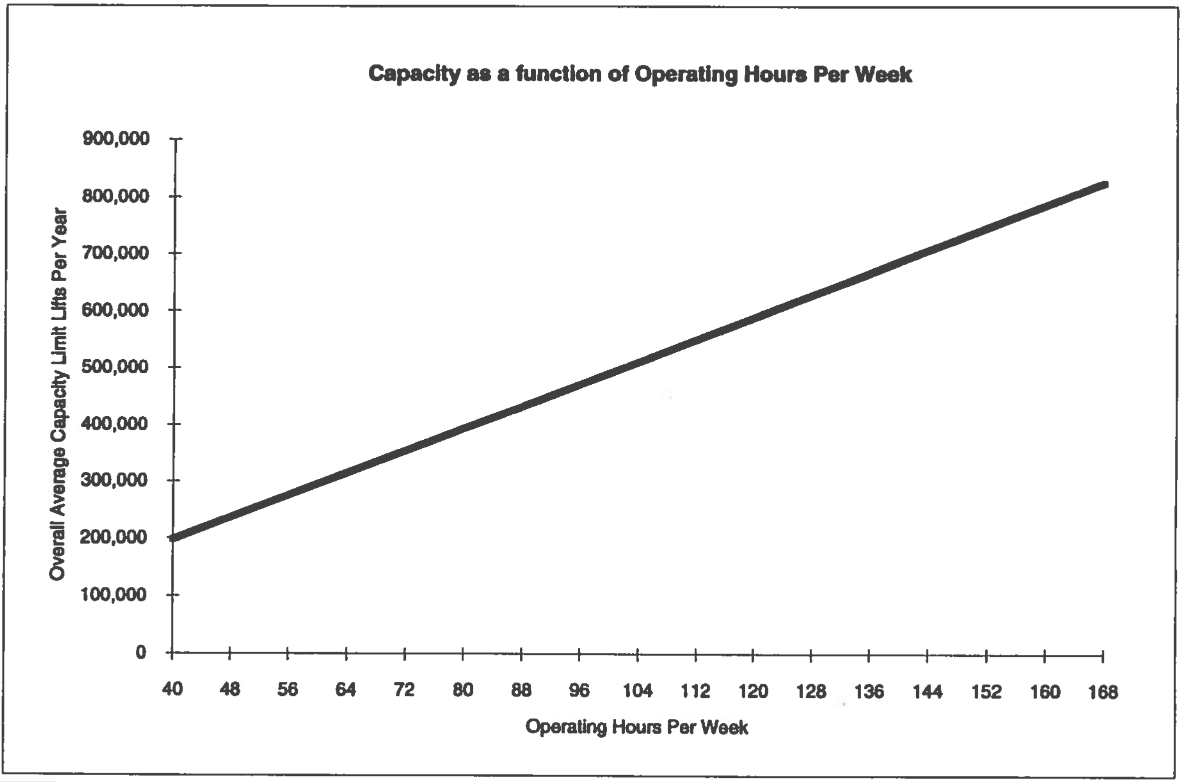
Avg Dwell Time In Hours	Parking Capacity	Overall Average Capacity Limit Lifts Per Year
12	876,000	825,552
18	584,000	825,552
24	438,000	825,552
30	350,400	825,552
36	292,000	825,552
42	250,286	825,552
48	219,000	825,552
54	194,667	825,552
60	175,200	825,552
66	159,273	825,552
72	146,000	825,552
78	134,769	825,552
84	125,143	825,552
90	116,800	825,552
96	109,500	825,552



Capacity as a function of Operating Hours Per Week

As Exhibit 12 illustrates, the Overall Capacity Limit is directly related to the Operating Hours Per Week. As Operating Hours Per Week doubles, so does the Overall Capacity Limit.

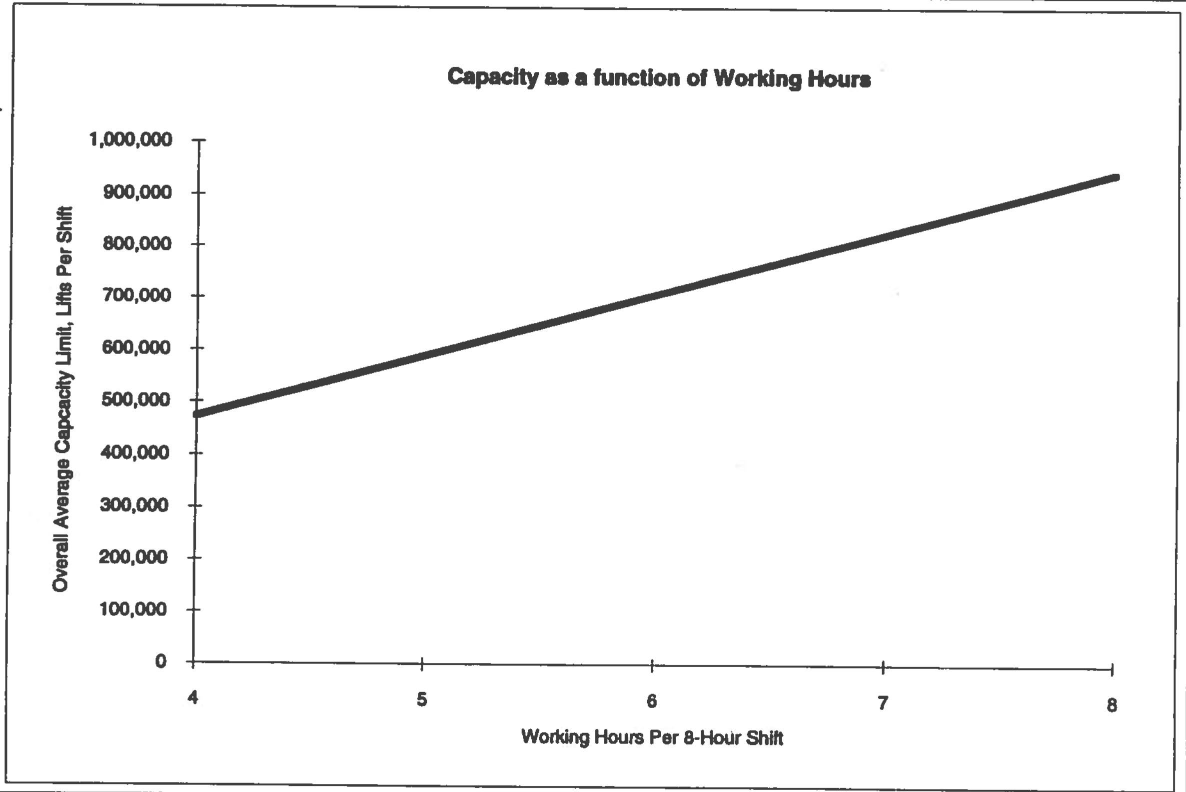
Operating Hours Per Week	Overall Average Capacity Limit Lifts Per Year
40	196,560
48	235,872
56	275,184
64	314,496
72	353,808
80	393,120
88	432,432
96	471,744
104	511,056
112	550,368
120	589,680
128	628,992
136	668,304
144	707,616
152	746,928
160	786,240
168	825,552


Capacity as a function of Operating Hours Per Week

Capacity as a function of Working Hours

As Exhibit 13 shows, there is a direct relationship between Working Hours Per 8-Hour Shift and the Overall Capacity Limit. As the Working Hours Per 8-Hour Shift doubles, so does the Overall Capacity Limit.

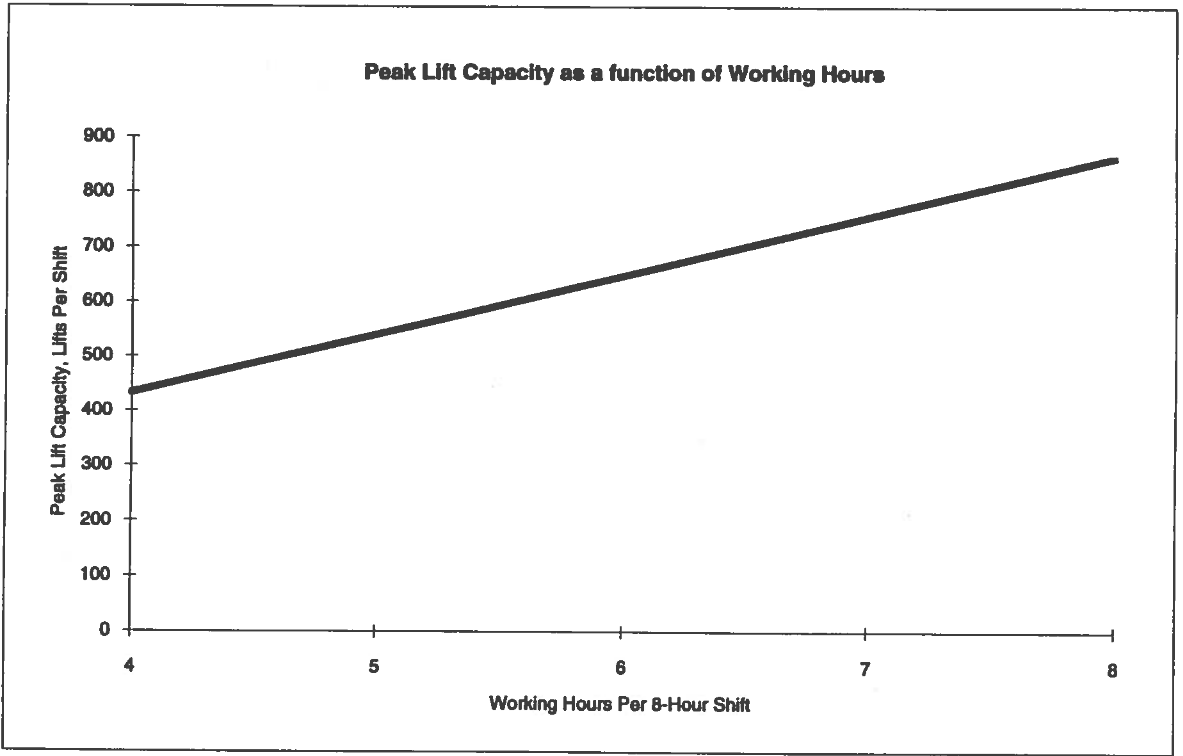
Working Hours Per 8-Hour Shift	Overall Average Capacity Limit Lifts Per Year
4	471,744
5	589,680
6	707,616
7	825,552
8	943,488



Peak Lift Capacity as a function of Working Hours

As Exhibit 14 illustrates, there is a direct relationship between Working Hours Per 8-Hour Shift and the Peak Lift Capacity. As the Working Hours Per 8-Hour Shift doubles, so does the Peak Lift Capacity.

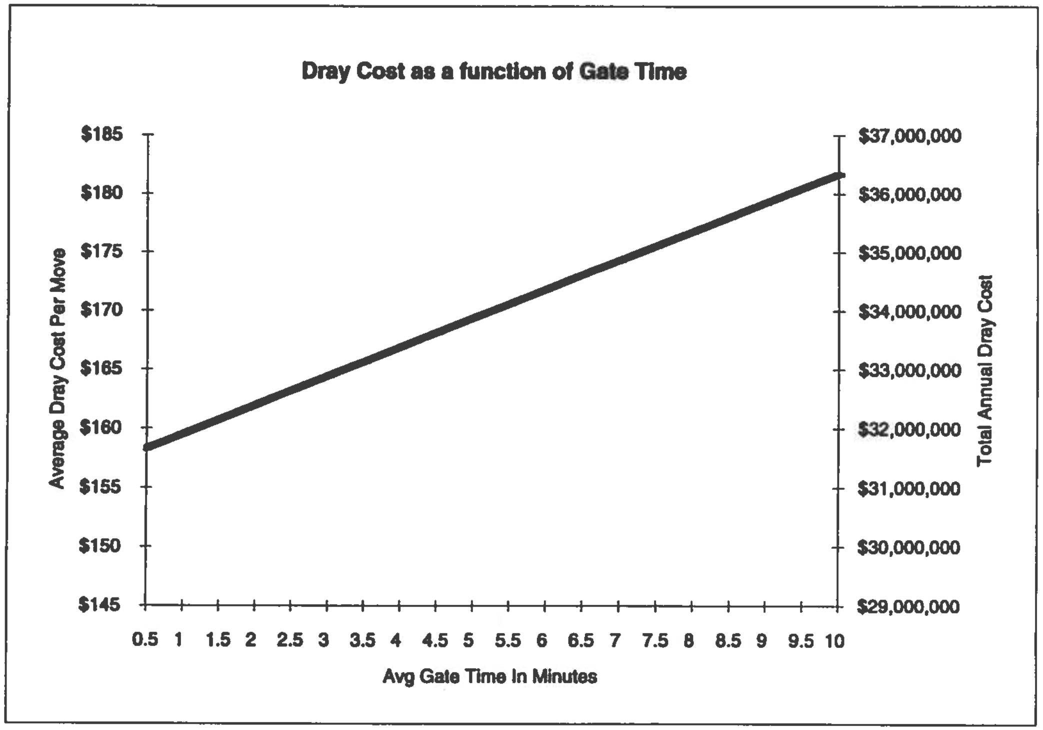
Working Hours Per 8-Hour Shift	Peak Lift Capacity, Lifts Per Shift
4	432
5	540
6	648
7	756
8	864



Dray Cost as a function of Gate Time

As Exhibit 15 shows, there is a linear relationship between the Avg Gate Time and the Dray Cost. Exhibit 15 shows this relationship with two different Dray Costs: Average Dray Cost Per Move and Total Annual Dray Cost. The one line represents both relationships. For each increase in Gate Time of one minute, there is an increase of about $2.50 per move, or a total annual increase of about $246,000.

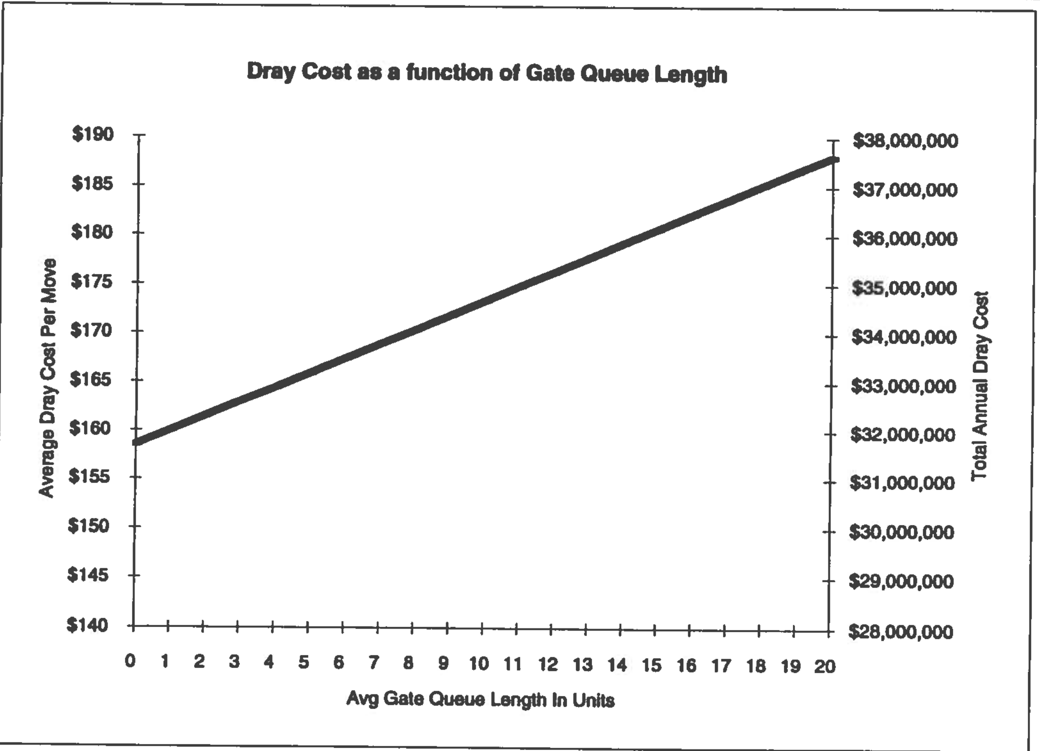
Avg Gate Time In Minutes	Average Dray Cost Per Move	Total Annual Dray Cost
0.5	$158	$31,649,694
1	$159	$31,896,278
1.5	$161	$32,142,861
2	$162	$32,389,444
2.5	$163	$32,636,028
3	$164	$32,882,611
3.5	$166	$33,129,194
4	$167	$33,375,778
4.5	$168	$33,622,361
5	$169	$33,868,944
5.5	$171	$34,115,528
6	$172	$34,362,111
6.5	$173	$34,608,694
7	$174	$34,855,278
7.5	$176	$35,101,861
8	$177	$35,348,444
8.5	$178	$35,595,028
9	$179	$35,841,611
9.5	$180	$36,088,194
10	$182	$36,334,778



Dray Cost as a function of Queue Length

As Exhibit 16 shows, there is a linear relationship between the Avg Gate Queue Length In Units and the Dray Cost. Exhibit 16 shows this relationship with two different Dray Costs: Average Dray Cost Per Move and Total Annual Dray Cost. The one line represents both relationships. For each increase in Queue Length of one unit, there is an increase of about $1.50 per move, or a total annual increase of about $296,000.

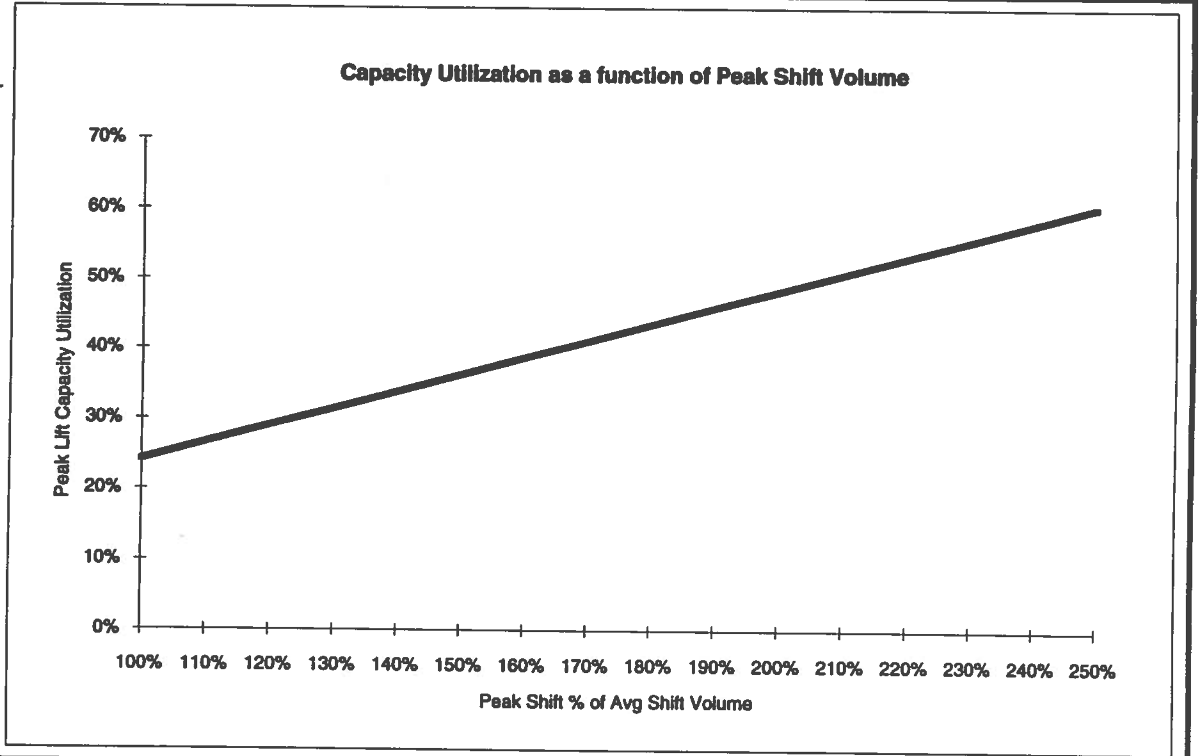
Avg Gate Queue Length In Units	Average Dray Cost Per Move	Total Annual Dray Cost
0	$158	$31,699,011
1	$160	$31,994,911
2	$161	$32,290,811
3	$163	$32,586,711
4	$164	$32,882,611
5	$166	$33,178,511
6	$167	$33,474,411
7	$169	$33,770,311
8	$170	$34,066,211
9	$172	$34,362,111
10	$173	$34,658,011
11	$175	$34,953,911
12	$176	$35,249,811
13	$178	$35,545,711
14	$179	$35,841,611
15	$181	$36,137,511
16	$182	$36,433,411
17	$184	$36,729,311
18	$185	$37,025,211
19	$187	$37,321,111
20	$188	$37,617,011



Capacity Utilization as a function of Peak Shift Volume

As Exhibit 17 illustrates, there is a direct relationship between the Peak Shift % of Avg Shift Volume and the Peak Lift Capacity Utilization. As the Peak Shift % of Avg Shift Volume doubles, so does the Peak Lift Capacity Utilization.

Peak Shift % of Avg Shift Volume	Peak Lift Capacity Utilization
100%	24%
110%	27%
120%	29%
130%	31%
140%	34%
150%	36%
160%	39%
170%	41%
180%	43%
190%	46%
200%	48%
210%	51%
220%	53%
230%	56%
240%	58%
250%	60%


Capacity Utilization as a function of Peak Shift Volume

Traffic Mix:

	Range of Graphs
% Traffic In Double-Stacks*	0%-100%
% Traffic In Conventional Flat Cars*	100%-0%

affecting Average Track Capacity, Lifts Per Year
and Overall Average Capacity Limit, Lifts Per Year
affecting Peak Track Capacity, Lifts Per Shift

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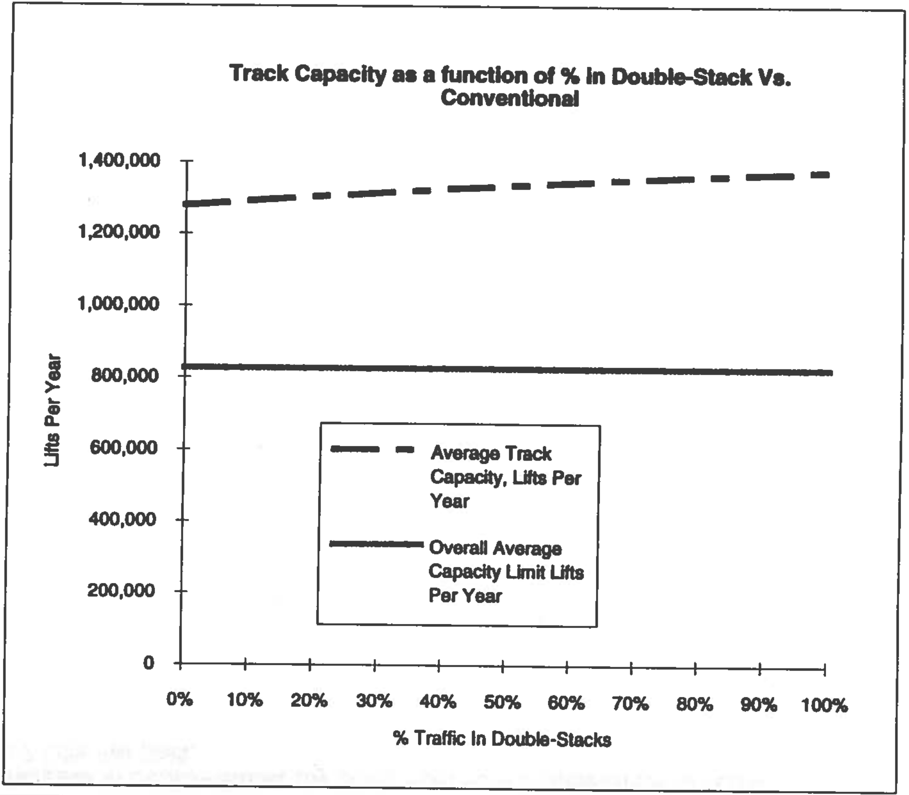
* For the purposes of the graphs, it was assumed that % Traffic In Double-Stacks + % Traffic In Conventional Flat Cars = 100%. Both of these variables equally influence the outputs, but only % Traffic In Double-Stacks is shown along the X-Axis.

Track Capacity as a function of % in Double-Stack Vs. Conventional

As Exhibit 18 shows, Double-Stacks is a more efficient means of transport than Conventional Cars. Using 100% Double-Stacks as opposed to 100% in Conventional Cars, increases the Track Capacity by almost an extra 100,000 Lifts Per Year, from 1,277,678 to 1,377,052. However, this increase in Track Capacity does not affect the Overall Capacity, for Lift Capacity, not Track Capacity is the limiting factor in determining Overall Capacity. Since Lift Capacity is so much lower than Track Capacity, any combination of Double-Stacks Vs. Conventional Cars will produce a Track Capacity well over that of the Lift Capacity; therefore, any combination will have no affect on the Overall Capacity Limit.

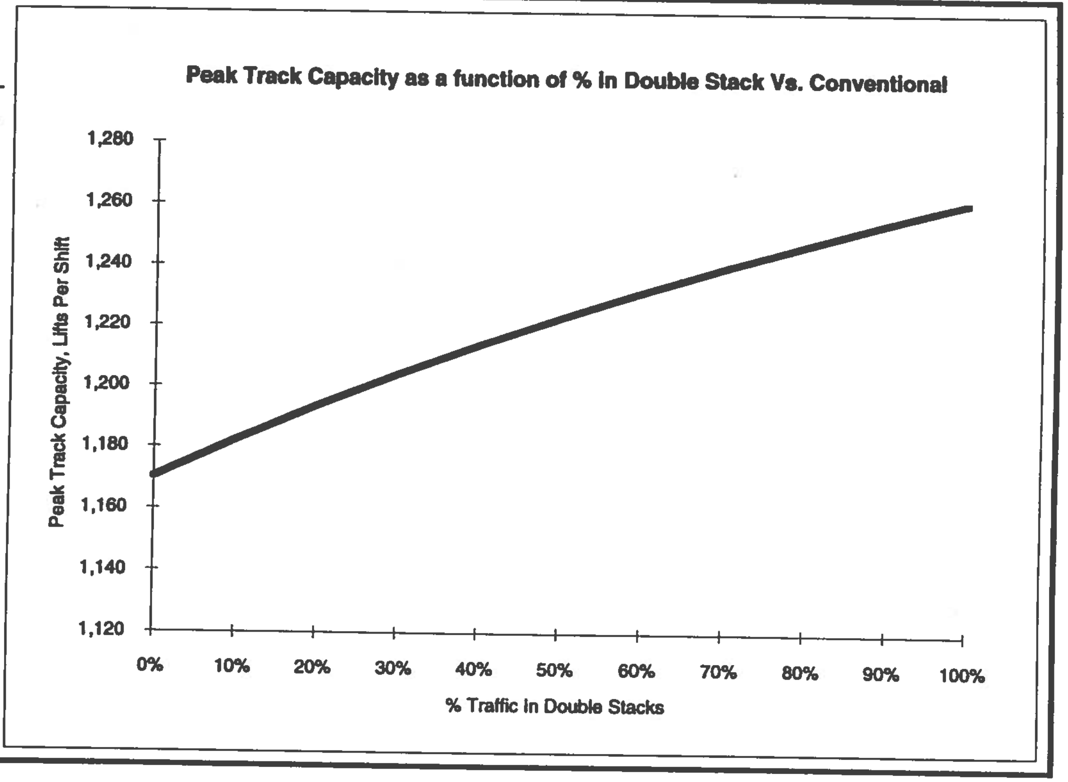
% Traffic In Double-Stacks	% Traffic In Conventional Flat Cars	Average Track Capacity, Lifts Per Year	Overall Average Capacity Limit Lifts Per Year
0%	100%	1,277,678	825,552
10%	90%	1,290,987	825,552
20%	80%	1,303,329	825,552
30%	70%	1,314,806	825,552
40%	60%	1,325,505	825,552
50%	50%	1,335,503	825,552
60%	40%	1,344,868	825,552
70%	30%	1,353,656	825,552
80%	20%	1,361,920	825,552
90%	10%	1,369,705	825,552
100%	0%	1,377,052	825,552



Peak Track Capacity as a function of % in Double-Stack Vs. Conventional

As Exhibit 19 shows, Double-Stacks is a more efficient means of transport than Conventional Cars. Using 100% Double-Stacks as opposed to 100% in Conventional Cars, increases the Peak Track Capacity by an extra 91 Lifts Per Shift. However, this relationship is one of diminishing returns. The first 10% increase in Double-Stacks (by going from no Double-Stacks to having 10% Double-Stacks) increases the Peak Track Capacity by 12 Lifts Per Shift. However, the last 10% increase in Double-Stacks (by going from 90% Double-Stack to 100% Double-Stacks) nets an increase of only 7 Lifts Per Shift.

% Traffic In Double-Stacks	% Traffic In Conventional Flat Cars	Peak Track Capacity, Lifts Per Shift
0%	100%	1,170
10%	90%	1,182
20%	80%	1,194
30%	70%	1,204
40%	60%	1,214
50%	50%	1,223
60%	40%	1,232
70%	30%	1,240
80%	20%	1,247
90%	10%	1,254
100%	0%	1,261



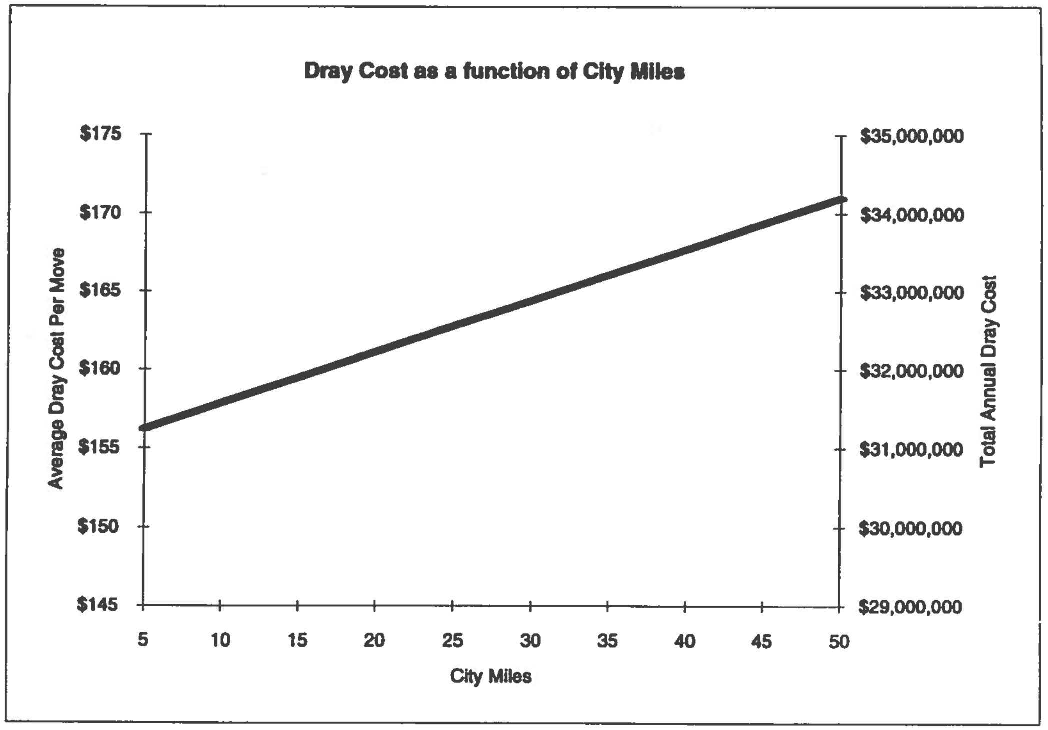
Drayage Factors:

	Range of Graphs
City Miles affecting Average Dray Cost Per Move and Total Annual Dray Cost	5-50 Miles
City Speed In MPH affecting Average Dray Cost Per Move and Total Annual Dray Cost	10-50 MPH
Hwy Speed In MPH affecting Average Dray Cost Per Move and Total Annual Dray Cost	30-60 MPH
Avg Dray Yard Time In Minutes Per Move affecting Average Dray Cost Per Move and Total Annual Dray Cost	15-90 Minutes
Avg Dray Length In Miles affecting Average Dray Cost Per Move and Total Annual Dray Cost	10-250 Miles
Dray Repositioning Allowance In % affecting Average Dray Cost Per Move and Total Annual Dray Cost	0%-100%

Dray Cost as a function of City Miles

As Exhibit 20 shows, there is a linear relationship between City Miles and the Dray Cost. Exhibit 20 shows this relationship with two different Dray Costs: Average Dray Cost Per Move and Total Annual Dray Cost. The one line represents both relationships. For each increase in City Miles of 5 miles, there is an increase of about $1.66 per move, or a total annual increase of about $329,000.

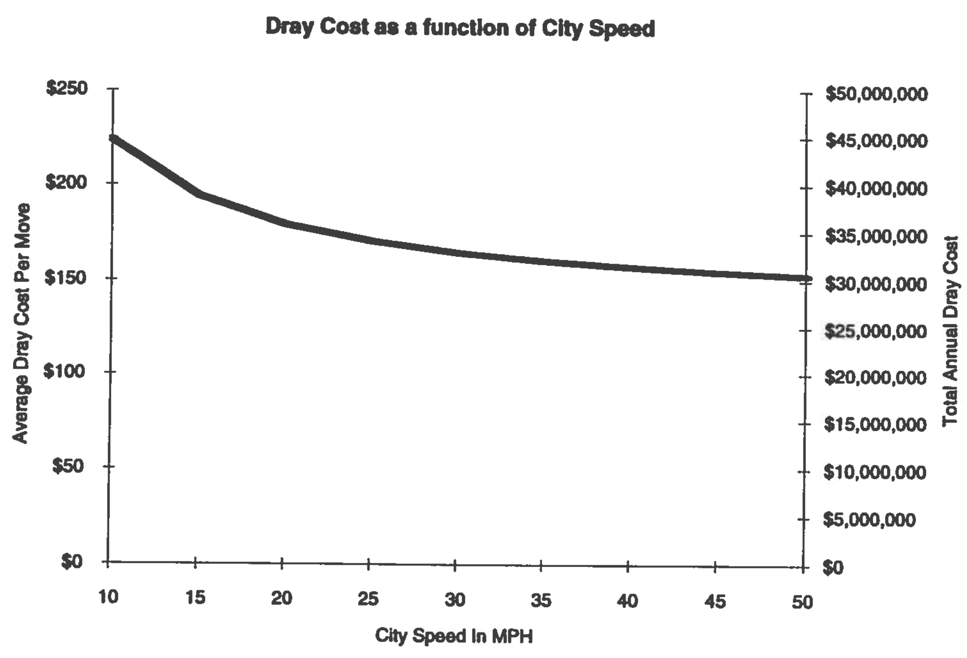
City Miles	Average Dray Cost Per Move	Total Annual Dray Cost
5	$156	$31,238,722
10	$158	$31,567,500
15	$159	$31,896,278
20	$161	$32,225,056
25	$163	$32,553,833
30	$164	$32,882,611
35	$166	$33,211,389
40	$168	$33,540,167
45	$169	$33,868,944
50	$171	$34,197,722



Dray Cost as a function of City Speed

As Exhibit 21 illustrates, there is a relationship of diminishing returns between the City Speed and the Dray Cost. Exhibit 21 shows this relationship with two different Dray Costs: Average Dray Cost Per Move and Total Annual Dray Cost. The one line represents both relationships. For the first 5 MPH increase in City Speed from 10 MPH to 15 MPH the Dray Cost comes down $30 per move or about $6,000,000 total annually. However, for the 5 MPH increase from 45 MPH to 50 MPH, the Dray Cost comes down only $2 per move or only about $400,000 total annually.

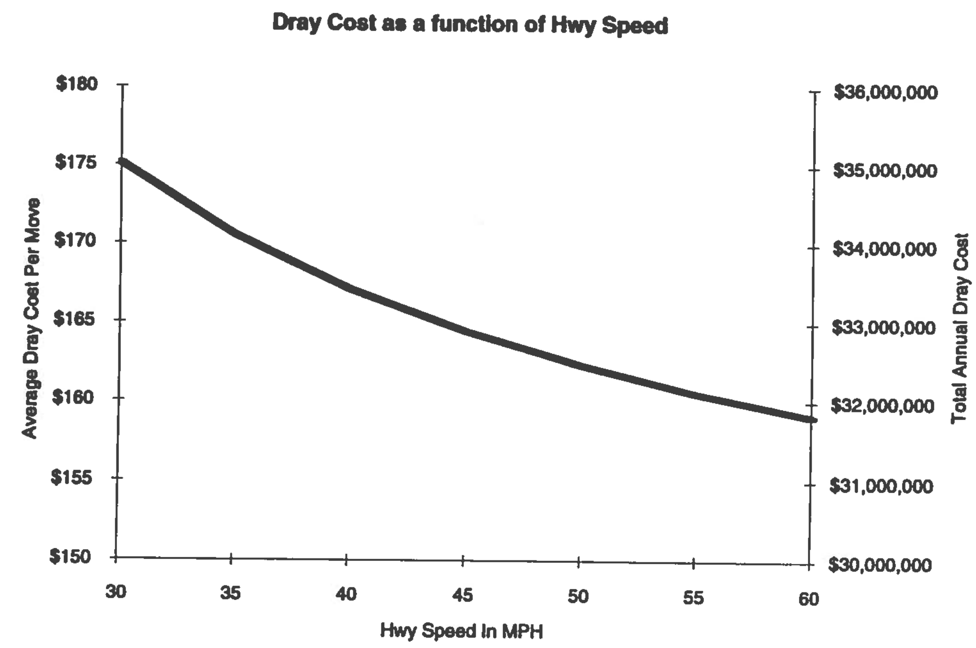
City Speed In MPH	Average Dray Cost Per Move	Total Annual Dray Cost
10	$224	$44,718,611
15	$194	$38,800,611
20	$179	$35,841,611
25	$170	$34,066,211
30	$164	$32,882,611
35	$160	$32,037,183
40	$157	$31,403,111
45	$155	$30,909,944
50	$153	$30,515,411



Dray Cost as a function of Hwy Speed

As Exhibit 22 illustrates, there is a relationship of diminishing returns between the Hwy Speed and the Dray Cost. Exhibit 22 shows this relationship with two different Dray Costs: Average Dray Cost Per Move and Total Annual Dray Cost. The one line represents both relationships. For the first 5 MPH increase in Hwy Speed from 30 MPH to 35 MPH the Dray Cost comes down $4 per move or about $900,000 total annually. However, for the 5 MPH increase from 55 MPH to 60 MPH, the Dray Cost comes down only $2 per move or only about $300,000 total annually.

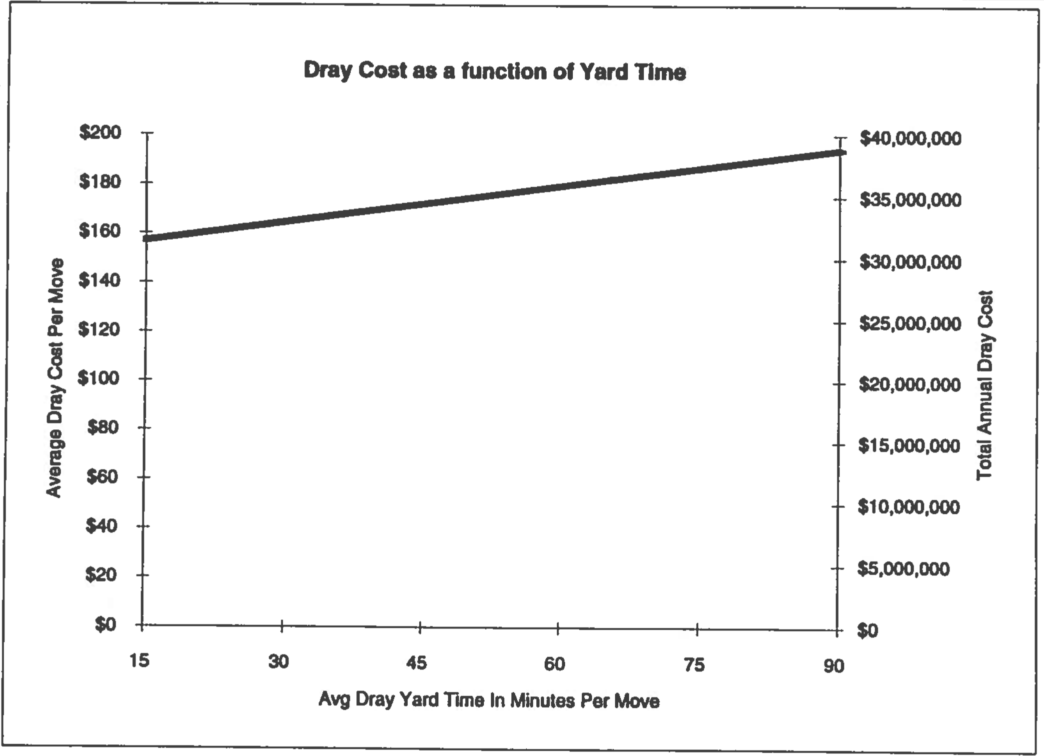
Hwy Speed In MPH	Average Dray Cost Per Move	Total Annual Dray Cost
30	$175	$35,019,667
35	$171	$34,103,786
40	$167	$33,416,875
45	$164	$32,882,611
50	$162	$32,455,200
55	$161	$32,105,500
60	$159	$31,814,083


Dray Cost as a function of Hwy Speed

Dray Cost as a function of Yard Time

As Exhibit 23 shows, there is a linear relationship between Yard Time and the Dray Cost. Exhibit 23 shows this relationship with two different Dray Costs: Average Dray Cost Per Move and Total Annual Dray Cost. The one line represents both relationships. For each increase in Yard Time of 15 minutes, there is an increase of about $7.40 per move, or a total annual increase of about $1,480,000.

Avg Dray Yard Time In Minutes Per Move	Average Dray Cost Per Move	Total Annual Dray Cost
15	$157	$31,403,111
30	$164	$32,882,611
45	$172	$34,362,111
60	$179	$35,841,611
75	$187	$37,321,111
90	$194	$38,800,611

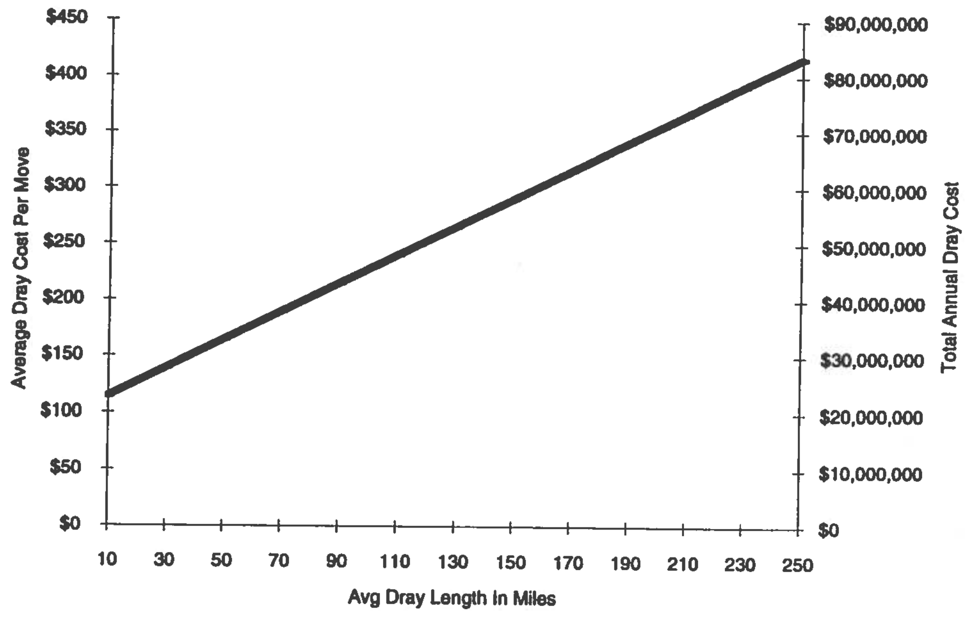


Dray Cost as a function of Dray Length

As Exhibit 24 shows, there is a linear relationship between Dray Length and the Dray Cost. Exhibit 24 shows this relationship with two different Dray Costs: Average Dray Cost Per Move and Total Annual Dray Cost. The one line represents both relationships. For each increase in Dray Length of 20 miles, there is an increase of about $25 per move, or a total annual increase of about $5,000,000.

Avg Dray Length In Miles	Average Dray Cost Per Move	Total Annual Dray Cost
10	$114	$22,807,056
30	$139	$27,844,833
50	$164	$32,882,611
70	$190	$37,920,389
90	$215	$42,958,167
110	$240	$47,995,944
130	$265	$53,033,722
150	$290	$58,071,500
170	$316	$63,109,278
190	$341	$68,147,056
210	$366	$73,184,833
230	$391	$78,222,611
250	$416	$83,260,389

Dray Cost as a function of Dray Length

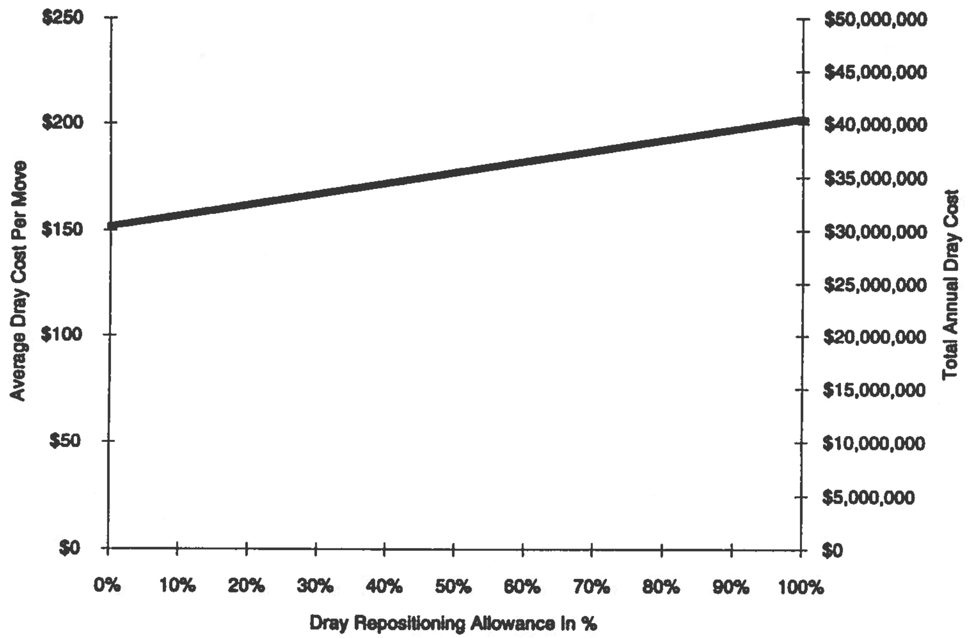


Dray Cost as a function of Dray Repositioning Allowance

As Exhibit 25 shows, there is a linear relationship between Dray Repositioning Allowance and the Dray Cost. Exhibit 25 shows this relationship with two different Dray Costs: Average Dray Cost Per Move and Total Annual Dray Cost. The one line represents both relationships. For each increase in Dray Repositioning Allowance of 10%, there is an increase of about $5 per move, or a total annual increase of about $1,000,000.

Dray Repositioning Allowance in %	Average Dray Cost Per Move	Total Annual Dray Cost
0%	$152	$30,363,722
10%	$157	$31,371,278
20%	$162	$32,378,833
30%	$167	$33,386,389
40%	$172	$34,393,944
50%	$177	$35,401,500
60%	$182	$36,409,056
70%	$187	$37,416,611
80%	$192	$38,424,167
90%	$197	$39,431,722
100%	$202	$40,439,278

Dray Cost as a function of Dray Repositioning Allowance



APPENDIX F - MODEL DOCUMENTATION

Inputs:

Terminal Characteristics

	Default Values
Total Working Track Length In Feet	16,000
Lift Machines	6
Optimal Lift Machine Spacing In Feet	1500
Lifts Per Machine-Hour	20
Lift Machine Availability In %	90%
Equipment Load Factor As A % of Capacity	95%
Switching Time Per Track Turnover In Hours	1
Parking Spaces	1200
Avg Dwell Time In Hours	48
Operating Hours Per Week	168
Working Hours Per 8-Hour Shift	7
Avg Gate Time In Minutes	3
Avg Gate Queue Length In Units	4
Peak Shift % of Avg Shift Volume	170%

Traffic Mix

	Default Values
Annual Volume In Lifts	200,000
% Traffic In Double-Stacks*	45%
% Traffic In Spine Cars*	10%
% Traffic In Conventional Flat Cars*	45%
% Traffic In Other*	0%
Double Stack: Units Per Car	10
Double Stack: Car Length In Feet	300
Spine Car: Units Per Car	5
Spine Car: Car Length In Feet	265
Conventional Flat Car: Units Per Car	2
Conventional Flat Car: Car Length In Feet	90
Other: Units Per Car	1
Other: Car Length In Feet	1

Drayage Factors

	Default Values
City Miles Input	30
City Speed In MPH	30
Hwy Speed In MPH	45
Avg Dray Yard Time In Minutes Per Move	30
Customer Hours Input	1.50
Overhead Cost Per Move	25
Dray Cost Per Hour	29.59
Dray Cost Per Mile	0.35
Avg Dray Length In Miles	50
Dray Repositioning Allowance In %	25%

---

*(% Traffic In Double-Stacks + % Traffic In Spine Cars + % Traffic In Conventional Flat Cars + % Traffic In Other) must be between 99% and 101% or ERROR!!! comes up in box A1 of the spreadsheet.

Outputs and Formulas:

Output: **Peak Lift Capacity, Lifts Per Shift [*T9*]**
Formula: Net Peak Lifts Per Hour [*H46*] * 8

- Net Peak Lifts Per Hour [*H46*] = {# of Machines [*C46*] * Net Lifts Per Hour [*F46*] * Operational Hours Per Shift [*G46*]} / 8
    - -# of Machines [*C46*] = **INPUT [*E9*]**
    - -Operational Hours Per Shift [*G46*] = **INPUT [*E18*]**
    - -Net Lifts Per Hour = Lifts Per Hour [*D46*] * Availability [*E46*]
        - Lifts Per Hour [*D46*] = **INPUT [*E11*]**
        - Availability [*E46*] = **INPUT [*E12*]**

Output: **Peak Lift Capacity Utilization [*T10*]**
Formula: Maximum Shift Volume [*N54*] / Peak Lift Capacity, Lifts Per Shift [*T9*]

- Peak Lift Capacity, Lifts Per Shift [*T9*] = **OUTPUT [*T9*]**
- Maximum Shift Volume [*N54*] = Avg Shift Volume [*M54*] * Peak % of Avg [*K54*]
    - -Avg Shift Volume [*M54*] = **INPUT [*J8*]** / (365*3)
    - -Peak % of Avg [*K54*] = **INPUT [*E21*]**

Output: **Average Lift Capacity, Lifts Per Year [*T11*]** (= Annual Lift Capacity [*J46*])
Formula: Net Peak Lifts Per Hour [*H46*] * Operating Hours Per Week [*E17*] * 52

- Operating Hours Per Week [*E17*] = **INPUT [*E17*]**
- Net Peak Lifts Per Hour [*H46*] = {# of Machines [*C46*] * Net Lifts Per Hour [*F46*] * Operational Hours Per Shift [*G46*]} / 8
    - -# of Machines [*C46*] = **INPUT [*E9*]**
    - -Operational Hours Per Shift [*G46*] = **INPUT [*E18*]**
    - -Net Lifts Per Hour = Lifts Per Hour [*D46*] * Availability [*E46*]
        - Lifts Per Hour [*D46*] = **INPUT [*E11*]**
        - Availability [*E46*] = **INPUT [*E12*]**

Output: **Machine Capacity Utilization In % [*T12*]**
Formula: Annual Volume Input [*T8*]/ Average Lift Capacity, Lifts Per Year [*T11*]

- Annual Volume Input [*T8*] = **OUTPUT [*T9*]**
- Average Lift Capacity, Lifts Per Year [*T11*] = **OUTPUT [*T11*]**

Output: Peak Track Capacity, Lifts Per Shift [*T13*] (=Maximum Track Capacity Per Shift [*H39*])
Formula: (8 / Maximum Yard Turnover Time, Including Switching [*G39*]) *
Track Capacity per Turnover @ Two Lifts Per Unit, With Given Load Factor [*E39*]

•Maximum Yard Turnover Time, Including Switching [*G39*] =
(Track Capacity per Turnover @ Two Lifts Per Unit, With Given Load Factor [*E39*] /
(Maximum Number of Lift Machines In Operation [*F39*] * Lifts Per Machine Hour [*E11*] *
(Working Hours Per 8-Hour Shift [*E18*] / 8))) + Switching Time Per Track Turnover In Hours [*E14*]

-Track Capacity per Turnover @ Two Lifts Per Unit, With Given Load Factor [*E39*] = **SEE INTERMEDIATE STEPS**
-Maximum Number of Lift Machines In Operation [*F39*] = Total Working Track Length In Feet [*E8*] /
Optimal Lift Machine Spacing In Feet [*E10*]

•Total Working Track Length In Feet [*E8*] = **INPUT [*E8*]**
•Optimal Lift Machine Spacing In Feet [*E10*] = **INPUT [*E10*]**
-Lifts Per Machine Hour [*E11*] = **INPUT [*E11*]**
-Working Hours Per 8-Hour Shift [*E18*] = **INPUT [*E18*]**
-Switching Time Per Track Turnover In Hours [*E14*] = **INPUT [*E14*]**
•Track Capacity per Turnover @ Two Lifts Per Unit, With Given Load Factor [*E39*] = **SEE INTERMEDIATE STEPS**

Output: Average Track Capacity, Lifts Per Year [*T14*] (=Maximum Annual Track Capacity [*I39*])
Formula: ((Operating Hours Per Week [*E17*] * 52) / Maximum Yard Turnover Time, Including Switching [*G39*]) *
Track Capacity per Turnover @ Two Lifts Per Unit, With Given Load Factor [*E39*]

•Operating Hours Per Week [*E17*] = **INPUT [*E17*]**
•Maximum Yard Turnover Time, Including Switching [*G39*] =
(Track Capacity per Turnover @ Two Lifts Per Unit, With Given Load Factor [*E39*] /
(Maximum Number of Lift Machines In Operation [*F39*] * Lifts Per Machine Hour [*E11*] *
(Working Hours Per 8-Hour Shift [*E18*] / 8))) + Switching Time Per Track Turnover In Hours [*E14*]

-Track Capacity per Turnover @ Two Lifts Per Unit, With Given Load Factor [*E39*] = **SEE INTERMEDIATE STEPS**
-Maximum Number of Lift Machines In Operation [*F39*] = Total Working Track Length In Feet [*E8*] /
Optimal Lift Machine Spacing In Feet [*E10*]
•Total Working Track Length In Feet [*E8*] = **INPUT [*E8*]**
•Optimal Lift Machine Spacing In Feet [*E10*] = **INPUT [*E10*]**
-Lifts Per Machine Hour [*E11*] = **INPUT [*E11*]**
-Working Hours Per 8-Hour Shift [*E18*] = **INPUT [*E18*]**
-Switching Time Per Track Turnover In Hours [*E14*] = **INPUT [*E14*]**
•Track Capacity per Turnover @ Two Lifts Per Unit, With Given Load Factor [*E39*] = **SEE INTERMEDIATE STEPS**

Output: **Track Capacity Utilization [_T15_]**
Formula: Annual Volume Input [_T8_] / Average Track Capacity, Lifts Per Year [_T14_]

- Annual Volume Input [_T8_] = **OUTPUT [_T8_]**
- Average Track Capacity, Lifts Per Year [_T14_] = **OUTPUT [_T14_]**

Output: **Parking Capacity [_T16_]** (=Annual Capacity [_F54_])
Formula: # of Spaces [_C54_] * Annual Turnover [_E54_]

- # of Spaces [_C54_] = **INPUT [_E15_]**
- Annual Turnover [_E54_] = 24 * 365 / Avg Dwell [_D54_]
  - Avg Dwell [_D54_] = **INPUT [_E16_]**

Output: **Parking Capacity Utilization [_T17_]**
Formula: Annual Volume Input [_T8_] / Parking Capacity [_T16_]

- Annual Volume Input [_T8_] = **OUTPUT [_T8_]**
- Parking Capacity [_T16_] = **OUTPUT [_T16_]**

Output: **Overall Peak Capacity Limit Lifts Per Shift [_T18_]**
Formula: MIN (Peak Lift Capacity, Lifts Per Shift [_T9_] , Peak Track Capacity, Lifts Per Shift [_T13_])

- Peak Lift Capacity, Lifts Per Shift [_T9_] = **OUTPUT [_T9_]**
- Peak Track Capacity, Lifts Per Shift [_T13_] = **OUTPUT [_T13_]**

Output: **Overall Average Capacity Limit Lifts Per Year [_T19_]**
Formula: MIN (Average Lift Capacity, Lifts Per Year [_T11_], Average Track Capacity, Lifts Per Year [_T14_])

- Average Lift Capacity, Lifts Per Year [_T11_] = **OUTPUT [_T11_]**
- Average Track Capacity, Lifts Per Year [_T14_] = **OUTPUT [_T14_]**

Output: **Average Terminal Dray Hours Per Move [_T20_]** (=Total Term Hours [_F61_])
Formula: Gate Hours [_C61_] + Queue Hours [_D61_] + Yard Hours [_E61_]

- Gate Hours [_C61_] = (Avg Dray Gate Time In Minutes [_E19_] * 2) / 60
  - Avg Dray Gate Time In Minutes [_E19_] = **INPUT [_E19_]**
- Queue Hours [_D61_] = (Avg Gate Queue Time In Units [_E20_] * Avg Dray Gate Time In Minutes [_E19_] * 2) / 60
  - Avg Gate Queue Time In Units [_E20_] = **INPUT [_E20_]**
  - Avg Dray Gate Time In Minutes [_E19_] = **INPUT [_E19_]**
- Yard Hours [_E61_] = (Avg Dray Yard Time In Minutes Per Move [_O11_] / 60) * 2
  - Avg Dray Yard Time In Minutes Per Move [_O11_] = **INPUT [_O11_]**

Output: Average Dray Cost Per Move [*T21*] (=Cost Per Move [*N61*])
Formula: **SEE INTERMEDIATE STEPS**

Output: Total Annual Dray Cost [*T22*] (= Total Drayage Cost [*O61*])
Formula: Cost Per Move [*N61*] * Annual Volume In Lifts [*J8*]

- Cost Per Move [*N61*] = **SEE INTERMEDIATE STEPS**
- Annual Volume In Lifts [*J8*] = **INPUT [*J8*]**

INTERMEDIATE STEPS

Intermediate Step: **Track Capacity per Turnover @ Two Lifts Per Unit, With Given Load Factor [*E39*]**
Formula: Total Working Track Capacity In Units [*D39*] * Equipment Load Factor As A % of Capacity [*E13*] * 2

•Total Working Track Capacity In Units [*D39*] = Average Units Per 1000 ft of Track [*C39*] * Total Working Track Length In Feet [*E8*] / 1000

-Average Units Per 1000 ft of Track [*C39*] = (% Traffic In Double•Stacks [*J9*] * (Double Stack Units Per Car [*J13*] / Double Stack Car Length In Feet [*J14*]) + % Traffic In Spine Cars [*J10*] * (Spine Car Units Per Car [*J15*] / Spine Car Length In Feet [*J16*]) + % Traffic In Conventional Flat Cars [*J11*] * (Conventional Flat Car Units Per Car [*J17*] / Conventional Flat Car Length In Feet [*J18*]) + % Traffic In Other[*J12*] * (Other Units Per Car [*J19*] / Other Length In Feet [*J20*])) * 1000

•% Traffic In Double•Stacks [*J9*] = INPUT [*J9*]
•(Double Stack Units Per Car [*J13*] = INPUT [*J13*]
•Double Stack Car Length In Feet [*J14*] = INPUT [*J14*]
•% Traffic In Spine Cars [*J10*] = INPUT [*J10*]
•Spine Car Units Per Car [*J15*] = INPUT [*J15*]
•Spine Car Length In Feet [*J16*] = INPUT [*J16*]
•% Traffic In Conventional Flat Cars [*J11*] = INPUT [*J11*]
•Conventional Flat Car Units Per Car [*J18*] = INPUT [*J17*]
•Conventional Flat Car Length In Feet [*J19*] = INPUT [*J18*]
•% Traffic In Other[*J12*] = INPUT [*J12*]
•Other Units Per Car [*J19*] = INPUT [*J19*]
•Other Length In Feet [*J20*] = INPUT [*J20*]

-Total Working Track Length In Feet [*E8*] = INPUT [*E8*]

•Equipment Load Factor As A % of Capacity [*E13*] = INPUT [*E13*]

Intermediate Step: Cost Per Move [*N61*]

Formula: ((Overhead Cost Per Move [*O13*] * 2) + (Total Hours [*M61*] * Dray Cost Per Hour [*O14*]) + (Total RT Miles[*G61*] * Dray Cost Per Mile [*O15*])) / 2

- Overhead Cost Per Move [*O13*] = **INPUT [*O13*]**
- Total Hours [*M61*] = Total Term Hours [*F61*] + City Hours @ 30 MPH [*I61*] + Hwy Hours @ 45MPH [*K61*] + Customer Hours Total [*L61*]
    - Total Term Hours [*F61*] = Gate Hours [*C61*] + Queue Hours [*D61*] + Yard Hours [*E61*]
        - Gate Hours [*C61*] = (Avg Dray Gate Time In Minutes [*E19*] * 2) / 60
            - Avg Dray Gate Time In Minutes [*E19*] = **INPUT [*E19*]**
        - Queue Hours [*D61*] = (Avg Gate Queue Time In Units [*E20*] * Avg Dray Gate Time In Minutes [*E19*] * 2) / 60
            - Avg Gate Queue Time In Units [*E20*] = **INPUT [*E20*]**
            - Avg Dray Gate Time In Minutes [*E19*] = **INPUT [*E19*]**
        - Yard Hours [*E61*] = (Avg Dray Yard Time In Minutes Per Move [*O11*] / 60) * 2
            - Avg Dray Yard Time In Minutes Per Move [*O11*] = **INPUT [*O11*]**
    - City Hours @ 30 MPH [*I61*] = City Miles Total [*H61*] / City Speed In MPH [*O9*]
        - City Miles Total [*H61*] = City Miles Input [*O8*] * 2
            - City Miles Input [*O8*] = **INPUT [*O8*]**
        - City Speed In MPH [*O9*] = **INPUT [*O9*]**
    - Hwy Hours @ 45 MPH [*K61*] = Hwy Miles [*J61*] / Hwy Speed In MPH [*O10*]
        - Hwy Miles [*J61*] = Total RT Miles[*G61*] • City Miles Total[*H61*]
            - Total RT Miles[*G61*] = (Avg Dray Length In Miles [*O16*] *2) * (1 + Dray Repositioning Allowance In % [*O17*]
                - Avg Dray Length In Miles [*O16*] = **INPUT [*O16*]**
                - Dray Repositioning Allowance In % [*O17*] = **INPUT [*O17*]**
            - City Miles Total [*H61*] = City Miles Input [*O8*] * 2
                - City Miles Input [*O8*] = **INPUT [*O8*]**
        - Hwy Speed In MPH [*O10*] = **INPUT [*O10*]**
    - Customer Hours Total [*L61*] = Customer Hours Input [*O12*] * 2
        - Customer Hours Input [*O12*] = **INPUT [*O12*]**
- Dray Cost Per Hour [*O14*]) = **INPUT [*O14*]**
- Total RT Miles[*G61*] = (Avg Dray Length In Miles [*O16*] *2) * (1 + Dray Repositioning Allowance In % [*O17*]
    - Avg Dray Length In Miles [*O16*] = **INPUT [*O16*]**
    - Dray Repositioning Allowance In % [*O17*] = **INPUT [*O17*]**
- Dray Cost Per Mile [*O15*] = **INPUT [*O15*]**

APPENDIX G - TIMELINE OF INTERMODAL DEVELOPMENTS

This timeline traces many of the developments that shaped the intermodal industry and intermodal terminal practices.[1]

1950s

1952	Rail-Trailer Company founded to promote piggyback service.
1953	Southern Pacific establishes Los Angeles-San Francisco dedicated piggyback service.
1954	The ICC responds to the "Twenty Questions" case brought by the New Haven (Movement of Trailers by Rail, 293 ICC 93), reducing railroad uncertainty and leading to expansion of piggyback service.
1954	Introduction of Plans I - V for piggyback service.
1955	Trailer-Train Company is established (later TTX) to supply piggyback cars.
1955	Piggyback service offered by Class I railroads in most, but not all regions.
1955	Implementation of the retractable hitch, eliminates chains and binders to secure loads.
1955	Introduction of TrucTrain service on Pennsylvania Railroad.
1956	Sea-Land's *Ideal X* sails with 58 containers from New York to Houston, the beginning of marine containerization.
1956	The Federal Aid to Highways Act is passed, establishing the Interstate System and increasing truck competitiveness.
1957	XTRA Leasing is formed to supply piggyback trailers.
1958	Matson Navigation's *Hawaiian Merchant* sails with 20 containers from San Francisco to Honolulu, the start of containerization in the Pacific.
1959	Introduction of specially built hostler tractors for yard use.
1959	Introduction of the 85-foot flatcar car with automatic retractable hitches, deployed by hostler tractor rather than a power wench.

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[1] The major source for this timeline was: David J. DeBoer, *Piggyback and Containers: A History of Rail Intermodal on America's Steel Highway* (San Marino, California: Golden West Books, 1992).

1960s

1960	Pullman Standard develops prototype 89-foot double hitch car which serves as the industry standard for the next 20 years.
1960	Realco Leasing is formed to supply piggyback trailers (becomes part of Transamerica in 1968).
1961	The Equipment Interchange Association is formed (becomes the Intermodal Transportation Association in 1976).
1961	The first Paceco gantry crane in service at Kearny, NJ.
1961	The AAR Motor Transportation Advisory Committee established.
1963	Santa Fe's Corwith Chicago terminal installed a newly designed crane that handled an "astounding" 125 trailers in a day.
1963	The first Drott gantry crane is delivered to ATSF's Corwith Yard.
1963	National Piggyback Association is formed (becomes the National Railroad Intermodal association in 1976).
1964	The first sideloader is adapted from a logging stacker, placed in service on Southern Pacific.
1965	Development of the TTAX all-purpose flatcar to carry either trailers of containers without chassis.
1965	An estimated 2100 piggyback ramps are in service, but only 3 percent are mechanized.
1966	Sea-Land introduces trans-Atlantic container service.
1966	The first LeTourneau wide-span (68 feet) gantry is delivered.
1966	The first production sideloader, the "Piggypacker," is introduced at the Bensenville terminal. in Chicago.
1966	United Parcel Service (UPS) begins using intermodal; it will become the largest intermodal customer.
1968	The National Association of Shipper's Agents is formed (becomes the Intermodal Marketing Association in 1987).
1968	Ropco Corporation (later Raygo-Wagner) develops a sideloader delivered to Union Pacific for use in Seattle.

1970s

1972	Landbridge service is introduced by Sea-Land.
1972	Minilandbridge service is introduced by SeaTrain.
1972	The 2 for 1 concept is implemented on the Reading Railroad in Philadelphia. Lanes on either side of the train, one inbound, one outbound, allow drivers to begin making "live" moves.
1972	Development of center-row parking at the reading. Center are for storage between two 2 for 1 tracks, allows for much more efficient movement of containers.
1973	ISO releases Standard 668 for intermodal containers, specifying measurements and attachment points, sets stage for growth of containerization.
1975	The terminal system stands at about 1500 ramps, 7 percent mechanized, before consolidation into the modern hub system.
1976	The "spine car" is introduced as Santa Fe's "six pack."
1977	First single-unit SP/ACF double-stack car is built and tested.
1978	Prototype RoadRailers are built and tested.
1979	APL introduces "Linertrain" dedicated intermodal service using leased conventional flatcars.

1980s

1980	The Staggers Act reforms railroad regulation and promotes competition.
1980	The Motor Carrier Act reduces trucking regulation and promotes competition, leading to eventual intermodal use by truckers.
1981	Southern Pacific ordered the first 42 five-unit production stack cars from ACF.
1981	First production five-unit SP/ACF double stack cars are built.
1981	Intermodal transportation by rail is exempted from ICC regulation.
1982	Burlington Northern begins condensing piggyback ramps into intermodal hubs, followed by other systems.
1983	Demonstration double-stack train operated for APL.
1984	APL introduces regular double-stack service with their own cars.
1984	The Shipping Act of 1984 liberalizes shipping regulation and encourages intermodalism.
1985	The intermodal system is condensed to about 430 ramps, 36 percent mechanized.
1986	The 48-foot domestic container is introduced.
1986	SP's ICTF opens in Southern California.
1986	Chassis racks are introduced to railroad practice at CNW's Global One facility in Chicago.
1987	Norfolk Southern establishes the Triple Crown subsidiary to operate RoadRailers.

1990s

1990	The terminal system is condensed to 231 ramps, 85 percent mechanized.
1990	The prototype single-unit, stand-alone double-stack car is introduced.
1992	The Intermodal Marketing Association, Intermodal Transportation Association, and National Railroad Intermodal association join to form the Intermodal Association of North America (IANA).

GLOSSARY

AAR	Association of American Railroads
AEI	Automatic Equipment Identification
APL	American President Lines
ATM	Automated Teller Machine
ATSF	Atcheson, Topeka & Santa Fe
AVI	Automated Equipment Identification
BN	Burlington Northern
CAA	Clean Air Act
CAD	Computer-Aided Design
CEO	Chief Executive Officer
CNW	Chicago & Northwestern
COFC	Container-on-flatcar
CP	Canadian Pacific
CR	Consolidated Rail Corporation (Conrail)
CSX	CSX Corporation
CSXI	CSX Intermodal
DOT	Department of Transportation
ECR	Efficient Customer Response
EDI	Electronic Data Interchange
FAK	Freight All Kinds
FSAC	Freight Station Accounting Code
GDP	Gross Domestic Product
GIS	Geographic Information System
HPMS	Highway Performance Monitoring System
ICC	Interstate Commerce Commission
ICTF	Intermodal Container Transfer Facility
IMC	Intermodal Marketing Company
IMU	Intermodal Unit

ISTEA	Intermodal Surface Transportation Efficiency Act
JIT	Just-in-Time
LTL	Less-than-Truckload
MGOS	Modular Grid Overlay System
MPO	Metropolitan Planning Organization
NAFTA	North American Free Trade Agreeement
NCIT	National Commission on Intermodal Transportation
NEC	Northeast Corridor
NHS	National Highway System
FGN	(Norfolk International Terminal)
NS	Norfolk Southern
NTS	National Transportation System
NW	Norfolk Western
SAS	Statistical Analysis System
SCAC	Standard Carrier Alpha Code
SIC	Standard Industrial Code
SIG	Seattle Intermodal Gateway
SMA	Standard Metropolitan Area
SP	Southern Pacific
SPLC	Standard Point Location Code
STCC	Standard Trade Commodity Code
TOFC	Trailer-on-Flatcar
TQM	Total Quality Management
TRB	Transportation Research Board
UP	Union Pacific
UPS	United Parcel Service
USPS	U.S. Postal Service
VKT	Vehicle Kilometers Traveled
VMT	Vehicle Miles Traveled
VNTSC	Volpe National Transportation Systems Center
VZM	Vickerman•Zachary•Miller
WIN	Weight-in-Motion

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