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Improving Performance of Intermodal Terminals through Automation and Rail-for-Truck Modal Switch

by

Athanasios Denisis

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Signature of Author...
Department of Ocean Engineering
February 11, 2002

Certified by...
Henry S. Marcus
Professor of Ocean Systems Management
Thesis Supervisor

Accepted by...
Henrik Schmidt
Professor of Ocean Engineering
Chairman, Department Committee on Graduate Students

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Abstract

The U.S. container trade has historically grown at high rates of 8 to 10 percent per year. Although the September 11 events have caused a temporary decline in the growth rate, it is expected to approach its historical growth rates again in the future. The congestion in certain U.S. intermodal port terminals will soon reach to a "deadlock" with further consequences for highway traffic and the environment. This paper deals with the possibilities for productivity improvements at intermodal terminals, as a way to accommodate ocean and rail freight transportation growth.

Current developments in the container market are examined. Automation of intermodal terminals and container handling operations, based on recent approaches, has been introduced in terminals in Asia and Europe with very promising results. Furthermore, the paper proposes an intermodal container terminal at a representative site as part of a network between the major U.S. East Coast ports and the major hub of Chicago. We examine the monetary and environmental benefits of a modal switch from truck to rail mode for the cargo that originates from these ports. The significant environmental benefits can justify public investments. The total cost savings can recover a significant proportion of the construction cost of the proposed intermodal terminal. Finally, the productivity improvements due to rail use and automation serve to reduce dwell time for containers transported by shuttle or freight trains and to improve land utilization by making available land formerly used for container storage.

Thesis supervisor: Henry S. Marcus
Title: Professor, Department of Ocean Engineering

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Chapter 1

Introduction

Container transportation demand is expected to grow significantly over the next 25 years, with the most rapid growth involving intermodal and international traffic. Congestion at U.S. terminal ports has been a growing transportation problem in recent years. Better understanding of the factors affecting terminal capacity and performance will help both the terminal operators that run the intermodal terminals and the port authorities that control port facilities. Furthermore, public agencies at the local, state, and federal level are highly concerned about traffic congestion and environmental issues. From a public perspective, railways are seen as one of the keys to relieving highway congestion around ports, as well as a critical factor supporting international trade. With the continuing growth of freight transportation, public agencies are beginning to recognize the importance of modernizing terminal infrastructure, including connecting links among highway, rail, and port facilities (i.e. Alameda Corridor).

This thesis has been conducted as a part of the research project of the MIT Center of Transportation Studies and the Affiliated Laboratory with the theme subject

"Opportunities for Enhancing the Capacity and Performance of Railroad Terminals," sponsored by the Association of American Railroads (AAR), in 2001. The primary objective of the project was to develop background material on terminal performance that could be used by the AAR in developing a research plan for terminals as part of its new "Strategic Research Initiative" addressing network efficiency. Our first contribution to this project was an annotated bibliography (Appendix E), a review of current published studies on marine container terminals.

In this paper, we address the major topic of productivity improvements that the U.S. intermodal terminals are going to face due to developments in the container market. First, we present the structure of the overall container market, its current developments and the challenges they create for ports and terminals. Many ports and terminal operators worldwide have handled these developments by implementing various technologies of automation in information data processing and cargo handling equipment. New fully automated terminals have been introduced the last decade, with broad use of Information Technology (IT) and Electronic Data Interchange (EDI). They use software programs for container storage and container tracking. Their cargo handling equipment includes larger, more sophisticated gantry cranes, and straddle carriers that load and unload the container ships much faster than the old conventional cranes. The advances in equipment along with their different operational patterns and labor relationships have resulted in a total annual throughput per acre in certain Asian ports to be almost four times higher than the average in U.S. ports.

In order to deal with these challenges and the foreign competition, U.S. terminal operators and ports should move towards investments in infrastructure and equipment, and changes in their operations. We present the future trends in terminal technology that prevail in the most technologically advanced ports of the world, like the Delta/Sea-Land terminal in Rotterdam (from Europe Combined Terminal (ECT) B.V) and the split terminal approach or Agile Port System proposed by Noell Crane Systems GmbH.

Furthermore, we propose a quantitative model for measuring the environmental and monetary impacts of a modal switch from truck mode to rail mode for a proposed intermodal terminal at a representative site. We use the cost formulas and assumptions from a similar mode comparison including three modes of transportation—rail, trucks, and barges—made for a Marine Transportation System (MTS) Task Force as part of an assessment of the U.S. marine transportation system, [1]. We examine how the monetary benefits and the container storage area savings from a modal switch, for this proposed terminal, could partially subsidize its construction cost. Our analysis indicates that the complex problem of cargo traffic growth and or terminal expansion can be solved in an efficient way by implementing automation technologies and fostering more the use of the rail mode in intermodal terminals.

However, it is the responsibility of the port and local authorities, and of the terminal operators to determine how they should implement these suggestions for technological improvements, in order to facilitate US foreign and domestic trade and to improve the environmental character of the port's surrounding area.

Chapter 2

The Container Market

2.1 Container Trade

Containerization began in 1955, when Malcolm McLean, the owner of a North Carolina trucking firm, packed individual pieces of cargo into a truck trailer and the entire trailer was then moved to the seaport, across the ocean, and to the door of the recipient. He purchased a shipping line, renamed it Sea-Land, and was experimenting with the movement of trailer loads of cargo, using refitted World War II tankers. The containerization of commerce had begun. In the years that followed, standardized trailer bodies were constructed, generally twenty or forty feet long, known as Twenty-foot Equivalent Unit (*TEU*) and Forty-foot Equivalent Unit (*FEU*) containers. The use of standardized containers meant that "*Intermodalism,*" the movement of goods from point to point by more than one mode of carrier, became commercially feasible. To accommodate these changes, new investments were needed on both land and water. Gradually, the refitted tankers and breakbulkers were replaced with vessels designed specifically to carry thousand of these standardized "boxes," the *containers*. On land, new terminal equipment was necessary –ship side cranes that could load and unload the containers and specialized equipment for moving the containers around the port yard.

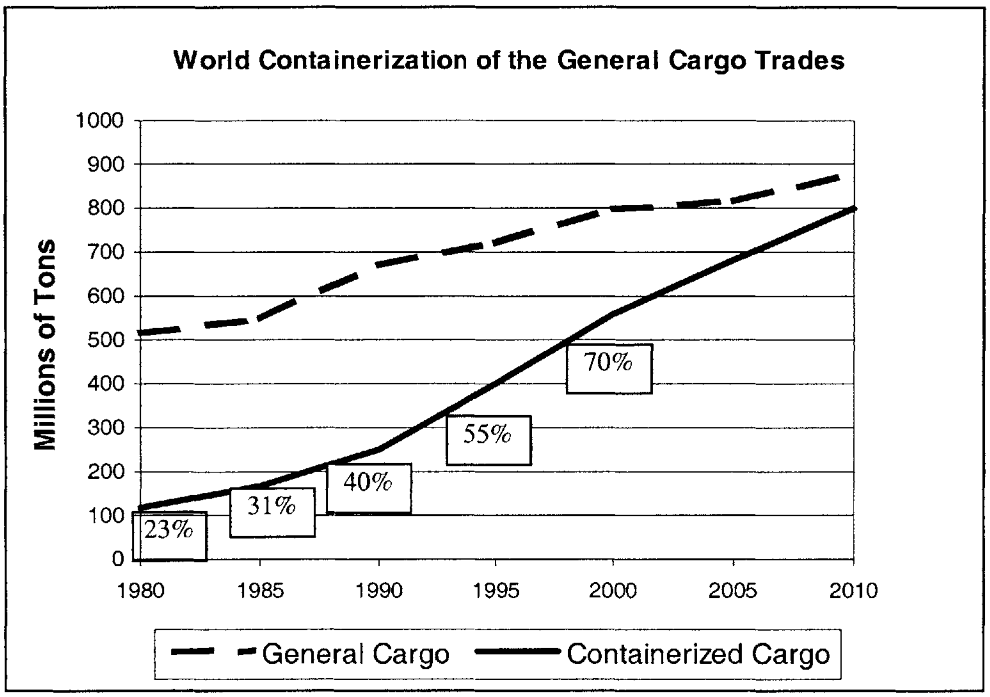
Postwar economic recovery and the sustained period of economic expansion brought high rates of growth in the value and volume of trade, especially among industrialized countries. During the two decades from 1960 to 1980, the world's gross product grew at an average annual rate of about five percent. The world followed with similar growth rates. In the 1990s, the overall world waterborne trade increased by 3.8 percent annually – on an average ton basis- during 1993 -1997, to a total 5.3 billions tons in 1997. In 1998, world seaborne trade recorded its thirteenth consecutive annual increase. For the same period, U.S. foreign waterborne trade grew by 4.6 percent annually to a total of 1,071 million tons, accounting for about 21 percent of the total waterborne trade, [1]. Tankers, dry-bulk and general cargo ships, such as containerships are the principal vessels operating in the deep-sea trade.

The container market sector is growing steadily at the highest rates, both globally and within the US. While for the world General Cargo Trade, an annual growth of 3 to 4 percent is forecasted until 2005, for the container sector, this is estimated at 8 to 10 percent on an annual basis (according to studies made before the September 11 events). The containership fleet will meet or exceed this trend by showing similar rates of growth, with significant upsizing of vessels (Table 2.1). The penetration of containerized cargo to total general cargo will exceed 70 percent by the year 2010 (Figure 2.1).

Table 2.1 World Trade Growth vs. Fleet Growth, to 2002

Trade / Vessel	Percent	
	Trade %	Fleet %
Dry bulk	3 – 4	1 – 2
Tanker	2 – 3	1 – 2
Product	4 – 5	3 – 4
Crude	1 – 2	0 – 1
General Cargo	6 – 7	2 – 3
Container	**8 – 10**	**8 – 10**
Other general cargo	0 – 1	-1 – 0

Source: U.S. Department of Commerce, 1999



Source: Maritime Reporter, November 1996

Figure 2.1 World Containerization of the General Cargo Trades

The largest volume of container trade is on the routes linking the three major industrial centers of the world, North America, Western Europe, and the Far East.. The three major trade routes are:

i. The North Atlantic route, covering the trade among Europe, Eastern Canada, and United States. This was the first liner route to be containerized. It covers the major European ports of Gothenburg, Hamburg, Le Havre, Antwerp, and Rotterdam. At the North American end, the ports of New York/New Jersey, Virginia – Hampton Roads, Philadelphia, and Charleston, are the regular port calls.

ii. Trans-Pacific trade route. It connects North America to the Far East, between the East and West Coasts of North America, and the Far East, stretching from Japan to Singapore. The major US port location on this trade is the combined area of the ports of Los Angeles and Long Beach. Cargo movements from the East Coast ports involve either the use of rail connections or transit through the Panama Canal (and to a lesser extent through the Suez Canal).

iii. Europe to the Far East, between Europe and Far Eastern countries. It is the longest trade route, in which the round voyage takes about sixty days.

Between the North American West Coast and the Far East, the number of liner firms has decreased over the last 20 years from 38 to 32 carriers (in fact, fewer carriers, since three of these carriers are really alliances). Between the U.S. East Coast and Europe, the number of liner operators has increased from 14 to 38 in this same time period, [2]. The top 20 carriers represent 17 out of the carriers on the Pacific trade and 15 of the operators on the Atlantic trade, showing the preference of most large carriers to provide global service.

2. 2. The Containership Liner Industry

With the advent of containerization in the 1950s, we saw the restructuring of the general cargo sector of shipping industry and the emergence of the container shipping industry as a separate sector. Banks made huge loans for new vessel construction and facilitated the development of the containership fleet. The role of a container shipping company is to provide fast, frequent, and reliable sea transport for any cargo placed in containers to almost any destination at a predictable charge. This function, which is called *Liner Service*, forms an essential link in a modern network of global trade. Liner companies operating on the same route form *cartels* or closed *conferences*, which restrict memberships, set freight rate, and often fix the trade share of each member of the conference.

During the 1980s, investors from the newly industrialized countries of Asia and the Pacific Rim—Japan, Taiwan, Hong Kong, Singapore, and Korea—emerged as major containership operators. By 1988, Asian operators controlled about 33 percent of the world container fleet, [2]. The American and European proportion declined below 50 percent.

However, nowadays as we consider the worldwide liner service, it becomes apparent that more than 600 companies operate in container shipping in a wide range of size and strategies. Since two of the three major trade routes in the world have only 53 different carriers, there must be many small companies operating around the world in secondary trades.

According to Marcus and Byrnes [2], containership operators can be categorized into three categories of tiers, depending on their market shares: large (for the first tier), medium (for the second tier), and small (for the third tier). The first tier carrier differentiates on the cost and quality of service it provides, although it is difficult to achieve both characteristics simultaneously. In practice the most successful first tier carriers are the ones with competitively high quality of service. The third tier carriers are the market niche players. Third tier carriers that penetrate a market niche are often successful and profitable, because of the competitive advantage in a specific market segment. First tier carriers typically benefit from economies of scale, but having varying profitability. The second tier is made up of all the remaining carriers. In terms of numbers this is the largest part on any trade route. This type of carriers is the most vulnerable because they lack the resources and services of the first tier but have larger expenses and less market focus than the third tier.

It also remarkable that the containership industry, as a whole, is characterized from low levels of profitability. Although there was a steady market growth around 6% annually and continuous steps in fleet modernizing, the industry's average operating profit margin over an eleven-year period was 3.1% [3]. Overcapacity and falling freight rates of the larger companies are two reasons for that performance.

2. 3 Container Ports

This segment of the water transportation industry handles foreign and domestic marine cargo as it moves across or through a dock, pier, terminal, staging area, or in-transit area before it is loaded or after it is unloaded. It also includes operation and maintenance of piers, docks, and associated buildings and facilities. The emergence of container cargo had a great impact on port operations. Intermodal transportation meant that movement of cargo required the cooperation of many modes of carrier. The point where the cargo interchange takes place is the port terminal. Ports started land expansion programs and large investments in equipment in order to facilitate this exchange of cargo.

Port activity is widely dispersed throughout the world, with the top 25 ports accounting for only 22 percent of vessel port calls. Of these top ports, 12 were in the Far East, 10 were in Europe, and 3 were in the United States: Houston, New Orleans, and Los Angeles (Table 2.2), [4].

International container trade through U.S. ports is highly concentrated. The top 10 container ports account for almost 80 percent of container traffic (measured in metric tons) in U.S.-foreign trade in 1997 (Table 2.3). Three of the top five container ports in the United States are on the West Coast. Los Angeles and Long Beach, California, had the largest absolute growth in container traffic between 1995 and 1997 (measured in TEUs), but Miami and West Palm Beach, Florida; Savannah, Georgia; Charleston, South Carolina; Houston, Texas; and Newport News, Virginia, showed the largest rates of growth over the period, reflecting high growth in U.S.-Latin America container trades.

Table 2.2. World Port Ranking in 1998 by Container Traffic ('000 TEUs)

RANK	PORT	COUNTRY	'000TEUs
1	Singapore	Singapore	15,136
2	Hong Kong	China	14,582
3	Kaohsiung	Taiwan	6,271
4	Rotterdam	Netherlands	6,004
5	Busan	South Korea	4,539
6	Long Beach	USA	4,098
7	Hamburg	Germany	3,566
8	Los Angeles	USA	3,378
9	Antwerp	Belgium	3,266
10	Shanghai	China	3,066
11	Dubai	UAE	2,804
12	Tokyo	Japan	2,495
13	NewYork / NewJersey	USA	2,466
14	Gioia Tauro	Italy	2,126
15	Yokohama	Japan	2,091
16	San Juan	USA	1,990
17	Kobe	Japan	1,901
18	Manila	Philippines	1,855
19	Algeciras	Spain	1,826
20	Port Kelang	Malaysia	1,820
21	Bremen Ports	Germany	1,811
22	Colombo	Sri Lanka	1,714
23	Felixstowe	UK	1,712
24	Keelung	Taiwan	1,707
25	Oakland	USA	1,575
26	Seattle	USA	1,544
27	Nagoya	Japan	1,458
28	Laem Chabang	Thailand	1,425
29	Tanjung Priok	Indonesia	1,425
30	London	UK	1,334
31	LeHavre	France	1,319
32	Charleston	USA	1,278
33	Genoa	Italy	1,266
34	Hampton Roads	USA	1,252
35	Dublin	Ireland	1,191
36	Tacoma	USA	1,156
37	Buenos Aires	Argentina	1,138
38	Melbourne	Australia	1,125
39	Bangkok	Thailand	1,114
40	Barcelona	Spain	1,095
41	Durban	South Africa	1,080
42	Valencia	Spain	1,005
43	Houston	USA	968
44	Jeddah	Saudi Arabia	968
45	Piraeus	Greece	933
46	Montreal	Canada	933
47	Taichung	Taiwan	880

Source: American Association of Port Authorities (AAPA), 1999

Table 2.3 U.S. Port Ranking in 1998 by Container Traffic (TEUs)

RANK	PORT	TEUs
1	Long Beach	4,097,689
2	Los Angeles	3,378,217
3	NewYork NewJersey	2,466,013
4	SanJuan	1,990,275
5	Oakland	1,575,406
6	Seattle	1,543,726
7	Charleston	1,277,514
8	Hampton Roads	1,251,891
9	Tacoma	1,156,495
10	Houston	968,169
11	Miami	813,761
12	Jacksonville	753,823
13	Savannah	730,611
14	Port Everglades	704,390
15	Baltimore	486,861
16	Honolulu	479,948
17	Anchorage	358,480
18	Portland (OR)	259,308
19	New Orleans	244,624
20	Philadelphia	233,728
21	Wilmington (DE)	199,240
22	Boston	147,156
23	Gulfport	144,961

Source: American Association of Port Authorities (AAPA), 1999

2.4 Container Terminals

In transportation terminology, terminal is the interchange area of cargo or passengers. Intermodal terminal is the place where containers received from one mode are transferred to another. For example, in a marine intermodal terminal, containers from a containership are loaded onto trucks or trains. However, the operation of a terminal is not that simple. A container terminal must perform four basic functions: receiving, storage, staging, and loading. Because of the significance to the transportation of goods and products as a critical node in the supply chain, different participants are involved, sometimes with conflicting interests, in the operation of a terminal; the shipper who loads the container, the inland carrier who transports it from and to the terminal, the terminal operator who manages the landside entry and exit of containers, the stevedore who loads and unloads the containership, and the recipient of cargo. The exact identity and role of each of these participants may vary.

The three important characteristics of an intermodal terminal, according to [5] are:

i. Location. Although initially it was function of geography and population, a recent trend is to locate intermodal terminals as distribution centers away from large cities in order to save by avoiding the high cost of real estate, labor, and environmental impacts.

ii. Access. Intermodal terminals should provide clear and easy access and other facilities for coordinating the interface of two or more different transportation modes. In the past, many seaport terminals were located and designed primarily for vessel loading, with little attention given to their ability to move cargo to and from inland efficiently. Today, after the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 there is a tendency to encourage the connections of different modes.

iii. Infrastructure. Infrastructure relates to the terminal design and equipment. Major elements are the water depth, the quay design and size the container yard, container cranes, inland container transfer vehicles, etc.

An intermodal terminal can be operated by a public port, a stevedoring private firm under long-term lease, a containership company that operates the terminal as a dedicated facility, or a railroad company that carries the containers inland. Today, there is a trend towards commercialization and privatization of ports and terminals around the world. The two main types of terminal management are established by the five large global terminal operators and the smaller specialized and more local terminal operators. The five global operators or "The Big Five" are: Hutchison Port Holdings – Hong Kong, P&O Ports – Australia, International Container Terminal services (ICTSI) – Philippines, PSA Corporation Ltd (Port of Singapore Authority) – Singapore, Stevedoring Services of America (SSA) – U.S.A., [6].

Besides these large operators, there is a number of specialized less globally oriented terminal operators. These are: Hamburger Hafen und Lagenrhaus Aktiengesellschaft (HHLA) – Germany, Eurokai – Germany, Hessenattie – Belgium, Pacific Ports Co. (PPC) – Hong Kong, Ceres terminals Inc – U.S.A., Europe Combined terminals (ECT) – Netherlands (in the process of been purchased by Hutchison, and Bremen Lagerhaus – Gesellscaft (BLG) – Germany.

2.5 Developments in the Container Market

From the presented data in Table 2.1, it is clear that the container market is the most expanding sector in shipping industry. However, it is not the most prosperous one. Of the top 20 containership liner companies, only one—according to the CEO of CP

Ships Inc.—has been able to achieve acceptable levels of profitability. In aggregate, carriers are estimated to have lost in 1998 $2.4 billion on east-west routes. The average revenue per one TEU container fell from $1,590 in 1996 to $1,370 in 1998, [3]. So, the container shipping industry remains an industry with financial problems.

Furthermore, current changes that occur in the container market are making the financial landscape for the containership industry even more uncertain. The profitability and the recent developments in the container market will have an immediate impact on US container ports and container terminals. I present these important developments.

2.5.1 Growing Levels of Demand

The world container trade will continue to grow at higher rates—forecasted about 8 to10 percent per year—than the other sectors of waterborne trade (Table 2.1). Some reasons that this trend will continue despite any short-term lulls in growth due to any future economic recession are:

- Globalization that favors the growth of world trade by cutting custom's tariffs and taxes among countries.
- Decentralized manufacturing processes from major manufacturing firms that move their production lines to low-labor-cost countries.
- Penetration of containerships to other trades, especially traditional dry bulk trades, such as bagged sugar, agribulks, or even forest products that until today are carried by general cargo vessels. This conversion of break bulk cargoes to "unitized"—or containerized cargo—will increase in the future.

- Withdrawal of the multi-purpose cargo ships, like the twin-deckers due to age.

2.5.2 Merger and Acquisition Activity

The merger and acquisition—or takeover—activity the last five years has played a part in the further concentration of ownership in the liner industry (Table 2.4). These mergers are basically cost-driven, providing savings in the administrative cost sector. Major mergers in the 1990s were the Maersk/Sealand and the P&O CL/Nedlloyd merger.

Table 2. 4 Concentration of the Containership Industry

Year	'000 TEU Operated by Top 20 Lines	% of World Total Slots Operated by Top 20 Lines
1992	1.43	39.6
1993	4.60	42.7
1994	1.84	44.8
1995	2.11	47.8
1996	2.30	47.6
1997	2.62	49.8
1998	3.11	53.0

Source: Drewry Shipping Consultants Co.Ltd, 1999

2.5.3 The Transshipments Incident and the Empty Containers Movements

The total activity of port handling consists of movements of loaded containers plus the empty ones, plus the transshipments. The volume of port-to-port loaded container movements has decreased, as a proportion of the total movements. The transshipments and the empty container movements are increasing at higher rates. Additionally, many large carriers have implemented multi-trade operational patterns and strategies, known as *"multi-trade pendulum routing,"* instead of direct port-to-port practices. The port of Singapore has the lead as a transshipment center for the Far East trade and the Freeport, Bahamas for the North Atlantic trade.

2.5.4 Imbalances in the World Trade

The incident of transshipments and empty containers movements will continue due to regional imbalances in demand. The Asia crisis in 1998 and its aftermath exacerbated an east-west imbalance, which had no precedent in the history of liner shipping. Eastbound trade is growing rapidly, while westbound is shrinking. This transpacific, Asia-North America, trade today is the one of the largest container trades, but also the most imbalanced.

However, the container trade is a round trip business, and the imbalanced demand is an unfortunate fact for many other routes also. The world in which every cargo flow has a mirror-image return load is a utopia, and in reality the majority of trade imbalances are unavoidable.

2.5.5 Deregulation of the Liner Trade (OSRA '98)

The Ocean Shipping Reform Act 1998 (OSRA'98), or Public Law 105-258, came into effect on May 1, 1999 and changed the nature of the commercial agreements, with the establishment of the confidential service contracts, which can be made between carriers –individually or collectively- and shippers. The general deregulation principles will open the liner market to new operators and will shrink the conferences' power. After the implementation of the OSRA'98 more carriers have been added to traditional trade routes. Furthermore, the OSRA'98 provides authority to port agencies to form port conferences, which now have the power to take action in the rationalization of port rates (tariffs).

2.5.6 Upsizing of the Containerships

The container ship fleet is becoming oriented towards even larger vessels. Not only are the largest ships in the fleet getting bigger year by year, but there is also only a noticeable growing trend in vessel upsizing through the fleet. Most ships on order are the large "post-panamax" size containerships (Table 2.5). The most tangible change that the U.S. ports will have to face in the near future is the arrival of these "mega ships," whose draught exceeds the forty feet limit of many coastal ports (as discussed below).

Table 2.5 Containership Orderbook by Size and Range

Vessel Size (TEU)	Capacity (TEU)	% of Capacity
< 500	5,589	0.8
500 - 999	33,929	4.8
1,000 – 1,499	47,710	6.7
1,500 – 1,999	53,467	7.6
2,000 – 2,499	47,569	6.7
2,500 – 2,999	24,830	3.5
3,000 – 3,499	16,001	2.3
3,500 – 3,999	53,048	7.5
> 4000	**424,656**	**60.1**
Total	706,799	100.0

Source: Drewry Shipping Consultants Co. Ltd, 1999

2.6 Challenges for the US ports

Along with the developments in the container market, many complex issues affect the U.S. public ports, including financing of current operations and future terminal development, complying with environmental laws and regulations, dredging, and addressing the challenges posed by global shipping alliances. Additionally, the growing use of intermodal transportation depends on improved landside access to marine terminals, which in turn may depend on port involvement in transportation planning. How these issues will be resolved is important not only to the public port industry, but to many other industries because of the key role ports play in intermodal transportation and national defense.

The major challenges that the U.S. ports have to face are divided into two main categories: a) infrastructure issues and b) environmental issues.

2.6.1 Infrastructure Issues

Within the notion of infrastructure we mostly refer to the yard capacity and equipment issues that includes:

i) Dredging. Dredging is one of the most visible and hotly discussed capacity issue. U.S. ports are continually faced with the challenge of handling larger ships. Currently, the next generation of containerships (megaships) is causing the most concern. These ships require sophisticated and efficient port and terminal facilities, with excellent landside intermodal connections. Megaships are being constructed with carrying capacities ranging from 4,500 to over 7,000 TEUs and fully loaded design drafts of 40 to

46 feet. In order to accommodate these vessels, channels, berths, and turning basins will need depths approaching 50 feet. Most U.S. ports are currently unable to handle these ships (Table 2.6), [7]. Only 4 of the top 10 U.S. container ports, which handle nearly 80 percent of the container traffic, have existing channel depths of 50 feet or more. Thus, dredging has become the leading issue concerning the ability of U.S. ports to handle megaships. The economics of these new vessels may result in fewer port calls per round trip. Additionally, megaships will impact terminal facilities, requiring larger cranes, berths, storage yards, and improved information systems. Landside access will also have to be improved to handle peak volumes of rail and truck traffic. Many U.S. ports have begun major expansion projects to address this issue.

Table 2.6 Water Depth of Top 10 U.S. Container Ports

Port	Channel depth, ft.	Berth depth, ft.	Container port rank
Long Beach, CA	76	35-50	1
Los Angeles, CA	45	45	2
NY/NJ	40	35-45	3
Charleston, SC	42	40	4
Seattle, WA	175	40-50	5
Oakland, CA	42	35-42	6
Hampton Roads, VA	50	32-45	7
Miami, FL	42	42	8
Houston, TX	40	38-40	9
Tacoma, WA	40-50	40-50	10

U.S.DOT - TSB, source: Mark Lambert, ed., (London: National Magazine Company, Ltd, 1999)

ii. Competing Land Uses. Many cities are trying to revitalize their communities through economic development. These efforts have led to renewed interest in urban waterfront areas. The primary focus of this waterfront redevelopment is on residential, commercial, recreational, and tourist-related uses. Intermodal connections may also suffer land constraints because of zoning and environmental regulations that restrict expansion, particularly in densely populated areas. Any kind of development can lead to increased congestion in and around marine port terminals and other marine activities. Landside access, which is often impeded by inadequate highway and rail access from the port of marine terminal to the distribution centers, is a persistent problem at many U.S. ports.

iii. Waterway Issues. The inland lock and dam system is aged and undersized, requiring the break up and reassembly of some tows. This increases transit times, produces queues at locks, and results in increased operating costs and decreased efficiency.

iv. Intermodal Connections. The adequate development and maintenance of the intermodal connections –roadways and railroads- is a particularly crucial capacity and performance consideration. The benefits of an integrated intermodal system can only be achieved by cost effective linking of the various modes of transportation. Good intermodal access is a prerequisite to support the growing demand and to reduce the average dwell time of 4-6 days for a container. Therefore, new improved link equipment and information systems that facilitate the connection of different modes should be installed.

2.7.2 Environmental Issues

Every major construction project raises environmental issues that must be taken into account. Environmental quality is essential for sustaining coastal and marine ecosystems, commercial and recreational fisheries, and economic vitality of the marine transportation systems. Thus, all the decision-making and planning efforts must acknowledge and account for the fundamental interdependency between them and the environment. A broad spectrum of environmental laws, regulations, and practices at the Federal, state, and local levels govern ports operation and may significantly delay, if not ban any work of port expansion and modernization.

Chapter 3

Terminal Productivity

Evaluating terminal performance is a difficult task. An intermodal or marine terminal is complex and consists of various components: berths, cranes, yard, gates, and labor force. Many other constituencies also play major roles in the operation of those components; terminal operators, port authorities, shipping lines, railroads, stevedoring companies, truckers, and longshoremen.

3.1 Definition of Port Terminal Productivity

By defining and measuring terminal productivity, all the involved parties from terminal operators and port authorities to the containership owners could successfully make their strategic decisions for efficient management of the container terminals. For example, the optimal decision on terminal expansion and yard management should be the one that facilitates the overall terminal productivity within the transportation system. The optimal decision on yard space utilization will be the one that satisfies the land acreage constraints.

Terminal productivity has no uniform definition. In Economics it is measured in monetary terms since management views the increases in productivity as an increase in profits. In Production Theory, it can be defined as the extent of outcomes for a given input for handling cargo. The Committee on Productivity of Marine Terminals (1986) proposed a profile of productivity measures, each of which addresses a particular important aspect of the marine terminal operation (Table 3.1), [9]. The combination of all of these measures would display how a particular terminal is being operated and give insight into the efficiency of the terminal.

Table 3.1 Profile of Productivity Measurement

Element of Terminal	Measurements of productivity	
Crane	Net Crane Productivity:	$\frac{\text{moves}}{\text{gross gang hours - downtime}}$
	Gross Crane Productivity	$\frac{\text{moves}}{\text{gross gang hours}}$
Berth	Net Berth Utilization	$\frac{\text{container vessel shifts worked per year}}{\text{container berths}}$
Yard	Yard Throughput	$\frac{\text{TEU/year}}{\text{gross acre}}$
	Yard Storage Productivity	$\frac{\text{TEUcapacity}}{\text{net storage acre}}$
Gate	Net Gate Throughput	$\frac{\text{Containers/hours}}{\text{lane}}$
	Gross Gate Throughput	$\frac{\text{equipment moves/hour}}{\text{lane}}$
	Truck Turnaround Time	$\frac{\text{total truck time in terminal}}{\text{numberof trucks}}$
Gang	Gross Labor Productivity	$\frac{\text{number of moves}}{\text{man} - \text{hours}}$

Source: Committee on Productivity of Marine Terminals, 1986

The number of containers per hour moved by a gantry crane is a typical measurement for port productivity. However, there are multiple and more complex measurements. Contradictory interests among carriers, terminal operators, and inland transportation companies may result in different kinds of productivity measurements.

3.2 Productivity Comparison

Container terminals in Europe and Asia are more efficient by any measurement. For example crane productivity in many European terminals is between 30-35 lifts per hour while in the U.S. it is about 25 lifts per hour, [9]. Another simple measure of productivity compares U.S., European, and Asian ports as annual throughput per acre (Table 3.2), [10].

Table 3.2 Port Terminal Productivity (Annual Throughput per Acre)

Asian Ports	8,834 TEUs / Acre
European Ports	2,974 TEUs / Acre
United States Ports	2,144 TEUs / Acre
US West Coast Ports	3,567 TEUs / Acre
US East Ports	1,281 TEUs / Acre

Source: TranSystems Co., presentation, August 2000

One important factor for these differences among ports is the state of the labor-management relations in US. Another key issue is the practice of stacking containers on top of each other in foreign container terminals versus the normal U.S. practice of storing each loaded container on a wheeled chassis. A factor that can improve port terminal productivity anywhere is the implementation of Information Technology techniques in the communication, collection, storage, and analysis of the information required for terminal operation. Reliable and accurate data give better productivity measurements.

3.3 Productivity Trade-offs

Dealing with the challenges of the future, both shipowners and terminal operators have to decide their strategies. Future strategies will be affected by future technologies. The technological advances at land and at sea gives them multiple options for expanding and modernizing their businesses. However, deciding which option is best and how to implement it are crucial strategic questions. Technological progress in the shipbuilding industry will allow the construction and operation of large 15,000 TEU containerships and smaller but faster vessels. On the port side, new fully automated terminals, occupying 300 acres of land is a viable option for the near future. Integrated automated identification systems, could be attached to every container, enabling real-time cargo tracking and opening new capabilities for the intermodal transportation. Below, I present three possible options for implementation of new technologies and the trade-offs of their applications.

3.3.1 Containerships Size and Terminal Size (Megaships and Megaterminals vs. Fastships and Smaller Automated Terminals)

The containership fleet is oriented towards even larger vessels. Megaships offer operational benefits through lower unit transit costs and fewer numbers of required vessels. Because megaships are extremely capital expensive, carriers will deploy them in concentrated trade lines, operate them over longer routes, and call on fewer ports. These vessels offer economies of scale at sea, but could incur diseconomies of scale in port.

A port, in order to service these megaships, should improve its entire portside infrastructure. Each channel berth and turning basin must be at least 50 feet in depth. Terminal design and equipment are substantially impacted by the deployment of megaships, particularly with respect to wharf crane and container storage requirements. Megaship ports will be required to have cranes to reach across the twenty-one-container-wide megaship. Stronger wharves are also likely to be required by the ports where megaships call. An example of a mega-terminal project is the Ceres Paragon Terminal at the port of Amsterdam (see Figure 3.1).

According to an analysis made by the U.S. DOT Office of Intermodalism, [11], an optimized intermodal terminal servicing megaships is estimated to have the following physical characteristics:

- From minimum 2,500 linear feet to 3,000 feet of berthing (two megaship berths at 1,250 feet each).
- 50 feet water depth at berth.
- High berth occupancy rates (50 % target).

- A minimum of three Beyond Post-Panamax (BPP) cranes per berth.
- Upgraded wharf load-bearing capacity for the BPP cranes.
- Up to 75 terminal acres per megaship berth or 50 acres per standard berth.

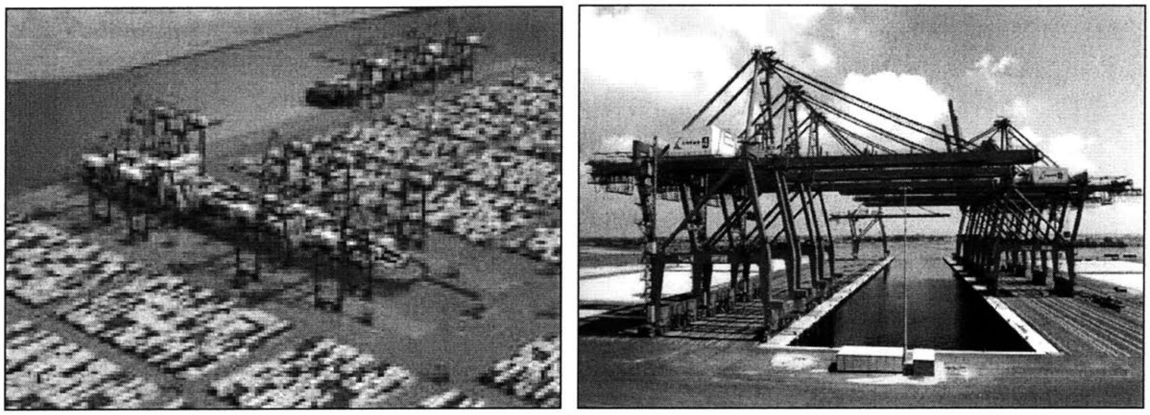


Figure 3.1 Ceres Paragon Terminal project at Port of Amsterdam
Source: CERES Terminals Inc.

The major trend to megaships and mega ports will continue. However, a minor trend to smaller but faster ships with direct service (particularly to *outports*) may constrain the rate of growth of that major trend. An extreme example is a proposed vessel with a capacity of 1400 TEUs and service speed 36-40 knots. This service will require smaller but equally efficient (possibly automated) dedicated ports, providing frequent service. The target market would be high-value, time-sensitive products. The dedicated terminal will have specialized cargo-handling facilities capable of completely unloading and reloading the ship at least four times faster than is the case with conventional crane technology.

The patented Container Platform Train loading system, [12], reduces port turnaround time from days to hours. Due to the use of a simple rail-based loading or unloading system moving up to sixty-eight TEU's at a time—without the use of cranes—CPT provides a major reduction in handling cost per box replacing the traditional method - whereby boxes are stacked in the port awaiting collection by truck or rail - by a seamless transfer straight from the CPT lanes in the port to the inland distribution system (Figure 3.2). Further economies arise from reducing the large amount of real estate required for the current method of stacking containers in the port, thus providing the railroad operators with new opportunities for cutting down-time and dead-heading of their expensive equipment. This, in turn, gives them new incentives to phase their systems into the FastShip arrival and departure schedules, which will be fixed to within plus or minus one hour.

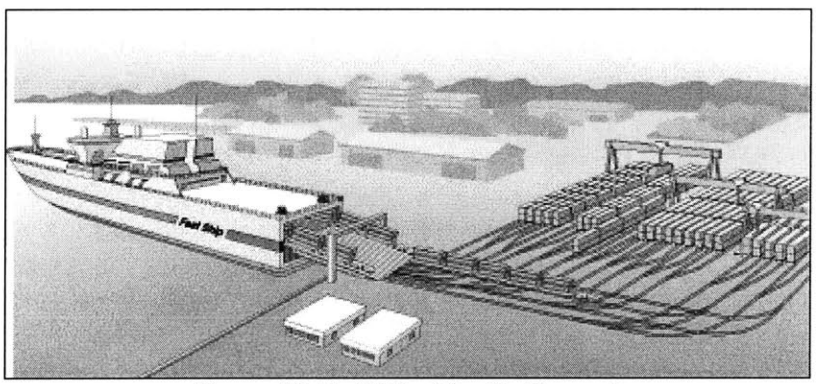


Figure 3.2 FastShip Atlantic Concept
Source: FastShip Atlantic, Inc.

3.3.2 Space Utilization (Stacking vs. Wheeled operations)

The term "space utilization" relates to how efficiently the physical land area on the terminal is used. Traditionally it has referred to how much of a terminal's space is occupied by containers. Space utilization is not a static problem. A key issue is the *"dwell time,"* or how long the containers remain on the terminal.

Actual terminal capacity is a series of trade offs with other aspects of terminal management. Placing containers in stacks, for example, is the most efficient way to occupy the physical space on the terminal. It is the least efficient, however, in moving containers to and from ships. Storing containers on chassis, on the other hand, is very efficient for moving them to and from ships but is land intensive—it requires more land per container.

Storing containers in stacks has the additional drawback of additional handling costs, especially where labors costs associated with moving boxes in and out of the stacks are high. Stacking also increases the time needed to get a container out of a stack for delivery to the customer. Information technology for planning and performing complex, interactive yard activities can facilitate stack operations for terminals.

One inference that might be drawn from the above analysis is that increasing customer demands for speed and reliability may favor the use of chassis-oriented operations in the future. Case studies were performed at Hamburg port, a relatively land-rich terminal [13]. The calculations indicated that each 40-foot chassis space was equivalent to 7.5 TEUs of stack space. The number is 7.5 instead of 6—which is the maximum number of stacked containers—because containers on chassis can not be stored as close to one another as in a stack, and drivers need maneuvering room when moving chassis in and out of their spaces. Furthermore, the large terminals are more likely to attract the port calls of the new mega-containerships and all the containers they discharge (unlike the RO-ROs and LO-ROs) will be without chassis. Outside the United States chassis owned by ocean carriers are a rarity. All these factors, along with the intense land constraints that the largest U.S. ports face make the stacking operation still a viable future solution.

3.3.3 Landside Access (On-dock Rail vs. Truck-only Access)

The landside access systems serving the U.S. ports have been evolving as rapidly as vessel design. In particular, the rapid rise of intermodal rail service has had a huge impact by facilitating the development of mini land-bridge services. As much as 40 percent of West Coast international containers are handled by intermodal rail. Three key trends are: the growing importance of intermodal rail; the continuing high proportion of truck access; and the degree to which effective landside access can "decouple" port locations from the metropolitan market areas they serve.

As a terminal operator attempts to move containers through a terminal, the typical result is congestion in trying to get containers in and out of the terminal. One partial solution is to have rail – hopefully double-stack – activities that extend to the dock. Such a service must be integrated into an overall rail network. Intermodal rail is a key attractor for shipping lines particularly if service by competing carriers is available. The facilities are on dock and the lines are cleared for double-stack trains. With ocean shippers and carriers becoming more integrated into the "total supply chain," they will increasingly choose to consolidate at ports with superior intermodal connectivity. Furthermore, the megaships can generate extremely high box traffic. To serve these vessels and minimize the congestion, terminals should provide on-dock or near-dock services. Environmental benefits are another result since fewer vehicle (truck) movements have lower emissions.

But, additional port-related rail traffic will trigger the need for significant improvements in the rail network, additional capital expenses, and for coordinated schedules between ship arrivals and train schedules

A new term has entered the market place lately: Shuttle trains. Railroads classify a shuttle train facility as a location that can serve a 100- to a 115-car train plus locomotives in one move off of their main lines. A shipper needs the ability to switch and load all cars and reassemble the train within 15 hours.

On the other hand, trucks are expected to continue to carry the majority of port traffic, but the highway accesses, gate queuing capacity, and clear signage within ports, will remain critical concerns. Truck-only access has the benefit of lower cost. For the shortest hauls –less than 300 to 500 miles, truck service is typically cheaper. Currently there is an increased interest from southeastern states for multi-state freight corridors to handle future port-related traffic from Latin American trade.

3.4 Improving Terminal Productivity

Productivity improvements can be done through a combination of capital investment with major infrastructure spending in equipment and terminal yard expansion, operations research and implementation of information technology in the operational status of the terminals and finally by improving working relationships between terminal's labor and management.

3.5 Automated intermodal terminals

The continuing growth of the international container trade and the scaling-up of the size of the containerships has led to a demand for more modern and more efficient intermodal port facilities. Certain marine terminals in Europe and Asia have implemented automation techniques. The two major areas of automation are the automation of information processing (cargo tracking and tracing) and the automation of the handling process itself. In the container handling process, automation integrates mechanical physical handling of cargo with computerized process control and data transmission into a new approach in operations management for the intermodal terminal. Although initially the concept of automation was intended to be for large terminals, its benefits are also obvious to small and medium size terminals (100,000 – 300,000 TEUs per year) and therefore can be applied to rail intermodal terminals.

3.5.1 Advantages of Automation

The main objectives of automation in container handling are better cargo flow control, operational flexibility, and long-term cost control. More specifically the automated terminals have the following advantages:

- Increased level of service and flexibility for the terminal customers.
- Overall cost savings (e.g. Initial costs increase by +15%, but annual operating costs are reduced by –20%, [14]).
- Better yard area utilization. No need for terminal expansion.
- Cargo flow with larger speed benefits the whole supply chain.

- Equipment maintenance and repair costs are reduced with better reliability.
- Better terminal performance and more container throughput lead to better financial results.
- Regional benefits and economic impacts from the increase of the trade business.
- Public benefits: Energy conservation and cleaner environment.

3.5.2 Requirements and Conditions

In order for the implementation of automation to be successful in an intermodal terminal, the following guidelines, [15] should be followed:

- The whole operational process of the terminal should be redesigned.
- All parts of the terminal should be involved in the automation process and work with closer business relationships.
- The equipment should be simple and reliable
- The areas of cargo handling and cargo storage should be well balanced according to the terminal's requirements.

3.6 Examples of Automated Terminals

Examples of applications of automation worldwide are the Europe Combined Terminal (ECT) B.V. Delta/Sea-Land terminal in Rotterdam and the Agile Port System approach or split terminal approach (EMT + IIC) proposed by Noell Crane systems GmbH.

3.6.1 ECT Delta-Sea-Land Terminal at Port of Rotterdam

ECT B.V. introduced the first automated Delta/Sea-Land terminal in Rotterdam in 1993. The key elements of this terminal are the quay cranes, the intra-terminal transport of 32 automated guided vehicles AGVs, and the container stack as the storage area [14]. The stacking of the containers takes place in 32 stacking lanes using 32 automatic stacking cranes that do the stacking and the removal of the containers. Typically the vehicles travel along the entire length of the ship and turn back along the stack. (see Figure 3.3).

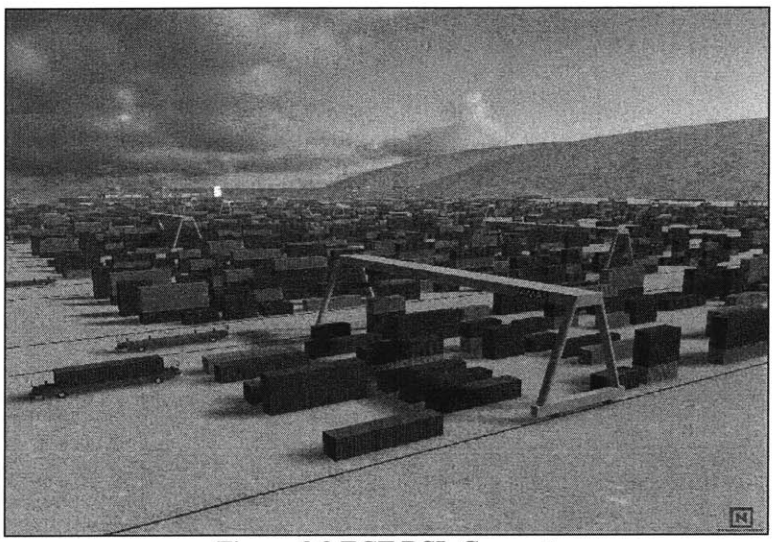


Figure 3.3 ECT DSL Concept
Source: Europe Combined Terminal (ECT) B.V.

3.6.2 The Agile Port System

The Agile Port System is a proposal to split a container port into two parts: An "Efficient Marine Terminal" (EMT) ashore and an" Intermodal Interface Center" (IIC) inland both connected by a dedicated railway line (Figure 3.4), [15].

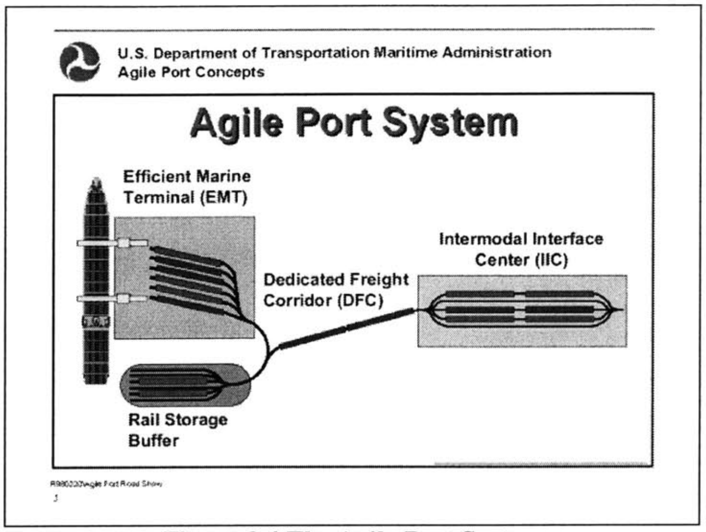


Figure 3.4 The Agile Port System
Source: Marine Administration- U.S.DOT

Noell Crane systems have developed the technology container-handling equipment for both parts. At EMT the technology proposed uses a box mover under the quay cranes that enables the containers to be transshipped directly between the ship and the freight trains without the need of yard transfer vehicles and the need to move the crane along the vessel for positioning purposes (see Figure 3.5). The IIC operates as a conventional rail terminal featuring a combination of semi-automated cantilevered rail-mounted gantry cranes and a sorting facility based on rail-mounted automated guided vehicles driven by linear motor technology enabling fast transshipments of containers between shuttle-trains and freight trains (see Figure 3.6).

The advantages are the productivity improvement because of the fast transshipment—zero days of dwell time—, with the automation of both parts, the saving of valuable land onshore, and the savings in labor and machinery from no use of transfer vehicles.

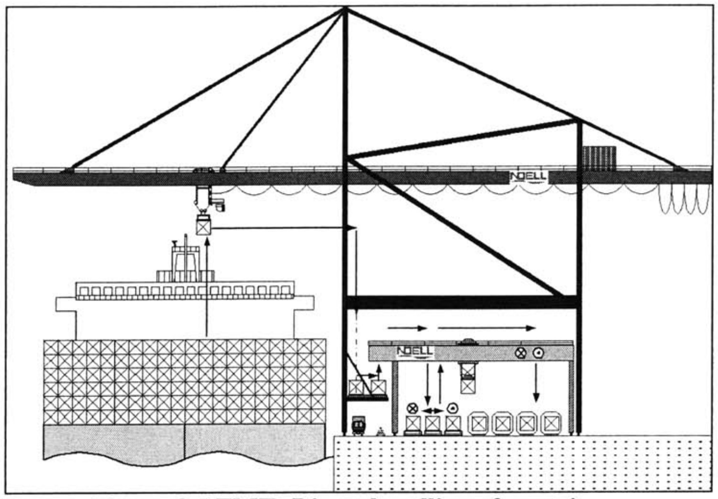


Figure 3.5 EMT- Direct handling of containers
Source: Noell Crane Systems GmbH

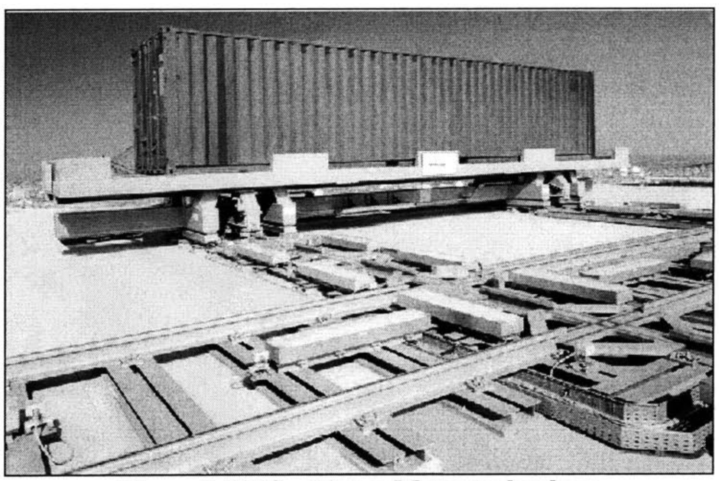


Figure 3.6 IIC – Linear Motor technology
Source: Noell Crane Systems GmbH

Chapter 4

Modal Switch for a Proposed Intermodal Terminal at a Representative Site

Every major infrastructure project, such as the technological improvements of the intermodal terminals, raises environmental issues that should be taken into account. Environmental quality is essential for the regional coastal or inland ecosystem, but also for the surrounding businesses. A broad spectrum of environmental laws, regulations and practices at the federal, state, and local levels governs the ports operation and may delay, if not ban, any work of terminal expansion and modernization.

One of the major problems is traffic congestion and delays occurring at the areas around the intermodal terminals. These problems will deteriorate dramatically with the projected growth of intermodal container cargo. When access problems to terminals occur, they substantially impede the freight flow. To alleviate these problems, I propose the modal switch from truck to rail mode. Adequate rail landside access, preferably double-stack or shuttle trains, will have both environmental benefits for the region and performance improvements for the terminal operators. These performance improvements result to a reduction of the container dwell time and so to reduction of the required storage area. In combination with ITS and automation, the benefits will be substantial.

4.1 Model & Analysis

A sample analysis is performed to look at the impact of building an inland intermodal terminal between the U.S. East Coast ports and Chicago. This example is loosely modeled after the ports of Boston, New York/New Jersey, Hampton Roads, Charleston, and Baltimore with the inland terminal loosely modeled after Pittsburgh. Examining the cargo flows (Commodity Flow Survey CFS 1997, [17]) from these five major U.S. East ports to a proposed intermodal in Pittsburgh, PA, I estimated the impacts, translated into monetary costs, of a modal switch from truck mode to rail mode.

The input data (Table 4.1) to the model are:

- The port's annual container throughput for the year 2000 (TEU/ year) as been published at each port's web site, [18].
- Proportion (%) of the port's throughput that goes to Pittsburgh. This is assumed equal with the state's export percentage of its total cargo export to the state of Pennsylvania.
- TEUs to PA: equals to the above percentage times the port's throughput.
- Modal split between truck and rail mode, for each cargo flow (%), taken from the state-to-state CFS 1993, [19].
- Approximate distance between the origin port and Pittsburgh in miles.

Table 4.1 East Coast Container Ports Cargo Data and Modal Split for Cargo Flows to Pittsburgh

Port	Annual Throughput (TEUs)	Cargo to PA		Modal split				Distance from Pittsburgh (Miles)
				Truck Cargo		Rail Cargo		
		%	TEUs	%	TEUs	%	TEUs	
Boston, MA	122,398	1.1%	1,346	90%	1,211	7%	95	570
NewYork/NewJersey	3,050,746	6.0%	183,045	88%	161,081	8%	14,644	360
Hampton Roads, VA	1,347,151	3.4%	45,083	44%	19,836	45%	20,287	420
Charleston, SC	1,574,467	1.3%	20,468	76%	15,556	22%	4,502	650
Baltimore, MD	486,861	6.5%	31,646	90%	28,481	8%	2,532	250

Source:, BTS-Commodity Flow Surveys, CFS 1993, CFS 1997

4.2 Cost Changes from Modal Switch

4.2.1 Pittsburgh

Switching various percentages (from 1% to 100%) of the cargo currently transported by truck to rail mode—thus subtracting it from truck and adding it to rail—I estimate the cost changes to various categories of cost, such as transportation cost, energy cost, emission cost, and highway maintenance cost (Analytical calculations in Appendix A). Table 4.2 has these cost changes for 20% of truck cargo switched to rail mode.

Table 4.2 Cost Changes for 20% of Cargo Switch from Truck Mode to Rail Mode (Pittsburgh)

Port	20%Cargo Switched (Tons)	# Trucks Off the Road (FEUs)	Total Transp. Cost Change ($)	Fuel Cost Change ($)	Emissions CostChange ($)	HighwayMaint. Cost Change ($)	TOTAL Cost Change ($)
Boston	2,423	121	-24,114	-19,795	-1,152	-1,658	-46,718
NY/NJ	322,159	16,108	-837,613	-1,661,915	-96,730	-139,173	-2,735,430
HamptonRoads	40,307	2,015	-189,442	-242,585	-14,119	-20,316	-466,460
Baltimore	56,963	2,848	71,203	-204,064	-11,877	-17,089	-161,827
Charleston	31,111	1,556	-396,671	-289,781	-16866	-24,267	-727,586
TOTALS	452,963.2	22,648	-1,376,637	-2,418,140	-140,744	-202,503	**-4,138,021**

The following graph presents the linear relationship between the amount of cargo switched and the money saved.

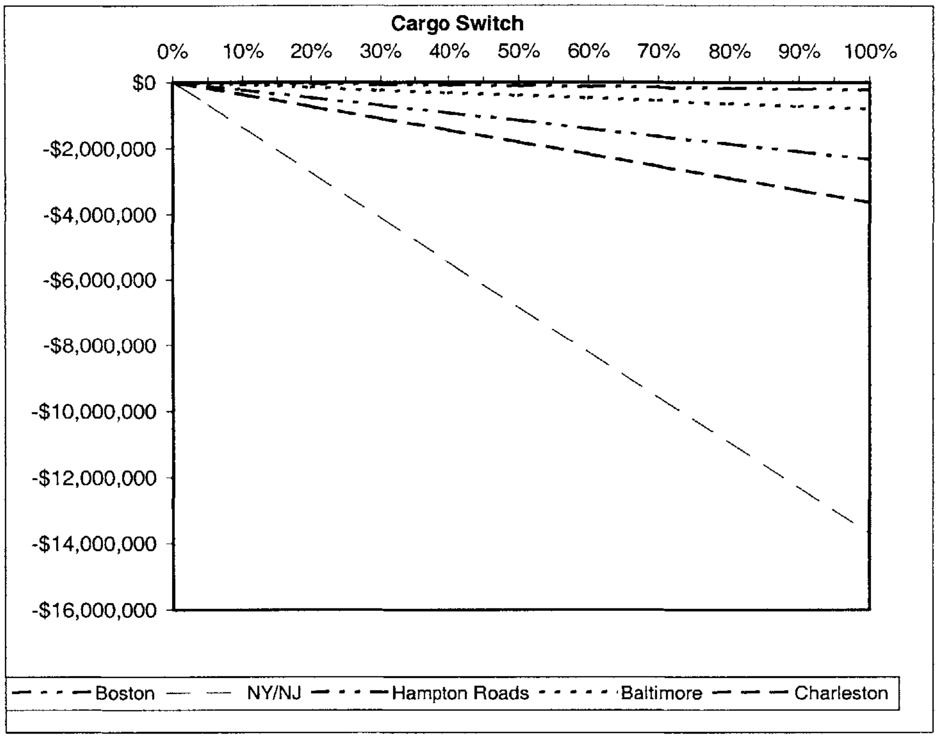


Figure 4.1. Total Cost Changes for Cargo Switch for Pittsburgh

4.2.2 Chicago

If we assume that rail shuttle trains are implemented between Pittsburgh and the five U.S. East Coast ports, and that—due to the improved service offered in conjunction with the rail shuttles—many shippers now moving their marine containers between these five ports and Chicago by truck decide to shift their cargo to rail. If 20 % of the present truck cargo shifts to rail, the impact is shown in the table below. (Analytical calculations in Appendix B).

The input data are in Table 4.3.

Table 4.3 East Coast Container Ports Cargo Data and Modal Split for Cargo Flows to Chicago

Port	Annual Throughput (TEUs)	Cargo to IL		Modal split: Truck Cargo		Modal split: Rail Cargo		Distance from Chicago (Miles)
		%	TEUs	%	TEUs	%	TEUs	
Boston, MA	122,398	0.5%	612	74%	453	9%	55	980
NewYork/NewJersey	3,050,746	0.9%	27,457	75%	20,593	8%	2,167	790
Hampton Roads, VA	1,347,151	0.9%	8,083	27%	2,182	64%	5,173	870
Charleston, SC	1,574,467	0.6%	9,447	55%	5,196	39%	3,684	900
Baltimore, MD	486,861	0.4%	1,947	49%	954	48%	935	690

Source: BTS-Commodity Flow Survey CFS 1997

The results are in Table 4.4.

Table 4.4 Cost Changes for 20% of Cargo Switch from Truck Mode to Rail Mode (Chicago)

Port	20%Cargo Switched (Tons)	# Trucks Off the Road (FEUs)	Total Transp. Cost Change ($)	Fuel Cost Change ($)	Emissions CostChange ($)	HighwayMaint. Cost Change ($)	TOTAL Cost Change ($)
Boston	906	45	-22,010	-12,719	-740	-1,065	-36,535
NY/NJ	41,185	2,059	-726,917	-466,233	-27,137	-39,043	-1,259,330
HamptonRoads	4,365	218	-89,260	-54,415	-3,167	-4,557	-151,398
Baltimore	1,908	95	-27,005	-18,870	-1,098	-1,580	-48,554
Charleston	10,391	520	-223,417	-134,016	-7,800	-11,223	-376,456
TOTALS	58,755.2	2,937	-1,088,609	-686,253	-39,942	-57,468	**-1,872,273**

Total cost savings from 20% of cargo switch for Pittsburgh and Chicago:

$4,138,021 + $1,872,273 = $6,010,294

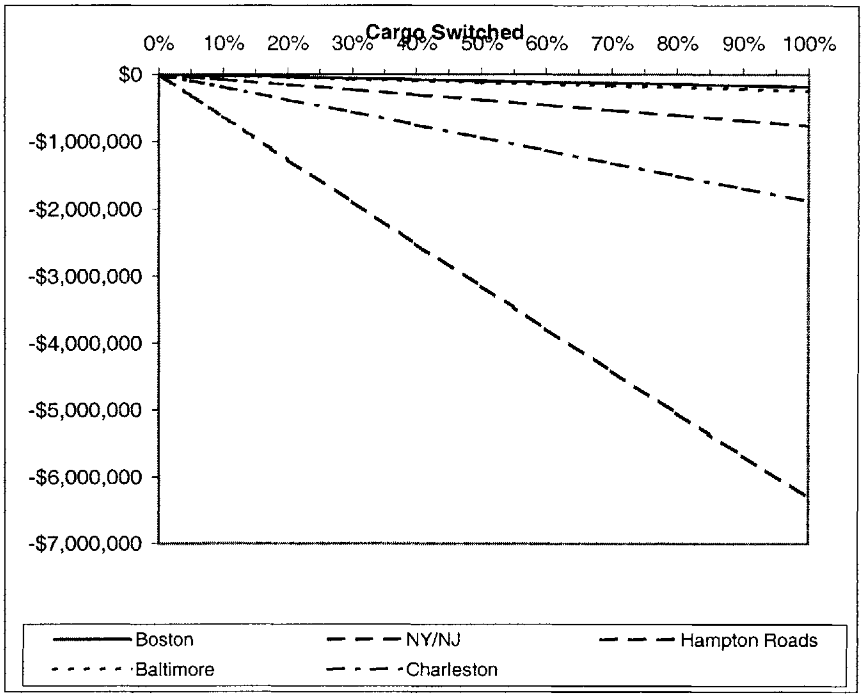


Figure 4.2 Total Cost Changes for Cargo Switch for Chicago

4.3 Assumptions

The calculations were based on the following assumptions, from [19]:

Transportation costs

Weight Conversions: 1 TEU = 10 tons,   1 FEU = 2 TEU = 20 tons

Transportation Costs (estimated for FEUs):

- Truck : $1.10/mile per FEU
- Rail : ($200 + $0.4/mile) per FEU

The critical—break-even—distance, beyond that the rail mode becomes cheaper is:

s= 286 miles.

Energy efficiencies – Fuel costs

From a comparison of different modes of transportation, [20], the number of miles, one ton of cargo can be carried, per gallon of fuel for the two modes are:

Table 4.5 Relative Energy Efficiencies

Mode	Miles/tons/gal*
Truck	59
Rail	202

*Number of Miles, One Ton can be carried Per Gallon of Fuel (mpg per gallon)
Source: USDOT-MARAD

From the relative efficiencies, given the number of miles for each destination and the amount of cargo, we get the total fuel consumption (gallons) for each cargo flow. Using the average unit fuel of: $1.2 per gallon for the year 2001 (USDOT data) we get the total fuel cost.

Emissions

Air pollution, as Relative Air Emissions in lbs. of Nitrous Oxide (N_2O) produced by the different modes when each burn one gallon of fuel.

Table 4.6 Relative Air Emissions

Mode	Lbs of N_2O*
Truck	0.6021
Rail	0.2718

* *Lbs of N_2O produced from one gallon of fuel.*
Source: Minnesota Department of Transportation

Environmental Cost average (ECA) for Nitrous Oxide: \$200 per lbs of N_2O

(Source: Environmental Protection Agency, Emission Control Lab)

Highway maintenance costs

Average Cost: \$0.024 per container mile traveled

(Source: Minnesota Department of Transportation)

4.4 Comments

- The volume of port cargo flow is approximate due to the use of state-to-state cargo percentages from CFS 1997.
- Truck is the dominant mode of transportation (3:1 over rail in most states). Significant exception is the state of Virginia (port of Hampton Roads).
- Environmental and energy advantage of rail over truck mode.
- Rail mode is more cost attractive for long-hauls s>286 miles.
- The results are very sensitive to distance and to transportation cost assumptions.

4.5 Container Storage Area Savings

The continuing growth of container traffic leads to a need for more land for container storage at intermodal terminals. Many ports have implemented plans for expanding their existing terminals and creating new ones through further land acquisition and reclamation projects. But, for some ports there is very little waterfront land left for expansion. The Port Authority of New York and New Jersey has forecasted that the volume of containerized cargo shipped through the port of NT/NJ will increase at 4.2 % annually which doubles current throughput by the year 2017. It has estimated that by the year 2040, 1120 acres of new land and 600 acres of reclaimed land will be required, [21].

An alternative option to physical terminal (land) expansion is the better utilization of the existing land through improvement of productivity. That concept has been successfully applied to most of Asian ports where land is sparse and more expensive. It is also likely that competitive interests in waterside and social pressures will force a shift to denser and more efficient terminal operations in U.S. too. In Table 3, it is shown that U.S. ports have approximately ¼ of the terminal throughput per acre of land than that of Asian ports. We have presented two ways of terminal productivity improvements, the automation and the cargo modal shift from truck to rail mode. Our proposed modal switch combined with major infrastructure improvements in container handling equipment and control systems can have as an additional benefit, the saving of land for container storage at waterfront terminals. The dwell time can be reduced from the current average of about 6 days for containers moving by truck to one day or less with shuttle trains. Containers are immediately transshipped from the containership to shuttle or freight trains, for an inland buffer rail storage or for the intermodal hub center. A precondition is the good coordination in ship arrivals and train schedules. Information Technology can play a crucial role in this coordination. Better utilization of land with modern automated equipment and reduced dwell time because of rail mode can lead to less container storage yard required.

Given the terminal productivity estimations for the U.S. East Coast ports, as total throughput (TEUs) per acre of terminal of 1,281 TEUs/Acre, from Table 3.2, I estimated the storage area that can be saved (as not required) due to 20% cargo switch from truck to rail mode for the five flows from the five U.S. East Coast ports to Pittsburgh and Chicago (assuming a 6-day dwell time for containers moved by truck and zero days by rail). Although the above measure of 1,281 TEUs per acre seems arbitrarily established, it can be justified in practice. For instance, the Conley terminal port of Boston has total annual throughput 122,398 TEUs and terminal area 101 acres (1,212 TEUs per acre).

Table 4.7 Maximum Container storage Area Saved from 20% Cargo switch

Port	20% Cargo Flow to Pittsburgh (TEUs)	20% Cargo Flow to Chicago (TEUs)	Total Cargo Switched to Rail (TEUs)	Maximum Container Storage Area Saved (Acres)
Boston, MA	242	90	332	0.259
NewYork/NewJersey	32,216	4,118	36,334	28.364
Hampton Roads, VA	4,030	436	4,466	3.486
Baltimore, MD	3,112	190	3,302	4.595
Charleston, SC	5,696	1,040	6,736	3.241

This amount of acres is the maximum amount of acres that can be saved. A basic precondition is that the rail mode can lead to dwell time of zero days. So, these containers do not remain in the terminal for any time, and so they do not occupy any storage space.

In practice, different values of dwell time greater than the optimal value of zero days may occur. We made a different analysis using a practical relationship that is used [6], to determine a theoretical measure of the annual container yard capacity from some parameters of the terminal.

The formula is:

$$\text{Annual yard capacity} = \frac{\text{Number of Terminal Ground Slots} \times \text{Average Stacking Height} \times 365}{\text{Average Dwell Time} \times \text{Peaking Factor}}$$

where:

- Annual yard capacity is the annual throughput in TEUs
- Terminal Ground Slots (TGS) is the footprint area of a standard twenty-feet container (1 TGS= 15 m^2)
- Average stacking height (SH): how many containers are stacked. An average value for U.S. ports is 2.5
- Peaking factor (PF) is a measure of congestion that indicates perfect container movement for 1.0. A representative number of 1.3 is acceptable

So the number of terminal ground slots is: $\text{TGS} = \frac{\text{PF} \times \text{TEUs}}{\text{SH} \times 365} \times \text{Dwell Time}$

From the above relationship it is assumed that the number of TGS, and so the terminal storage area, increases linearly with dwell time. Applying the above formula for the every port we get the reduced storage area (Table 4.8 and Figure 4.3) Given the number of TEUs that are been carried by rail we estimate the number of TGS that can been freed for values of dwell time from 6 days to 1 day. Our objective is to measure the increase in percentile of the storage area that can be saved due to decrease in dwell time by one day. This percentage is 16.7%. By reducing the dwell time by one day the storage area is been reduced by 16.7% of the maximum saved area (that corresponds the zero dwell time from Table 4.7).

Table 4.8 Storage Area Savings

Dwell days	Reduced storage area as % of the maximum
6	0%
5	16.7%
4	33.3%
3	50.0%
2	66.7%
1	83.3%
0	100.0%

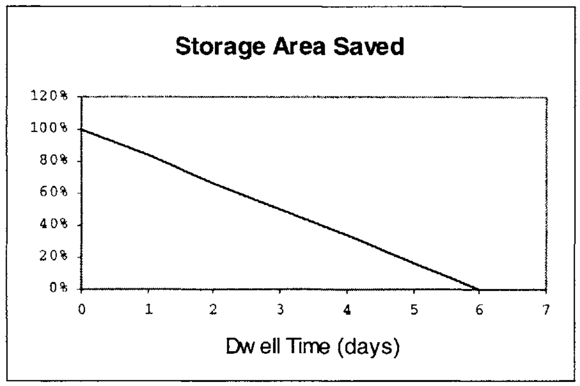


Figure 4.3 Linear Relationship between Dwell Time and Saved Storage Area

For each port we get the terminal area that can be saved with the reduction of dwell time from the average 6 days that exits today to the optimum of zero days with, perfect coordination of shuttle or freight trains and adequate level of automated equipment.

Table 4.9 Terminal Area that can be Reduced from the 20% Modal Cargo Switch

Dwell Time Days	Reduced Storage Area (Acres)					
	Boston	New York	Hampton Roads	Baltimore	Charleston	TOTAL
6	0	0	0	0	0	0
5	0.043	4.727	0.581	0.766	0.540	6.658
4	0.086	9.455	1.162	1.532	1.080	13.315
3	0.130	14.182	1.743	2.297	1.621	19.973
2	0.173	18.909	2.324	3.063	2.161	26.630
1	0.216	23.636	2.905	3.829	2.701	33.288
0	0.259	28.364	3.486	4.595	3.241	39.945

4.6 Construction Cost Estimations for a New Terminal

Based on a summary of key costs and operating benchmarks from Drewry's, [6], the construction cost estimations for a new terminal are:

$18.5 million per 100,000 TEUs or $2 million per acre.

(This cost includes the civil and the equipment cost of a new terminal, but no land costs)

The proposed terminal at the representative site of Pittsburgh that will handle the 20% of cargo that switched from truck to rail will have approximate capacity of **51,000 TEUs** (for marine containers, not counting what other domestic cargo it will handle). So, its approximate cost—using the marine container figures—will be around **$9.4 million.** (=18.5x100,000/51,000)

This cost estimation does not include land costs, but only civil and equipment costs. The major equipment cost is the cranes cost. For the proposed terminal this is about

$**6.2million** and it covers only the cost of one quay crane (35m boom). However, an inland terminal will use smaller, cheaper cranes.

The monetary savings from energy and environmental benefits as expressed previously for Pittsburgh and Chicago from Tables 4.2 and 4.4 are:

$4,138,021 + $1,872,273 = $6,010,294 or approximately **$6 million.**

Furthermore, the maximum total land saved from the 20% of cargo switched from all five ports is approximately **40 acres.** Assuming the average waterfront land costs $1 million per acre, the land savings in the waterfront area are approximately **$40 million**

Given the low productivity of 1,281 TEUs per acre the 51,000 TEUs inland terminal will need storage area of **39.8 acres** (=51,0000/1,281) that is roughly equal the land saved in waterfront port areas. But, the land cost at an inland site is definitely less that at port areas.

Consequently, overall the land savings in waterfront overweigh the total capital cost of an inland terminal.

Chapter 5

Conclusions

This paper proposes as solutions to the issues of terminal productivity and capacity the modal switch of container movements from truck to rail mode and the implementation of automation technologies in intermodal terminals. Both the container market worldwide and the U.S. terminal traffic are growing fast. Current developments are merger activity, the upsizing of containerships, and deregulation laws, such as the Ocean Shipping Reform Act of 1998. The U.S. intermodal terminals that handle this inbound and outbound traffic will need to improve their performance in order to accommodate all this growth in the most efficient way. Operational patterns, including labor relations, have led U.S. terminals to perform at generally lower levels than foreign terminals. Since the early 1990s, European and Asian port terminals provide a clear precedent in terms of application of technology and labor.

Automation can be applied to any size of intermodal terminals from mega-terminals to smaller ones. Implementations during the last decade have shown a boost in terminal productivity. Capital expenses, though large initially, can be balanced by the lowered operating expenses and the increases in revenues due to more throughput.

Terminals can save land through better land utilization from the reduction of the dwell time for containers, which currently may average up to six days. Public benefits also emerge from the relief of the traffic congestion around terminal areas and the related regional economic benefits involved.

The current modal split at many U.S. East Coast ports shows the domination of the truck mode. By switching cargo movements from truck to rail, the energy, the environmental, and the total transportation costs are reduced in accordance with the amount of cargo switched. However, the possible longer transit time has not been considered in my analysis. The construction cost of an automated intermodal terminal can be partially covered from the total cost savings due to better terminal performance. Furthermore the environmental benefits may attract public investments. These benefits should bolster even more strongly the ideas of automation and shift to rail mode for the U.S. intermodal terminals. _

Appendix A

Calculations for Pittsburgh

For cargo percentages 1% to 100% of the current truck cargo—originating from the five U.S. East ports to Pittsburgh—switched to rail mode, we calculate the following cost categories:

- Freight transportation cost
- Fuel consumption cost
- Emissions cost
- Highway maintenance cost

(Formulas and assumptions were based on a similar mode comparison including three modes of transportation—rail, trucks, and barges—made for a Marine Transportation System (MTS) Task Force as part of an assessment of the U.S. marine transportation system (A Report to Congress, [1])

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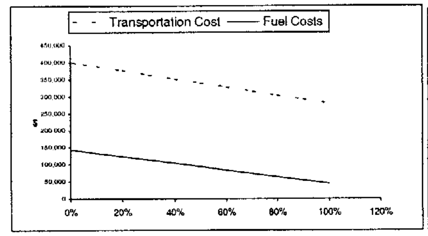
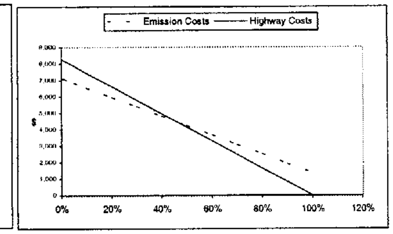
From Port of: **BOSTON, MA** **To:** **PITTSBURGH,PA**





CARGO

Port Thr/put TEUs:	122,398	Metric Tons:	1,223,980	Mileage:	570
% to PA:	1.1%	TEUs: 1,346		tons: 13,464	

Modal Split:	Truck	Rail	Total
%:	90.0%	7.0%	
TEUs:	1,212	94	1,346
FEUs:	606	47	673
tons:	12,117	942	13,464

TRANSPORTATION COSTS

Truck: 1.1 $/mile*FEU
Rail: 200 $/FEU + 0.4 $/mile*FEU

Current Cost: Truck: 379,881 $
Rail: 20,169 $

FUEL COST

FUEL CONSUMPTION			TOTAL
Truck:	59.2 mpg per ton	0.0169 gal/mile per ton	116,671 gallons
Rail:	202 mpg per ton	0.0050 gal/mile per ton	2,659 gallons

Current Cost: Truck: 140,005 $ Fuel Price: 1.2 $/gal
Rail: 3,191 $

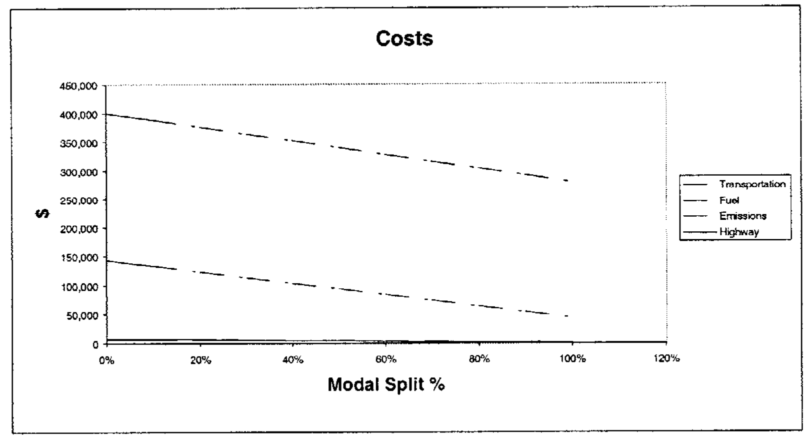
EMISSIONS

Truck:	0.6021 lbs NOx per gal	35.1 tons of NOx	ECA:	200 $/ton
Rail:	0.3697 lbs NOx per gal	0.5 tons of NOx		

Current Cost: Truck: 7,025 $
Rail: 98 $

HIGHWAY MAINTENANCE COSTS

# of Trucks= FEUs= 606 Highway Cost: 0.024 $ per mile travelled
Current Cost: 8,288 $



Modal Switch	tons	FEUs	(tons) Truck	Rail	Transportation Cost ($) Truck	Rail	Total	Change	Fuel Cost ($) Truck	Rail	Total	Change	Emission Costs ($) Truck	Rail	Total	Change	Highway ($) Costs	Change	($) TOTAL
0%	0	0	12,117	942	379,881	20,169	400,049	0	140,005	3,191	143,196	0	7,025	98	7,123	0	8,288	0	0
1%	121	6	11,996	1,064	376,082	22,762	398,844	-1,206	138,605	3,602	142,207	-990	6,955	111	7,065	-58	8,205	-83	-2,336
5%	606	30	11,512	1,548	360,887	33,134	394,021	-6,028	133,005	5,243	138,248	-4,949	6,674	162	6,835	-288	7,874	-414	-11,680
10%	1,212	61	10,906	2,154	341,892	46,100	387,992	-12,057	126,005	7,294	133,299	-9,897	6,322	225	6,547	-576	7,459	-829	-23,359
20%	2,423	121	9,694	3,366	303,904	72,031	375,936	-24,114	112,004	11,398	123,402	-19,795	5,620	351	5,971	-1,152	6,631	-1,658	-46,718
30%	3,635	182	8,482	4,578	265,916	97,962	363,879	-36,170	98,004	15,501	113,504	-29,692	4,917	478	5,395	-1,728	5,802	-2,486	-70,077
40%	4,847	242	7,270	5,789	227,928	123,894	351,822	-48,227	84,003	19,604	103,607	-39,590	4,215	604	4,819	-2,304	4,973	-3,315	-93,436
50%	6,059	303	6,059	7,001	189,940	149,825	339,765	-60,284	70,003	23,707	93,709	-49,487	3,512	730	4,243	-2,880	4,144	-4,144	-116,796
60%	7,270	364	4,847	8,213	151,952	175,756	327,708	-72,341	56,002	27,810	83,812	-59,384	2,810	857	3,667	-3,456	3,315	-4,973	-140,155
70%	8,482	424	3,635	9,425	113,964	201,687	315,652	-84,398	42,002	31,913	73,915	-69,282	2,107	983	3,091	-4,032	2,486	-5,802	-163,514
80%	9,694	485	2,423	10,636	75,976	227,619	303,595	-96,455	28,001	36,016	64,017	-79,179	1,405	1,110	2,515	-4,609	1,658	-6,631	-186,873
90%	10,906	545	1,212	11,848	37,988	253,550	291,538	-108,511	14,001	40,119	54,120	-89,077	702	1,236	1,938	-5,185	829	-7,459	-210,232
100%	12,117	606	0	13,060	0	279,481	279,481	-120,568	0	44,223	44,223	-98,974	0	1,362	1,362	-5,761	0	-8,288	-233,591

From Port of: NY/NJ   To: PITTSBURGH,PA

CARGO

Port Thr/put TEUs: 3,050,746   **Metric Tons:** 30,507,460   **Mileage:** 360

% to PA: 6.0%   **TEUs:** 183,045   **tons:** 1,830,448

Modal Split:	Truck	Rail	Total
%:	88.0%	8.0%	
TEUs:	161,079	14,644	183,045
FEUs:	80,540	7,322	91,522
tons:	1,610,794	146,436	1,830,448

TRANSPORTATION COSTS

Truck: 1.1 $/mile*FEU
Rail: 200 $/FEU + 0.4 $/mile*FEU

Truck: 31,893,719 $
Rail: 2,518,696 $

FUEL COST

FUEL CONSUMPTION			TOTAL
Truck:	59.2 mpg per ton	0.0169 gal/mile per ton	9,795,368 gallons
Rail:	202 mpg per ton	0.0050 gal/mile per ton	260,975 gallons

Current Cost: **Truck:** 11,754,442 $ **Fuel Price:** 1.2 $/gal
Rail: 313,170 $

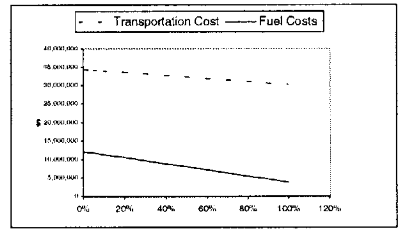
EMISSIONS

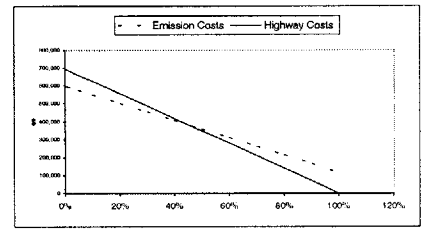
Truck: 0.6021 lbs NOx per gal   2948.9 tons of NOx   **ECA:** 200 $/ton
Rail: 0.3697 lbs NOx per gal   48.2 tons of NOx

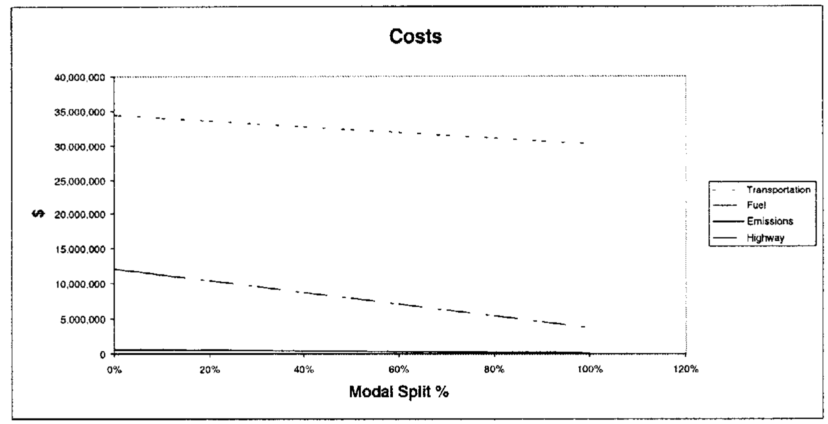
Current Cost: **Truck:** 589,779 $
Rail: 9,648 $

HIGHWAY MAINTENANCE COSTS

# of Trucks= FEUs= 80,540   **Highway Cost:** 0.024 $ per mile travelled
Total Highway Cost: 695,863 $



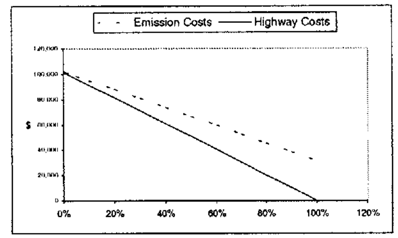


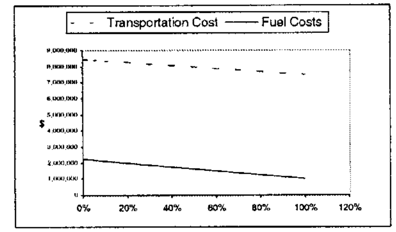


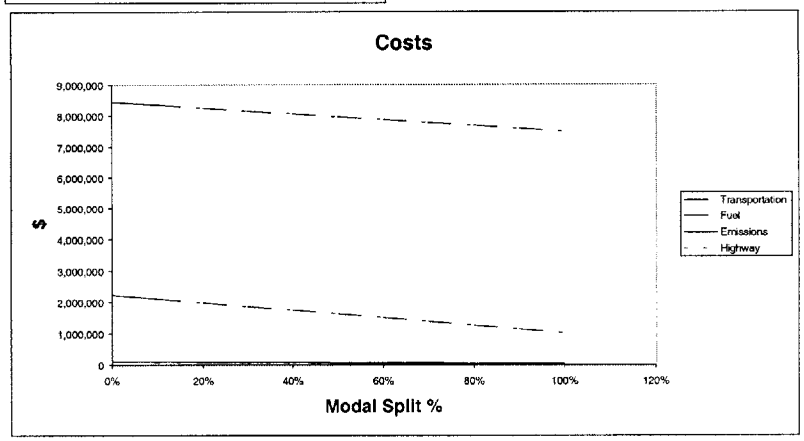
Modal Switch	tons	FEUs	(tons) Truck	Rail	Transportation Cost ($) Truck	Rail	Total	Change
0%	0	0	1,610,794	146,436	31,893,719	2,518,696	34,412,415	0
1%	16,108	805	1,594,686	162,544	31,574,782	2,795,752	34,370,534	-41,881
5%	80,540	4,027	1,530,254	226,976	30,299,033	3,903,979	34,203,012	-209,403
10%	161,079	8,054	1,449,714	307,515	28,704,347	5,289,261	33,993,608	-418,806
20%	322,159	16,108	1,288,635	468,595	25,514,975	8,059,827	33,574,802	-837,613
30%	483,238	24,162	1,127,556	629,674	22,325,603	10,830,392	33,155,996	-1,256,419
40%	644,318	32,216	966,476	790,753	19,136,231	13,600,958	32,737,189	-1,675,226
50%	805,397	40,270	805,397	951,833	15,946,859	16,371,523	32,318,383	-2,094,032
60%	966,476	48,324	644,318	1,112,912	12,757,488	19,142,089	31,899,576	-2,512,838
70%	1,127,556	56,378	483,238	1,273,992	9,568,116	21,912,654	31,480,770	-2,931,645
80%	1,288,635	64,432	322,159	1,435,071	6,378,744	24,683,220	31,061,964	-3,350,451
90%	1,449,714	72,486	161,079	1,596,150	3,189,372	27,453,785	30,643,157	-3,769,258
100%	1,610,794	80,540	0	1,757,230	0	30,224,351	30,224,351	-4,188,064

Modal Switch	Fuel Cost ($) Truck	Rail	Total	Change	Emission Costs ($) Truck	Rail	Total	Change	Highway ($) Costs	Change	($) TOTAL
0%	11,754,442	313,170	12,067,612	0	589,779	9,648	599,427	0	695,863	0	0
1%	11,636,897	347,618	11,984,516	-83,096	583,881	10,710	594,591	-4,836	688,904	-6,959	-136,772
5%	11,166,720	485,413	11,652,133	-415,479	560,290	14,955	575,245	-24,182	661,070	-34,793	-683,858
10%	10,578,998	657,656	11,236,654	-830,958	530,801	20,261	551,063	-48,365	626,277	-69,586	-1,367,715
20%	9,403,554	1,002,143	10,405,696	-1,661,915	471,823	30,874	502,698	-96,730	556,690	-139,173	-2,735,430
30%	8,228,109	1,346,629	9,574,739	-2,492,873	412,845	41,487	454,333	-145,095	487,104	-208,759	-4,103,145
40%	7,052,665	1,691,116	8,743,781	-3,323,830	353,867	52,100	405,968	-193,459	417,518	-278,345	-5,470,861
50%	5,877,221	2,035,603	7,912,824	-4,154,788	294,890	62,714	357,603	-241,824	347,931	-347,931	-6,838,576
60%	4,701,777	2,380,089	7,081,866	-4,985,745	235,912	73,327	309,238	-290,189	278,345	-417,518	-8,206,291
70%	3,526,333	2,724,576	6,250,909	-5,816,703	176,934	83,940	260,873	-338,554	208,759	-487,104	-9,574,006
80%	2,350,888	3,069,063	5,419,951	-6,647,661	117,956	94,553	212,509	-386,919	139,173	-556,690	-10,941,721
90%	1,175,444	3,413,549	4,588,993	-7,478,618	58,978	105,166	164,144	-435,284	69,586	-626,277	-12,309,436
100%	0	3,758,036	3,758,036	-8,309,576	0	115,779	115,779	-483,649	0	-695,863	-13,677,151

From Port of: HAMPTON ROADS, \ To: PITTSBURGH,PA







CARGO

Port Thr/put TEUs: 1,347,151 Metric Tons: 13,471,510 Mileage: 420

% to PA: 3.4% TEUs: 45,803 tons: 458,031

Modal Split:	Truck	Rail	Total
%:	44.0%	45.0%	
TEUs:	20,153	20,611	45,803
FEUs:	10,077	10,306	22,902
tons:	201,534	206,114	458,031

TRANSPORTATION COSTS

Truck: 1.1 $/mile*FEU
Rail: 200 $/FEU + 0.4 $/mile*FEU

Truck: 4,655,431 $
Rail: 3,792,499 $

FUEL COST

FUEL CONSUMPTION			TOTAL
Truck:	59.2 mpg per ton	0.0169 gal/mile per ton	1,429,801 gallons
Rail:	202 mpg per ton	0.0050 gal/mile per ton	428,554 gallons

Current Cost: Truck: 1,715,761 $ Fuel Price: 1.2 $/gal
Rail: 514,265 $

EMISSIONS

Truck: 0.6021 lbs NOx per gal 430.4 tons of NOx ECA: 200 $/ton
Rail: 0.3697 lbs NOx per gal 79.2 tons of NOx

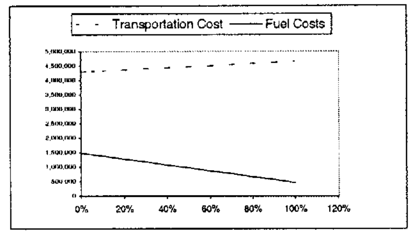
Current Cost: Truck: 86,088 $
Rail: 15,844 $

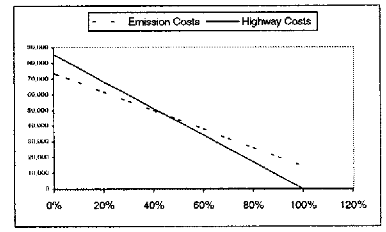
HIGHWAY MAINTENANCE COSTS

of Trucks= FEUs= 10,077 Highway Cost: 0.024 $ per mile travelled
Total Highway Cost: 101,573 $

Modal Switch	tons	FEUs	(tons) Truck	Rail	Transportation Cost ($) Truck	Rail	Total	Change	Fuel Cost ($) Truck	Rail	Total	Change	Emission Costs ($) Truck	Rail	Total	Change	Highway ($) Costs	Change	($) TOTAL
0%	0	0	201,534	206,114	4,655,431	3,792,499	8,447,930	0	1,715,761	514,265	2,230,026	0	86,088	15,844	101,932	0	101,573	0	0
1%	2,015	101	199,518	208,129	4,608,876	3,829,582	8,438,458	-9,472	1,698,603	519,293	2,217,896	-12,129	85,227	15,999	101,226	-706	100,557	-1,016	-23,323
5%	10,077	504	191,457	216,191	4,422,659	3,977,911	8,400,570	-47,360	1,629,973	539,407	2,169,379	-60,646	81,784	16,618	98,402	-3,530	96,494	-5,079	-116,615
10%	20,153	1,008	181,380	226,267	4,189,887	4,163,322	8,353,209	-94,721	1,544,185	564,549	2,108,733	-121,292	77,479	17,393	94,872	-7,060	91,416	-10,157	-233,230
20%	40,307	2,015	161,227	246,421	3,724,344	4,534,144	8,258,488	-189,442	1,372,609	614,832	1,987,441	-242,585	68,871	18,942	87,813	-14,119	81,258	-20,315	-466,460
30%	60,460	3,023	141,074	266,574	3,258,801	4,904,966	8,163,767	-284,163	1,201,032	665,116	1,866,148	-363,877	60,262	20,491	80,753	-21,179	71,101	-30,472	-699,691
40%	80,614	4,031	120,920	286,728	2,793,258	5,275,788	8,069,047	-378,884	1,029,456	715,400	1,744,856	-485,170	51,653	22,040	73,693	-28,239	60,944	-40,629	-932,921
50%	100,767	5,038	100,767	306,881	2,327,715	5,646,610	7,974,326	-473,604	857,880	765,683	1,623,564	-606,462	43,044	23,589	66,634	-35,298	50,787	-50,787	-1,166,151
60%	120,920	6,046	80,614	327,034	1,862,172	6,017,433	7,879,605	-568,325	686,304	815,967	1,502,271	-727,754	34,435	25,139	59,574	-42,358	40,629	-60,944	-1,399,381
70%	141,074	7,054	60,460	347,188	1,396,629	6,388,255	7,784,884	-663,046	514,728	866,251	1,380,979	-849,047	25,826	26,688	52,514	-49,418	30,472	-71,101	-1,632,612
80%	161,227	8,061	40,307	367,341	931,086	6,759,077	7,690,163	-757,767	343,152	916,534	1,259,686	-970,339	17,218	28,237	45,455	-56,477	20,315	-81,258	-1,865,842
90%	181,380	9,069	20,153	387,495	465,543	7,129,899	7,595,442	-852,488	171,576	966,818	1,138,394	-1,091,631	8,609	29,786	38,395	-63,537	10,157	-91,416	-2,099,072
100%	201,534	10,077	0	407,648	0	7,500,721	7,500,721	-947,209	0	1,017,102	1,017,102	-1,212,924	0	31,335	31,335	-70,597	0	-101,573	-2,332,302

From Port of: BALTIMORE, MD To: PITTSBURGH,PA





CARGO

Port Thr/put TEUs: 486,861 **Metric Tons:** 4,868,610 **Mileage:** 250

% to PA: 6.5% **TEUs:** 31,646 **tons:** 316,460

Modal Split:	Truck	Rail	Total
%:	90.0%	8.0%	
TEUs:	28,481	2,532	31,646
FEUs:	14,241	1,266	15,823
tons:	284,814	25,317	316,460

TRANSPORTATION COSTS

Truck: 1.1 $/mile*FEU
Rail: 200 $/FEU + 0.4 $/mile*FEU

Truck: 3,916,188 $
Rail: 379,752 $

FUEL COST

FUEL CONSUMPTION TOTAL

Truck: 59.2 mpg per ton 0.0169 gal/mile per ton 1,202,760 gallons
Rail: 202 mpg per ton 0.0050 gal/mile per ton 31,333 gallons

Current Cost: **Truck:** 1,443,313 $ **Fuel Price:** 1.2 $/gal
Rail: 37,599 $

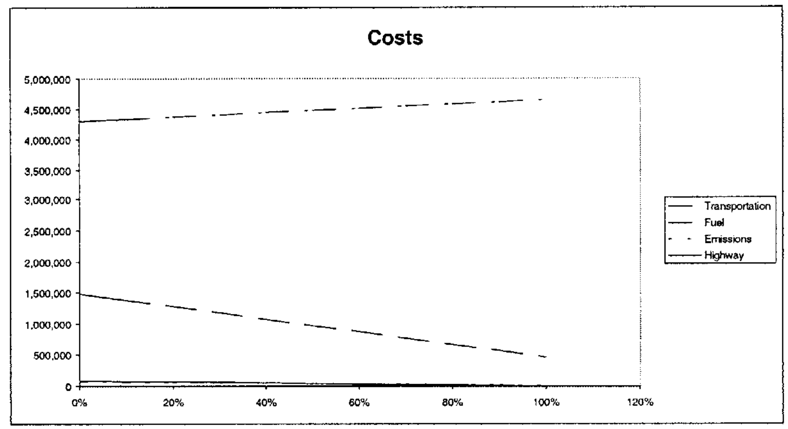
EMISSIONS

Truck: 0.6021 lbs NOx per gal 362.1 tons of NOx **ECA:** 200 $/ton
Rail: 0.3697 lbs NOx per gal 5.8 tons of NOx

Current Cost: **Truck:** 72,418 $
Rail: 1,158 $

HIGHWAY MAINTENANCE COSTS

# of Trucks= **FEUs=** 14,241 **Highway Cost:** 0.024 $ per mile travelled
Total Highway Cost: 85,444 $



Modal Switch	tons	FEUs	(tons) Truck	Rail	Transportation Cost ($) Truck	Rail	Total	Change	Fuel Cost ($) Truck	Rail	Total	Change	Emission Costs ($) Truck	Rail	Total	Change	Highway ($) Costs	Change	($) TOTAL
0%	0	0	284,814	25,317	3,916,188	379,752	4,295,940	0	1,443,313	37,599	1,480,912	0	72,418	1,158	73,577	0	85,444	0	0
1%	2,848	142	281,966	28,165	3,877,026	422,474	4,299,500	3,560	1,428,879	41,829	1,470,709	-10,203	71,694	1,289	72,983	-594	84,590	-854	-8,091
5%	14,241	712	270,573	39,557	3,720,379	593,362	4,313,741	17,801	1,371,147	58,749	1,429,896	-51,016	68,797	1,810	70,607	-2,969	81,172	-4,272	-40,457
10%	28,481	1,424	256,332	53,798	3,524,569	806,972	4,331,541	35,602	1,298,981	79,898	1,378,880	-102,032	65,176	2,462	67,638	-5,939	76,900	-8,544	-80,914
20%	56,963	2,848	227,851	82,280	3,132,951	1,234,193	4,367,143	71,203	1,154,650	122,197	1,276,847	-204,064	57,935	3,765	61,699	-11,877	68,355	-17,089	-161,827
30%	85,444	4,272	199,370	110,761	2,741,332	1,661,413	4,402,745	106,805	1,010,319	164,496	1,174,815	-306,097	50,693	5,068	55,761	-17,816	59,811	-25,633	-242,741
40%	113,925	5,696	170,888	139,242	2,349,713	2,088,634	4,438,347	142,407	865,988	206,795	1,072,783	-408,129	43,451	6,371	49,822	-23,755	51,266	-34,178	-323,654
50%	142,407	7,120	142,407	167,724	1,958,094	2,515,854	4,473,948	178,009	721,656	249,094	970,751	-510,161	36,209	7,674	43,883	-29,693	42,722	-42,722	-404,568
60%	170,888	8,544	113,925	196,205	1,566,475	2,943,075	4,509,550	213,610	577,325	291,394	868,719	-612,193	28,967	8,977	37,945	-35,632	34,178	-51,266	-485,481
70%	199,370	9,968	85,444	224,686	1,174,856	3,370,295	4,545,152	249,212	432,994	333,693	766,686	-714,225	21,725	10,281	32,006	-41,571	25,633	-59,811	-566,395
80%	227,851	11,393	56,963	253,168	783,238	3,797,516	4,580,753	284,814	288,663	375,992	664,654	-816,258	14,484	11,584	26,067	-47,509	17,089	-68,355	-647,308
90%	256,332	12,817	28,481	281,649	391,619	4,224,736	4,616,355	320,415	144,331	418,291	562,622	-918,290	7,242	12,887	20,129	-53,448	8,544	-76,900	-728,222
100%	284,814	14,241	0	310,130	0	4,651,957	4,651,957	356,017	0	460,590	460,590	-1,020,322	0	14,190	14,190	-59,387	0	-85,444	-809,136

From Port of: CHARLESTON, SC To: PITTSBURGH,PA

CARGO

Port Thr/put TEUs:	1,574,467	**Metric Tons:**	15,744,670	**Mileage:**	650
% to PA:	1.3%	**TEUs:**	20,468	**tons:**	204,681

Modal Split:	**Truck**	**Rail**	**Total**
%:	76.0%	22.0%	
TEUs:	15,556	4,503	20,468
FEUs:	7,778	2,251	10,234
tons:	155,557	45,030	204,681

TRANSPORTATION COSTS

Truck: 1.1 $/mile*FEU
Rail: 200 $/FEU + 0.4 $/mile*FEU

Truck: 5,561,175 $
Rail: 1,035,684 $

FUEL COST

FUEL CONSUMPTION			TOTAL
Truck:	59.2 mpg per ton	0.0169 gal/mile per ton	1,707,978 gallons
Rail:	202 mpg per ton	0.0050 gal/mile per ton	144,898 gallons

Current Cost: **Truck:** 2,049,573 $ **Fuel Price:** 1.2 $/gal
Rail: 173,877 $

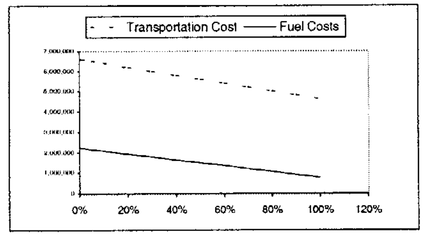
EMISSIONS

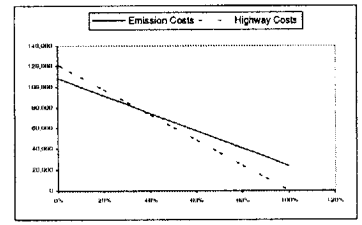
Truck:	0.6021 lbs NOx per gal	514.2 tons of NOx	**ECA:**	200 $/ton
Rail:	0.3697 lbs NOx per gal	26.8 tons of NOx		

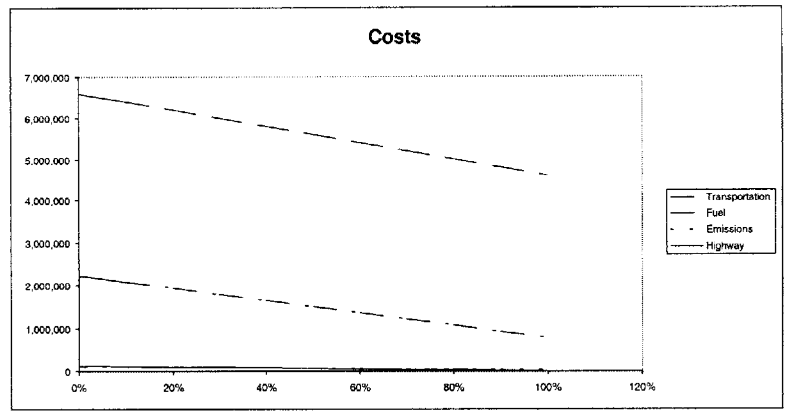
Current Cost: **Truck:** 102,837 $
Rail: 5,357 $

HIGHWAY MAINTENANCE COSTS

# of Trucks= **FEUs=** 7,778 **Highway Cost:** 0.024 $ per mile travelled
Total Highway Cost: 121,335 $







Modal Switch	tons	FEUs	(tons) Truck	Rail	Transportation Cost ($) Truck	Rail	Total	Change	Fuel Cost ($) Truck	Rail	Total	Change	Emission Costs ($) Truck	Rail	Total	Change	Highway ($) Costs	Change	($) TOTAL
0%	0	0	155,557	45,030	5,561,175	1,035,684	6,596,859	0	2,049,573	173,877	2,223,450	0	102,837	5,357	108,194	0	121,335	0	0
1%	1,556	78	154,002	46,585	5,505,563	1,071,463	6,577,026	-19,834	2,029,077	179,884	2,208,961	-14,489	101,809	5,542	107,351	-843	120,121	-1,213	-36,379
5%	7,778	389	147,779	52,808	5,283,116	1,214,575	6,497,691	-99,168	1,947,094	203,911	2,151,005	-72,445	97,695	6,282	103,978	-4,217	115,268	-6,067	-181,896
10%	15,556	778	140,002	60,585	5,005,057	1,393,466	6,398,524	-198,336	1,844,616	233,944	2,078,560	-144,891	92,554	7,207	99,761	-8,433	109,201	-12,133	-363,793
20%	31,111	1,556	124,446	76,141	4,448,940	1,751,248	6,200,188	-396,671	1,639,658	294,011	1,933,669	-289,781	82,270	9,058	91,328	-16,866	97,068	-24,267	-727,586
30%	46,667	2,333	108,890	91,697	3,892,822	2,109,030	6,001,852	-595,007	1,434,701	354,077	1,788,779	-434,672	71,986	10,909	82,895	-25,300	84,934	-36,400	-1,091,379
40%	62,223	3,111	93,334	107,253	3,336,705	2,466,812	5,803,517	-793,342	1,229,744	414,144	1,643,888	-579,562	61,702	12,759	74,461	-33,733	72,801	-48,534	-1,455,171
50%	77,779	3,889	77,779	122,808	2,780,587	2,824,594	5,605,181	-991,678	1,024,787	474,211	1,498,997	-724,453	51,419	14,610	66,028	-42,166	60,667	-60,667	-1,818,964
60%	93,334	4,667	62,223	138,364	2,224,470	3,182,376	5,406,846	-1,190,014	819,829	534,277	1,354,107	-869,344	41,135	16,460	57,595	-50,599	48,534	-72,801	-2,182,757
70%	108,890	5,445	46,667	153,920	1,668,352	3,540,158	5,208,510	-1,388,349	614,872	594,344	1,209,216	-1,014,234	30,851	18,311	49,162	-59,032	36,400	-84,934	-2,546,550
80%	124,446	6,222	31,111	169,476	1,112,235	3,897,939	5,010,174	-1,586,685	409,915	654,411	1,064,325	-1,159,125	20,567	20,161	40,729	-67,465	24,267	-97,068	-2,910,343
90%	140,002	7,000	15,556	185,031	556,117	4,255,721	4,811,839	-1,785,020	204,957	714,478	919,435	-1,304,015	10,284	22,012	32,296	-75,899	12,133	-109,201	-3,274,136
100%	155,557	7,778	0	200,587	0	4,613,503	4,613,503	-1,983,356	0	774,544	774,544	-1,448,906	0	23,862	23,862	-84,332	0	-121,335	-3,637,929

Appendix B

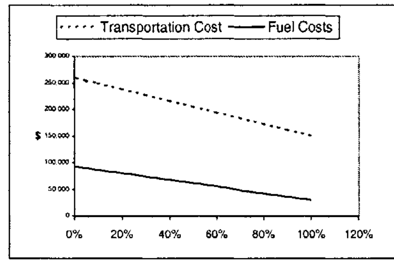
Calculations for Chicago

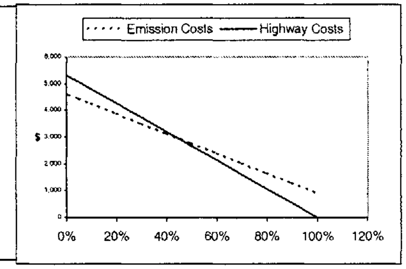
For cargo percentages 1% to 100% of the current truck cargo—originating from the five U.S. East ports to Chicago—switched to rail mode, we calculate the following cost categories:

- Freight transportation cost
- Fuel consumption cost
- Emissions cost
- Highway maintenance cost

(Formulas and assumptions were based on a similar mode comparison including three modes of transportation—rail, trucks, and barges—made for a Marine Transportation System (MTS) Task Force as part of an assessment of the U.S. marine transportation system (A Report to Congress, [1]).

From: BOSTON, MA **To:** CHICAGO,IL





CARGO

Port Thr/put TEUs:	122,398	**Metric Tons:**	1,223,980	**Mileage:**	980
% to PA:	0.5%	**TEUs:**	612	**tons:**	6,120

Modal Split:	**Truck**	**Rail**	**Total**
%:	74 0%	9 0%	
TEUs:	453	55	612
FEUs:	226	28	306
tons:	4,529	551	6,120

TRANSPORTATION COSTS

Truck:	**1.1** $/mile*FEU		
Rail:	**200** $/FEU	+	**0.4** $/mile*FEU
Truck:	**244,098** $		
Rail:	**16,303** $		

FUEL COST

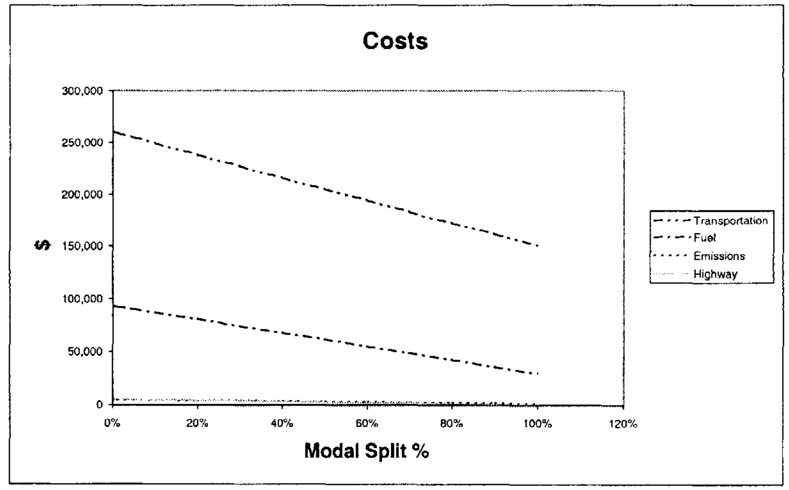
	FUEL CONSUMPTION			TOTAL
	Truck:	**59.2** mpg per ton	**0.0169** gal/mile per ton	**74,969** gallons
	Rail:	**202** mpg per ton	**0.0050** gal/mile per ton	**2,672** gallons
Current Cost:	**Truck:**	**89,963** $	**Fuel Price:**	1.2 $/gal
	Rail:	**3,207** $		

EMISSIONS

	Truck:	**0.6021** lbs NOx per gal	**22.6** tons of NOx	**ECA:**	200 $/ton
	Rail:	**0.3697** lbs NOx per gal	**0.5** tons of NOx		
Current Cost:	**Truck:**	**4,514** $			
	Rail:	**99** $			

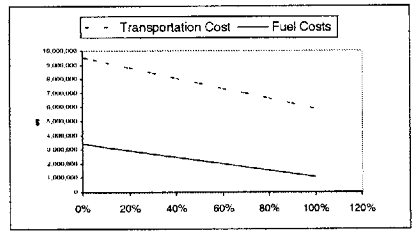
HIGHWAY MAINTENANCE COSTS

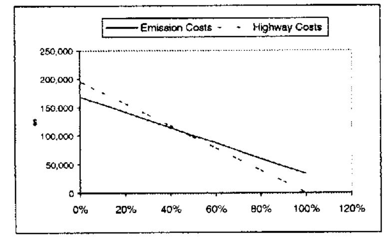
# of Trucks=	**FEUs=** 226	**Highway Cost:**	0.024 $ per mile travelled
Total Highway Cost:	5,326 $		



Modal Switch	tons	FEUs	(tons) Truck	Rail	Transportation Cost ($) Truck	Rail	Total	Change	Fuel Cost ($) Truck	Rail	Total	Change	Emission Costs ($) Truck	Rail	Total	Change	Highway Costs	Change	TOTAL
0%	0	0	4,529	551	244,098	16,303	260,402	**0**	89,963	3,207	93,169	**0**	4,514	99	4,613	**0**	5,326	**0**	**0**
1%	45	2	4,483	596	241,657	17,644	259,301	**-1,100**	89,063	3,470	92,533	**-636**	4,469	107	4,576	**-37**	5,273	**-53**	**-1,827**
5%	226	11	4,302	777	231,893	23,006	254,899	**-5,502**	85,464	4,525	89,989	**-3,180**	4,288	139	4,428	**-185**	5,059	**-266**	**-9,134**
10%	453	23	4,076	1,004	219,688	29,708	249,397	**-11,005**	80,966	5,843	86,809	**-6,360**	4,062	180	4,242	**-370**	4,793	**-533**	**-18,267**
20%	906	45	3,623	1,457	195,279	43,113	238,392	**-22,010**	71,970	8,480	80,450	**-12,719**	3,611	261	3,872	**-740**	4,261	**-1,065**	**-36,535**
30%	1,359	68	3,170	1,909	170,869	56,519	227,387	**-33,014**	62,974	11,116	74,090	**-19,079**	3,160	342	3,502	**-1,110**	3,728	**-1,598**	**-54,802**
40%	1,811	91	2,717	2,362	146,459	69,924	216,383	**-44,019**	53,978	13,753	67,730	**-25,439**	2,708	424	3,132	**-1,481**	3,195	**-2,130**	**-73,069**
50%	2,264	113	2,264	2,815	122,049	83,329	205,378	**-55,024**	44,981	16,389	61,370	**-31,799**	2,257	505	2,762	**-1,851**	2,663	**-2,663**	**-91,336**
60%	2,717	136	1,811	3,268	97,639	96,734	194,373	**-66,029**	35,985	19,026	55,011	**-38,158**	1,806	586	2,392	**-2,221**	2,130	**-3,195**	**-109,604**
70%	3,170	159	1,359	3,721	73,229	110,139	183,368	**-77,034**	26,989	21,662	48,651	**-44,518**	1,354	667	2,022	**-2,591**	1,598	**-3,728**	**-127,871**
80%	3,623	181	906	4,174	48,820	123,544	172,363	**-88,038**	17,993	24,299	42,291	**-50,878**	903	749	1,651	**-2,961**	1,065	**-4,261**	**-146,138**
90%	4,076	204	453	4,627	24,410	136,949	161,359	**-99,043**	8,996	26,935	35,932	**-57,238**	451	830	1,281	**-3,331**	533	**-4,793**	**-164,405**
100%	4,529	226	0	5,080	0	150,354	150,354	**-110,048**	0	29,572	29,572	**-63,597**	0	911	911	**-3,702**	0	**-5,326**	**-182,673**

From: NY/NJ **To:** CHICAGO,IL





CARGO

Port Thr/put TEUs:	3,050,746	**Metric Tons:**	30,507,460	**Mileage:**	790
% to PA:	0.9%	**TEUs:**	27,457	**tons:**	274,567

Modal Split:	**Truck**	**Rail**	**Total**
%:	75.0%	8.0%	
TEUs:	20,593	2,197	27,457
FEUs:	10,296	1,098	13,728
tons:	205,925	21,965	274,567

TRANSPORTATION COSTS

Truck: **1.1** $/mile*FEU
Rail: **200** $/FEU + **0.4** $/mile*FEU

Truck: **8,947,457** $
Rail: **566,707** $

FUEL COST

FUEL CONSUMPTION			TOTAL
Truck:	**59.2** mpg per ton	**0.0169** gal/mile per ton	**2,747,990** gallons
Rail:	**202** mpg per ton	**0.0050** gal/mile per ton	**85,904** gallons

Current Cost: **Truck:** **3,297,588** $ **Fuel Price:** 1.2 $/gal
Rail: **103,085** $

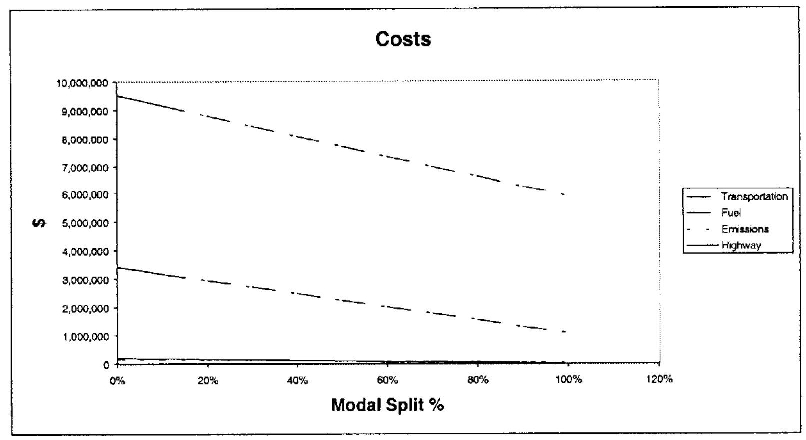
EMISSIONS

Truck:	**0.6021** lbs NOx per gal	**827.3** tons of NOx	**ECA:**	200 $/ton
Rail:	**0.3697** lbs NOx per gal	**15.9** tons of NOx		

Current Cost: **Truck:** **165,457** $
Rail: **3,176** $

HIGHWAY MAINTENANCE COSTS

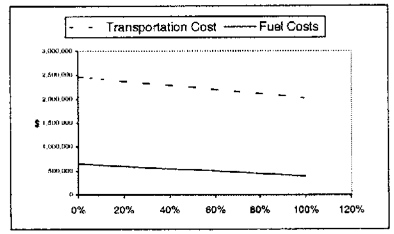
# of Trucks= **FEUs=** 10,296 **Highway Cost:** 0.024 $ per mile travelled
Total Highway Cost: 195,217 $

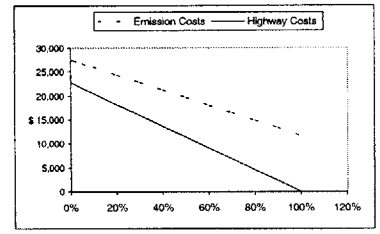


Modal Switch	tons	FEUs	(tons) Truck	Rail	Transportation Cost ($) Truck	Rail	Total	Change
0%	0	0	205,925	21,965	8,947,457	566,707	9,514,163	**0**
1%	2,059	103	203,866	24,025	8,857,982	619,835	9,477,817	**-36,346**
5%	10,296	515	195,629	32,262	8,500,084	832,350	9,332,434	**-181,729**
10%	20,593	1,030	185,333	42,558	8,052,711	1,097,994	9,150,705	**-363,458**
20%	41,185	2,059	164,740	63,150	7,157,965	1,629,281	8,787,247	**-726,917**
30%	61,778	3,089	144,148	83,743	6,263,220	2,160,569	8,423,788	**-1,090,375**
40%	82,370	4,119	123,555	104,336	5,368,474	2,691,856	8,060,330	**-1,453,833**
50%	102,963	5,148	102,963	124,928	4,473,728	3,223,144	7,696,872	**-1,817,291**
60%	123,555	6,178	82,370	145,521	3,578,983	3,754,431	7,333,414	**-2,180,750**
70%	144,148	7,207	61,778	166,113	2,684,237	4,285,718	6,969,955	**-2,544,208**
80%	164,740	8,237	41,185	186,706	1,789,491	4,817,006	6,606,497	**-2,907,666**
90%	185,333	9,267	20,593	207,298	894,746	5,348,293	6,243,039	**-3,271,124**
100%	205,925	10,296	0	227,891	0	5,879,581	5,879,581	**-3,634,583**

Modal Switch	Fuel Cost ($) Truck	Rail	Total	Change	Emission Costs ($) Truck	Rail	Total	Change	Highway Costs	Change	TOTAL
0%	3,297,588	103,085	3,400,673	**0**	165,457	3,176	168,632	**0**	195,217	**0**	**0**
1%	3,264,613	112,749	3,377,362	**-23,312**	163,802	3,474	167,276	**-1,357**	193,265	**-1,952**	**-62,966**
5%	3,132,709	151,406	3,284,115	**-116,558**	157,184	4,665	161,848	**-6,784**	185,456	**-9,761**	**-314,832**
10%	2,967,830	199,727	3,167,557	**-233,117**	148,911	6,153	155,064	**-13,568**	175,696	**-19,522**	**-629,665**
20%	2,638,071	296,369	2,934,440	**-466,233**	132,365	9,131	141,496	**-27,137**	156,174	**-39,043**	**-1,259,330**
30%	2,308,312	393,012	2,701,324	**-699,350**	115,820	12,108	127,928	**-40,705**	136,652	**-58,565**	**-1,888,995**
40%	1,978,553	489,654	2,468,207	**-932,467**	99,274	15,085	114,359	**-54,273**	117,130	**-78,087**	**-2,518,660**
50%	1,648,794	586,296	2,235,090	**-1,165,583**	82,728	18,063	100,791	**-67,841**	97,609	**-97,609**	**-3,148,324**
60%	1,319,035	682,938	2,001,974	**-1,398,700**	66,183	21,040	87,223	**-81,410**	78,087	**-117,130**	**-3,777,989**
70%	989,277	779,580	1,768,857	**-1,631,817**	49,637	24,018	73,655	**-94,978**	58,565	**-136,652**	**-4,407,654**
80%	659,518	876,223	1,535,740	**-1,864,933**	33,091	26,995	60,086	**-108,546**	39,043	**-156,174**	**-5,037,319**
90%	329,759	972,865	1,302,624	**-2,098,050**	16,546	29,972	46,518	**-122,114**	19,522	**-175,696**	**-5,666,984**
100%	0	1,069,507	1,069,507	**-2,331,166**	0	32,950	32,950	**-135,683**	0	**-195,217**	**-6,296,649**

From: HAMPTON ROADS, **To:** CHICAGO,IL





__CARGO__

Port Thr/put TEUs:	1,347,151	**Metric Tons:**	13,471,510	**Mileage:**	870
% to PA:	0.6%	**TEUs:**	8,083	**tons:**	80,829

Modal Split:	**Truck**	**Rail**	**Total**
%:	27.0%	64.0%	
TEUs:	2,182	5,173	8,083
FEUs:	1,091	2,587	4,041
tons:	21,824	51,731	80,829

__TRANSPORTATION COSTS__

Truck: 1.1 $/mile*FEU
Rail: 200 $/FEU + 0.4 $/mile*FEU

Truck: 1,044,271 $
Rail: 1,417,418 $

__FUEL COST__

FUEL CONSUMPTION			TOTAL
Truck:	59.2 mpg per ton	0.0169 gal/mile per ton	320,722 gallons
Rail:	202 mpg per ton	0.0050 gal/mile per ton	222,800 gallons

Current Cost: **Truck:** 384,866 $ — **Fuel Price:** 1.2 $/gal
Rail: 267,360 $

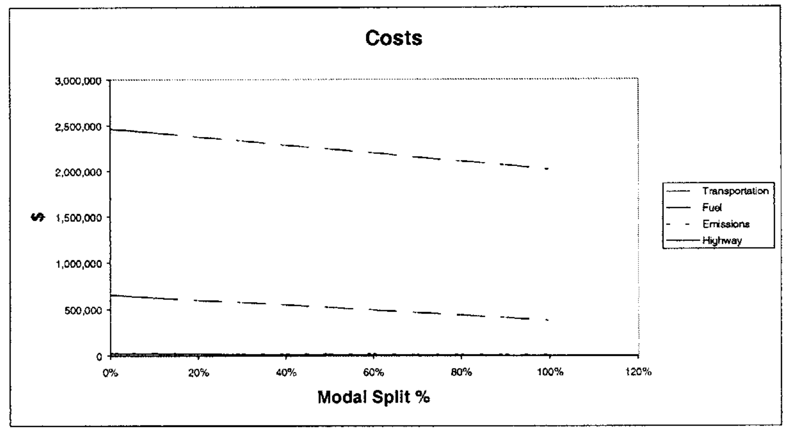
__EMISSIONS__

Truck:	0.6021 lbs NOx per gal	96.6 tons of NOx	**ECA:** 200 $/ton
Rail:	0.3697 lbs NOx per gal	41.2 tons of NOx	

Current Cost: **Truck:** 19,311 $
Rail: 8,237 $

__HIGHWAY MAINTENANCE COSTS__

# of Trucks= **FEUs=** 1,091 — **Highway Cost:** 0.024 $ per mile travelled
Total Highway Cost: 22,784 $



Modal Switch	tons	FEUs	(tons) Truck	Rail	Transportation Cost ($) Truck	Rail	Total	Change	Fuel Cost ($) Truck	Rail	Total	Change	Emission Costs ($) Truck	Rail	Total	Change	Highway Costs	Change	TOTAL
0%	0	0	21,824	51,731	1,044,271	1,417,418	2,461,689	**0**	384,866	267,360	652,227	**0**	19,311	8,237	27,548	**0**	22,784	**0**	**0**
1%	218	11	21,606	51,949	1,033,828	1,423,398	2,457,226	**-4,463**	381,018	268,488	649,506	**-2,721**	19,118	8,272	27,389	**-158**	22,556	**-228**	**-7,570**
5%	1,091	55	20,733	52,822	992,057	1,447,317	2,439,375	**-22,315**	365,623	273,000	638,623	**-13,604**	18,345	8,411	26,756	**-792**	21,645	**-1,139**	**-37,850**
10%	2,182	109	19,641	53,913	939,844	1,477,216	2,417,060	**-44,630**	346,380	278,639	625,019	**-27,207**	17,380	8,584	25,964	**-1,584**	20,506	**-2,278**	**-75,699**
20%	4,365	218	17,459	56,095	835,417	1,537,013	2,372,430	**-89,260**	307,893	289,919	597,812	**-54,415**	15,449	8,932	24,380	**-3,167**	18,227	**-4,557**	**-151,398**
30%	6,547	327	15,277	58,278	730,990	1,596,810	2,327,800	**-133,889**	269,407	301,198	570,604	**-81,622**	13,517	9,279	22,797	**-4,751**	15,949	**-6,835**	**-227,097**
40%	8,730	436	13,094	60,460	626,563	1,656,608	2,283,170	**-178,519**	230,920	312,477	543,397	**-108,830**	11,586	9,627	21,213	**-6,334**	13,670	**-9,114**	**-302,797**
50%	10,912	546	10,912	62,643	522,136	1,716,405	2,238,541	**-223,149**	192,433	323,756	516,190	**-136,037**	9,655	9,974	19,630	**-7,918**	11,392	**-11,392**	**-378,496**
60%	13,094	655	8,730	64,825	417,708	1,776,202	2,193,911	**-267,779**	153,947	335,036	488,982	**-163,244**	7,724	10,322	18,046	**-9,501**	9,114	**-13,670**	**-454,195**
70%	15,277	764	6,547	67,007	313,281	1,836,000	2,149,281	**-312,408**	115,460	346,315	461,775	**-190,452**	5,793	10,669	16,463	**-11,085**	6,835	**-15,949**	**-529,894**
80%	17,459	873	4,365	69,190	208,854	1,895,797	2,104,651	**-357,038**	76,973	357,594	434,567	**-217,659**	3,862	11,017	14,879	**-12,669**	4,557	**-18,227**	**-605,593**
90%	19,641	982	2,182	71,372	104,427	1,955,594	2,060,022	**-401,668**	38,487	368,873	407,360	**-244,867**	1,931	11,364	13,295	**-14,252**	2,278	**-20,506**	**-681,292**
100%	21,824	1,091	0	73,554	0	2,015,392	2,015,392	**-446,298**	0	380,153	380,153	**-272,074**	0	11,712	11,712	**-15,836**	0	**-22,784**	**-756,991**

From: BALTIMORE, MD To: CHICAGO,IL

CARGO

Port Thr/put TEUs:	486,861	**Metric Tons:**	4,868,610	**Mileage:**	690
% to PA:	0.4%	**TEUs:** 1,947		**tons:** 19,474	

Modal Split:	**Truck**	**Rail**	**Total**
%:	49.0%	48.0%	
TEUs:	954	935	1,947
FEUs:	477	467	974
tons:	9,542	9,348	19,474

TRANSPORTATION COSTS

Truck: 1.1 $/mile*FEU
Rail: 200 $/FEU + 0.4 $/mile*FEU

Truck: 362,137 $
Rail: 222,476 $

FUEL COST

FUEL CONSUMPTION			TOTAL
Truck:	**59.2** mpg per ton	**0.0169** gal/mile per ton	**111,221** gallons
Rail:	**202** mpg per ton	**0.0050** gal/mile per ton	**31,930** gallons

Current Cost: **Truck:** 133,466 $ — **Fuel Price:** 1.2 $/gal
Rail: 38,316 $

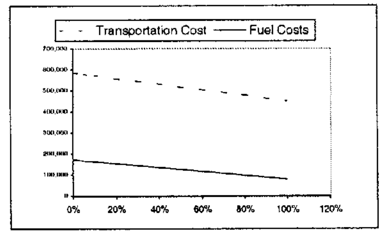
EMISSIONS

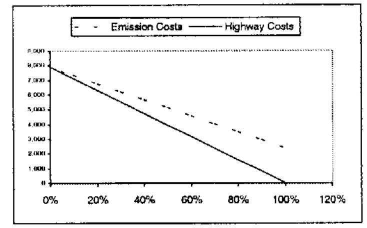
Truck:	**0.6021** lbs NOx per gal	**33.5** tons of NOx	**ECA:**	200 $/ton
Rail:	**0.3697** lbs NOx per gal	**5.9** tons of NOx		

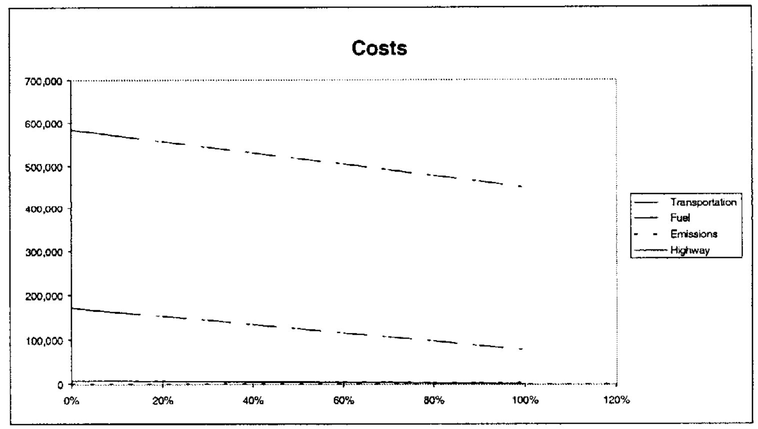
Current Cost: **Truck:** 6,697 $
Rail: 1,180 $

HIGHWAY MAINTENANCE COSTS

# of Trucks= **FEUs=** 477 — **Highway Cost:** 0.024 $ per mile travelled
Total Highway Cost: 7,901 $



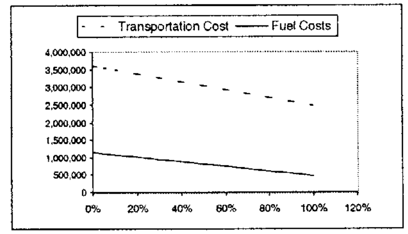


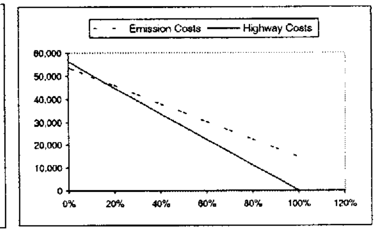


Modal Switch	tons	FEUs	(tons) Truck	Rail	Transportation Cost ($) Truck	Rail	Total	Change
0%	0	0	9,542	9,348	362,137	222,476	584,613	0
1%	95	5	9,447	9,443	358,516	224,747	583,263	-1,350
5%	477	24	9,065	9,825	344,030	233,832	577,862	-6,751
10%	954	48	8,588	10,302	325,923	245,187	571,110	-13,503
20%	1,908	95	7,634	11,256	289,710	267,898	557,608	-27,005
30%	2,863	143	6,680	12,210	253,496	290,609	544,105	-40,508
40%	3,817	191	5,725	13,165	217,282	313,320	530,603	-54,010
50%	4,771	239	4,771	14,119	181,068	336,031	517,100	-67,513
60%	5,725	286	3,817	15,073	144,855	358,743	503,597	-81,016
70%	6,680	334	2,863	16,027	108,641	381,454	490,095	-94,518
80%	7,634	382	1,908	16,982	72,427	404,165	476,592	-108,021
90%	8,588	429	954	17,936	36,214	426,876	463,090	-121,523
100%	9,542	477	0	18,890	0	449,587	449,587	-135,026

Modal Switch	Fuel Cost ($) Truck	Rail	Total	Change	Emission Costs ($) Truck	Rail	Total	Change	Highway Costs	Change	TOTAL
0%	133,466	38,316	171,782	0	6,697	1,180	7,877	0	7,901	0	0
1%	132,131	38,708	170,839	-944	6,630	1,193	7,822	-55	7,822	-79	-2,428
5%	126,792	40,272	167,065	-4,718	6,362	1,241	7,603	-275	7,506	-395	-12,138
10%	120,119	42,228	162,347	-9,435	6,027	1,301	7,328	-549	7,111	-790	-24,277
20%	106,773	46,139	152,912	-18,870	5,357	1,421	6,779	-1,098	6,321	-1,580	-48,554
30%	93,426	50,051	143,477	-28,305	4,688	1,542	6,230	-1,647	5,531	-2,370	-72,831
40%	80,079	53,962	134,042	-37,740	4,018	1,662	5,680	-2,197	4,741	-3,160	-97,108
50%	66,733	57,874	124,607	-47,176	3,348	1,783	5,131	-2,746	3,951	-3,951	-121,385
60%	53,386	61,785	115,172	-56,611	2,679	1,904	4,582	-3,295	3,160	-4,741	-145,662
70%	40,040	65,697	105,736	-66,046	2,009	2,024	4,033	-3,844	2,370	-5,531	-169,939
80%	26,693	69,608	96,301	-75,481	1,339	2,145	3,484	-4,393	1,580	-6,321	-194,216
90%	13,347	73,520	86,866	-84,916	670	2,265	2,935	-4,942	790	-7,111	-218,493
100%	0	77,431	77,431	-94,351	0	2,386	2,386	-5,492	0	-7,901	-242,770

From: CHARLESTON, SC To: CHICAGO,IL





CARGO

Port Thr/put TEUs:	1,574,467	**Metric Tons:**	15,744,670	**Mileage:**	900
% to PA:	0.6%	**TEUs:**	9,447	**tons:**	94,468

Modal Split:	**Truck**	**Rail**	**Total**
%:	55.0%	39.0%	
TEUs:	5,196	3,684	9,447
FEUs:	2,598	1,842	4,723
tons:	51,957	36,843	94,468

TRANSPORTATION COSTS

Truck: **1.1** $/mile*FEU
Rail: **200** $/FEU + **0.4** $/mile*FEU

Truck: **2,571,892** $
Rail: **1,031,591** $

FUEL COST

FUEL CONSUMPTION			TOTAL
Truck:	**59.2** mpg per ton	**0.0169** gal/mile per ton	**789,893** gallons
Rail:	**202** mpg per ton	**0.0050** gal/mile per ton	**164,150** gallons

Current Cost: **Truck:** **947,872** $ **Fuel Price:** 1.2 $/gal
Rail: **196,980** $

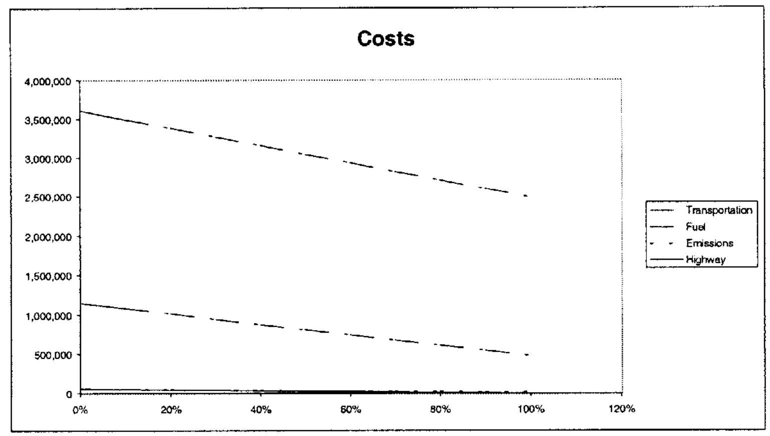
EMISSIONS

Truck:	**0.6021** lbs NOx per gal	**237.8** tons of NOx	**ECA:** 200 $/ton
Rail:	**0.3697** lbs NOx per gal	**30.3** tons of NOx	

Current Cost: **Truck:** **47,559** $
Rail: **6,069** $

HIGHWAY MAINTENANCE COSTS

# of Trucks= **FEUs=** 2,598 **Highway Cost:** 0.024 $ per mile travelled
Total Highway Cost: 56,114 $



Modal Switch	tons	FEUs	(tons) Truck	Rail	Transportation Cost ($) Truck	Rail	Total	Change	Fuel Cost ($) Truck	Rail	Total	Change	Emission Costs ($) Truck	Rail	Total	Change	Highway Costs	Change	TOTAL
0%	0	0	51,957	36,843	2,571,892	1,031,591	3,603,483	0	947,872	196,980	1,144,852	0	47,559	6,069	53,628	0	56,114	0	0
1%	520	26	51,438	37,362	2,546,173	1,046,139	3,592,312	**-11,171**	938,393	199,758	1,138,151	**-6,701**	47,084	6,154	53,238	**-390**	55,553	**-561**	**-18,823**
5%	2,598	130	49,360	39,440	2,443,297	1,104,331	3,547,628	**-55,854**	900,478	210,869	1,111,348	**-33,504**	45,181	6,497	51,678	**-1,950**	53,308	**-2,806**	**-94,114**
10%	5,196	260	46,762	42,038	2,314,703	1,177,072	3,491,774	**-111,708**	853,085	224,759	1,077,844	**-67,008**	42,804	6,924	49,728	**-3,900**	50,503	**-5,611**	**-188,228**
20%	10,391	520	41,566	47,234	2,057,513	1,322,552	3,380,066	**-223,417**	758,297	252,538	1,010,836	**-134,016**	38,048	7,780	45,828	**-7,800**	44,891	**-11,223**	**-376,456**
30%	15,587	779	36,370	52,430	1,800,324	1,468,033	3,268,357	**-335,125**	663,510	280,317	943,828	**-201,024**	33,292	8,636	41,928	**-11,700**	39,280	**-16,834**	**-564,684**
40%	20,783	1,039	31,174	57,625	1,543,135	1,613,514	3,156,649	**-446,834**	568,723	308,097	876,820	**-268,032**	28,536	9,492	38,028	**-15,600**	33,668	**-22,446**	**-752,912**
50%	25,979	1,299	25,979	62,821	1,285,946	1,758,995	3,044,940	**-558,542**	473,936	335,876	809,812	**-335,040**	23,780	10,348	34,128	**-19,501**	28,057	**-28,057**	**-941,140**
60%	31,174	1,559	20,783	68,017	1,028,757	1,904,475	2,933,232	**-670,251**	379,149	363,655	742,804	**-402,048**	19,024	11,204	30,227	**-23,401**	22,446	**-33,668**	**-1,129,367**
70%	36,370	1,819	15,587	73,213	771,568	2,049,956	2,821,524	**-781,959**	284,362	391,434	675,796	**-469,056**	14,268	12,059	26,327	**-27,301**	16,834	**-39,280**	**-1,317,595**
80%	41,566	2,078	10,391	78,408	514,378	2,195,437	2,709,815	**-893,667**	189,574	419,214	608,788	**-536,064**	9,512	12,915	22,427	**-31,201**	11,223	**-44,891**	**-1,505,823**
90%	46,762	2,338	5,196	83,604	257,189	2,340,918	2,598,107	**-1,005,376**	94,787	446,993	541,780	**-603,072**	4,756	13,771	18,527	**-35,101**	5,611	**-50,503**	**-1,694,051**
100%	51,957	2,598	0	88,800	0	2,486,398	2,486,398	**-1,117,084**	0	474,772	474,772	**-670,080**	0	14,627	14,627	**-39,001**	0	**-56,114**	**-1,882,279**

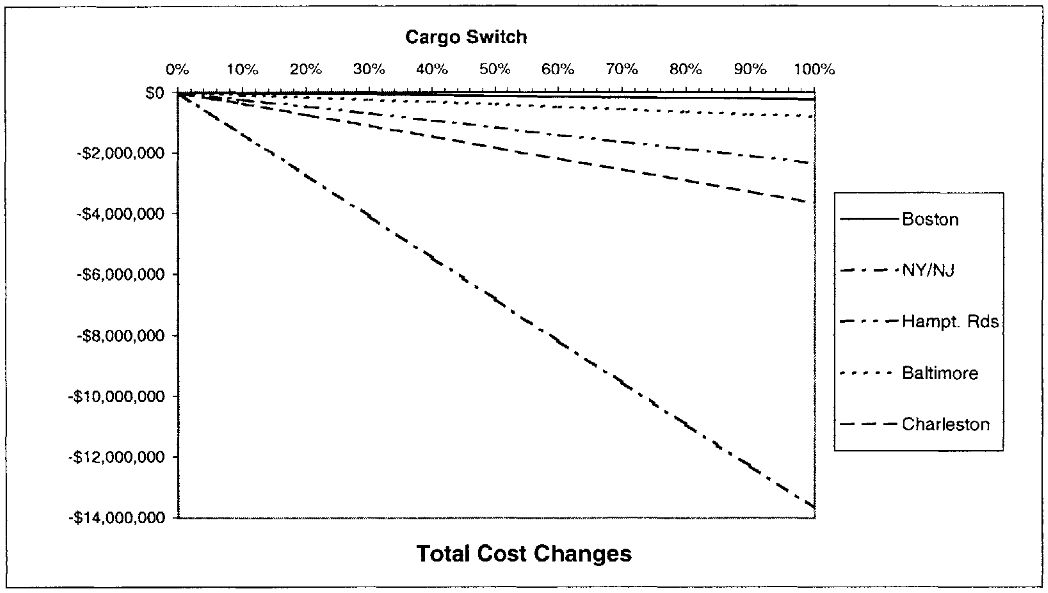
Appendix C

Total Cost Changes with Percentage of Cargo Switched

Adding the cost changes for the Pittsburgh cargo (1% to 100%) and the Chicago cargo (1% to 100%) switched, we get the total cost savings for the five U.S. East ports in relation with the percentage of cargo switched.

Total Cost Changes for % of Cargo Switched From Truck to Rail Mode

Cargo Switch	Boston	NY/NJ	Hampt. Rds	Baltimore	Charleston
0%	0	0	0	0	0
1%	-2,336	-136,772	-23,323	-8,091	-36,379
5%	-11,680	-683,858	-116,615	-40,457	-181,896
10%	-23,359	-1,367,715	-233,230	-80,914	-363,793
20%	-46,718	-2,735,430	-466,460	-161,827	-727,586
30%	-70,077	-4,103,145	-699,691	-242,741	-1,091,379
40%	-93,436	-5,470,861	-932,921	-323,654	-1,455,171
50%	-116,796	-6,838,576	-1,166,151	-404,568	-1,818,964
60%	-140,155	-8,206,291	-1,399,381	-485,481	-2,182,757
70%	-163,514	-9,574,006	-1,632,612	-566,395	-2,546,550
80%	-186,873	-10,941,721	-1,865,842	-647,308	-2,910,343
90%	-210,232	-12,309,436	-2,099,072	-728,222	-3,274,136
100%	-233,591	-13,677,151	-2,332,302	-809,136	-3,637,929



Appendix D

Storage Area Saved with Dwell Time Reduction

- Estimation of the percentage of terminal storage land that can be saved by reducing dwell time by one day from the maximum of 6 days to minimum 0 days.
- Calculation of the maximum land that can be saved at each port from the 20% cargo switch.

STORAGE AREA SAVED - DWELL TIME

TEUs/acre: 1,281

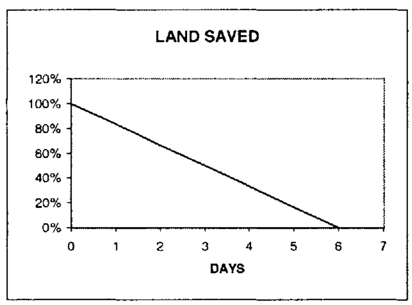
Port	20% cargo Chicago FEUs	TEUs	20% cargo Pittsburgh FEUs	TEUs	TOTAL	acres
BOS	45	90	121	242	332	0.259
NY	2,059	4,118	16108	32216	36,334	28.364
HR	218	436	2015	4030	4,466	3.486
BAL	95	190	2848	5696	5,886	4.595
CHARL	520	1,040	1556	3112	4,152	3.241

$$TGS = \frac{PF}{SH \times 365} \times TEUS \times DWELL$$

Port	Boston	DWELL	required TGS	saved
TEUs	242	6	2.069	0.0%
PF	1.3	5	1.724	16.7%
SH	3	4	1.379	33.3%
days	365	3	1.034	50.0%
		2	0.690	66.7%
		1	0.345	83.3%
		0	0	100.0%

Port	Boston	Port	NY	Port	HR
DWELL	saved area	DWELL	saved area	DWELL	saved area
6	0.000	6	0.000	6	0.000
5	0.043	5	4.727	5	0.581
4	0.086	4	9.455	4	1.162
3	0.130	3	14.182	3	1.743
2	0.173	2	18.909	2	2.324
1	0.216	1	23.636	1	2.905
0	0.259	0	28.364	0	3.486

Port	BAL	Port	CHARL
DWELL	saved area	DWELL	saved area
6	0.000	6	0.000
5	0.766	5	0.540
4	1.532	4	1.080
3	2.297	3	1.621
2	3.063	2	2.161
1	3.829	1	2.701
0	4.595	0	3.241



Term.Size	210000	600000	210000	600000
Acres	19.8	39.5	163.93443	400
TEUs/Acre	10606.06	15189.87	1281	1500
Total Cost	40	108	331.18066	1,097
$m/Acre	2.020202	2.741772	2.020202	2.7417722

Terminal Area that can be saved from 20% modal cargo switch

Boston	NY/NJ	HR	Baltimore	Charleston	TOTAL
0.000	0.000	0.000	0.000	0.000	**0.000**
0.043	4.727	0.581	0.766	0.540	**6.658**
0.086	9.455	1.162	1.532	1.080	**13.315**
0.130	14.182	1.743	2.297	1.621	**19.973**
0.173	18.909	2.324	3.063	2.161	**26.630**
0.216	23.636	2.905	3.829	2.701	**33.288**
0.259	28.364	3.486	4.595	3.241	**39.945**

Appendix E

Annotated Bibliography

This Annotated Bibliography has been submitted to the Technology Scanning Program of the American Association of Railroads in December 20, 2000, as part of a Status Report on "Opportunities for Enhancing the Capacity and Performance of Railroad Terminals." It is a collection of published material on rail terminal performance that covers the major topics:

I. General Transportation Information and Data
II. The container Shipping Industry
III. Intermodal Transportation – Port and Terminal Productivity

I. GENERAL TRANSPORTATION INFORMATION AND DATA

TOPIC: The Marine Transportation System

TITLE 1. U.S. DOT. *An Assessment of The U.S. Marine Transportation System (MTS). A REPORT TO CONGRESS,* September 1999, [1].

DISCUSSION:

The U.S. DOT through the Coast Guard and the MARAD establish a task force to assess the adequacy of the Nation's marine transportation system to operate in a safe, efficient, and environmentally sound manner.

The U.S. Marine Transportation System consists of waterways, ports and their intermodal connections, vessels, vehicles, and system users. Today, the MTS is under pressure from: growing levels of demand, shifting user requirements, such as changes in business practice, changes in freight transportation requirements, and intermodal transportation industry, changing infrastructure needs: technology advances, competing water and land issues, national security needs and awareness for the environment. The task force adopted a vision statement for a desired state of the USMTS in 2020 and proposes strategic areas of action.

COMMENTS:

A general discussion on the critical issues affecting the MTS, plus some transportation maritime cargo data.

TITLE 2. U.S. DOT, MARAD. *Proceedings of the Marine Transportation System (MTS) Research and Development Coordination Conference,* November 2-4, 1999, [22].

DISCUSSION:

The conference focused on coordination of research and development within the marine transportation system. The purpose of the conference was:

- Discuss and assess the research and technology needs for improved MTS management and operation
- Encourage and facilitate coordination among federal and state agencies, industry, academia, and the maritime community in R&D leading to improvements in U.S. marine transportation and the management and operation of U.S. waterways, ports and their intermodal connections

- Discuss the establishment of a national cooperative research programs for the MTS
- Discuss the state of the art in technology and techniques for navigating and managing the nation's coastal and inland waterways, ports and their intermodal connections.

COMMENTS:

Some current technological innovations are presented, such as Information Technology, Information Management (navigation information and cargo flow), future vessels, etc.

TITLE 3. U.S.DOT. *Effective Global Transportation in the Twenty-First Century: A Vision Document. Prepared by "One Dot" Working Group.* September 1999, [23].

DISCUSSION:

This vision document is intended to summarize what a future transportation system might look like in the period around 2020, based on an environmental scan and trend analysis, originally undertaken to support development of the U.S. DOT Strategic Plan and the NSTC Transportation Science and Technology Strategy.

The transportation system of 2020 will be global in scale, and more technically advanced. It will have to accommodate many more users of varying abilities and needs. It will have to be safer, accessible, faster and cleaner. It will have to be much more dynamic and flexible, adapting ti its wide variety of users quickly and efficiently. Advanced research and innovative technologies can contribute to making this vision of transportation a reality.

The challenges and opportunities for the transportation in 2020 are the changing demographics, the economic growth and globalization, urbanization and motorization, safety, and the Information Technology revolution.

TOPIC: National Science and Technology Council (NSTC) Reports

The NSTC developed the Transportation Science and Technology Strategy to help Congress and the Administration establish national transportation research and technology priorities and coordinated research activities. The strategy provided a direction and framework for transportation research and development in a four-tiered approach:

- Strategic Planning and Assessment

- Private –Public Technology Partnerships
- Enabling Research
- Education and Training

TITLE 4. National Science and Technology Council (NSTC). Subcommittee on Transportation R&D. *Partnership to Promote Enhanced Freight Movement at Ports and Intermodal Terminals. A Strategic Plan.* February 2000, [24].

TITLE 5. National Science and Technology Council (NSTC). *National Transportation Science and Technology Strategy.* April 1999, [25].

TITLE 6. National Science and Technology Council (NSTC). *National Transportation Technology Plan.* May 2000, [26].

TITLE 7. National Science and Technology Council (NSTC). *National Transportation Strategic Research Plan.* May 2000, [27].

DISCUSSION:

The subcommittee on Transportation R&D, other NTSC, released its first Federal Transportation Technology Strategic Plan, presenting initial strategies for the private-public partnership that has three goals: (1) improve freight mobility at land borders and ports, (2) ensure the diffusion of freight information technologies and networks; and (3) expedite the global flow of goods.

The partnership promotes national goals for economic growth and trade competitiveness by achieving four key outcome goals:

1. Ensure adequate throughput and intermodal capacity at the nations ports and other intermodal fright facilities
2. Promote advanced multimodal terminals and consolidated cargo-handling hubs and feeder facilities
3. Support the development and diffusion of next generation freight transportation technologies
4. Support interagency efforts to coordinate the development of standard technology protocols, shared information systems, and joint-use military facilities

For each of theses goals this section of the plan presents: (1) an investment strategy, (2) anticipated impacts; (3) critical technology elements; and (4) case studies

COMMENTS:

Case studies, such as the Agile Port, the Alameda Corridor, Container Handling Cooperative Program (CHCP), and FastShip Atlantic show the implementation of sophisticated techniques to intermodal transportation.

TOPIC: Trade and Transportation Data from U.S. DOT Reports.

TITLE 8. U.S. DOT, Bureau of Transportation Statistics, USCG *Marine Trade & Transportation 199,* [7].

DISCUSSION:

This report is a cooperative effort of BTS, MARAD, and U.S. CG to provide comprehensive and relevant maritime-related statistics and information to decision makers at all levels of government and in private industry. It addresses U.S. DOT five strategic goals to promote safety, improve mobility, advance economic growth, protect human and natural environment, and strengthen national security. The report covers major trends in maritime trade transportation and shipbuilding, and reviews the maritime transportation industry's contribution to the U.S. economy, its safety record, and environmental impacts. It also discusses national security, advances in navigation technologies, and key information and data gaps.

TITLE 9. U.S. DOT, Bureau of Transportation Statistics. *Transportation Statistics Annual Report 1999,* [8].

DISCUSSION:

This report discusses the extent and condition of the transportation system; its use, performance, and safety record; transportation's economic contributions and costs; and its energy and environmental impacts. All modes of transportation are covered.

COMMENTS:

Recent data on cargo movements and port sizes. It also addresses some port issues.

TITLE 10. USDOT- Office of Intermodalism. *The Impact of Changes in Ship Design on Transportation Infrastructure and Operations.* February 1998, [11].

DISCUSSION:

This report presents the input received by the U.S. DOT at four regional meetings. The fundamental issue addressed in these meetings was how improving infrastructure links to ports is a critical prerequisite for transportation to function as system. The introduction of larger ships and more international freight are carefully examined. Also

detailed data on container market and industry's trends, with the next-generation vessels, terminal design and equipment issues, landside access and implications for future improvements are presented in the technical appendix
COMMENTS:

The Technical Appendix presents very detailed information on the introduction of megaships and their consequences for market and impacts on infrastructure, analyzing the terminal design parameters.

II. THE CONTAINER SHIPPING INDUSTRY

TOPIC: The Container Trade. Market Structure and Data.

TITLE 11. H.S.Marcus, J.L.S.Byrnes. *A perspective on Liner Strategy and the Containership Charter Market.* MIT August 2000, [2].

DISCUSSION:

This paper presents an overview of the containership industry with particular emphasis on those factors that affect the carrier's corporate strategies. A brief history and the changes in the industry over time, the interrelationships between strategy and technology, a look at the future technology is given. The impact of liner strategy and technology on the containership charter market is described. As the ship technology and liner strategy have changed over time, the viability of a charter market for containership has increased.

The future will provide changes in technology and possibly in the role of governmental subsidies. In addition the trend to mergers and alliances will continue. The confidential rates allowed by the Ocean Shipping Reform Act will facilitate the creation of partnerships between shippers and carriers.

COMMENTS:

A detailed overview of the structure and the background development of the container market.

TITLE 12. Drewry Shipping Consultants Ltd. *Container Market Outlook.* October 1999, [3].

DISCUSSION:

World Container Trade continues to grow at rates 8-10% annually. But this growth has become much more imbalanced. However, container shipping remains an industry with problems and low profitability. The OSRA 98 deregulation has prompted an over-reaction in rate cutting, along with the overcapacity will keep rates to low levels. Major trends the wave of mergers and the building of mega-containerships. The data for 1998 presented a bleak year for carriers. Drewry's forecasts for the near future also reflect continuing problems for ocean carriers.

COMMENTS:

Detailed data and forecasts for the containership market.

TITLE 13. M.L.Chadwin, J.A.Pope, W.K.Talley. *Ocean Container Transportation. An Operational Perspective.* Taylor & Francis, 1990, [13].

DISCUSSION:

Much of this book focused on the problem of optimizing efficiency in the movement of ocean containers. The book is organized into three parts. The first focuses on marine terminals, describing how a marine container terminal functions, presenting techniques for allocating the cost of terminal operation, and describing operational problems. The second part focuses on containerships and the third considers ocean container transportation and intermodalism.

COMMENTS:

Description of the terminal operation and an economic cost capacity model are presented.

III. INTERMODAL TRANSPORTATION – PORT & TERMINAL PRODUCTIVITY

TOPIC: PORT PRODUCTIVITY

TITLE 14. Jaehyunk Auh. *Port Productivity Change of Container Terminal in Port of Boston.* MIT April 29, 1998, [28].

DISCUSSION:

Port productivity can be roughly defined as the extent of outcomes for a given input for handling the cargo. There are three components: input, system, and output, which are all hard to define. Previous efforts in measuring port productivity include De Neufville, et al. (1981), the measurements of the Committee on Productivity of marine Terminals (1986), and Talley (1994). These theories are applied with real operational data (cargo handling) from the years 1993 to 1997 for the two terminals in the port of Boston. The results have shown the changes in port productivity, and the factors that causing them. Also the problems are indicated and solutions are proposed. The author suggests that more comprehensive research should explore:

- The development of a simple and practical productivity indicator.
- The application of the theory of a factory productivity measurement.
- Supplement of the port productivity measurement with computer simulation techniques.

COMMENTS:

This research comes with a general overview of the container port operation and the importance of measuring port productivity in container terminal operation. Although it just presents some aspects of container terminal operation, it gives an idea of improving the total port productivity. For the future, it is very important to develop a methodology to incorporate diverse productivity statistics into one or two simple productivity indicators.

TOPIC: CONTAINER TRACKING

TITLE 15. H.S.Marcus, J.Sussman, J.D.Nyhart, M.Wolfe, J.Auh, K.Sandven. *Improving the Movement of Marine Containers: The Role of Smart Identification Tags*. MIT, June 2000, [29].

DISCUSSION:

This research report describes the business strategies that potential entrants into container tracking market can follow, based on current market structure and technology trends. Three strategies are presented here: Transponder Manufacturer (TM), Tracking Service Provider (TSP), and Total System Integrator (TSI). Michael Porter's Industry Structure Analysis methodology is used to provide more insight in the competitive analysis involved. Each strategy has its own strengths and weaknesses. Also, the three strategies are interrelated. Careful evaluation will be needed in order for the potential market entrants to be successful in the future.

The size of the chassis and container tracking markets for the future are discussed, with emphasis on the U.S. The discussion includes an overview of potential markets, qualitative characteristics of the market evolution, and estimation of market size.

There are two types of customers for better container tracking information. One is the transportation operator (e.g., ocean carrier, trucker, railroad company), or a terminal operator. The other is the shipper, whose concern is the cargo inside the container. Shippers include the beneficial owners of the cargo -- manufacturers, distributors, and retailers—and their agents, such as freight forwarders or 3rd party logistic companies that coordinate the cargo transport from the shippers to the final consignees.

Customer benefits fall into three categories: (1) Efficiency and Productivity, (2) Service Quality, and (3) Shipment and Service Integrity. We provide a discussion of each category of benefit. In some instances the potential benefits are too difficult to quantify or are too dependent on company-specific characteristics. Benefits are described qualitatively. Where possible, a break-even calculation is performed to show how much operational improvement is needed to pay for the added cost of tracking equipment.

General conclusions to date include:

- There is no doubt that AIT will play a larger role in the international movement of marine containers in the future. The smart data carrier industry will be a strong and growing one for years to come.
- While the number of ID technologies being introduced and developed continues to grow, we expect to see a shake-out in the future. Any shake-out will be to the advantage of low cost, high quality manufacturers.
- No one has yet fully integrated a container tracking system for the international movement of marine containers. There are definite potential business opportunities in this area.
- There is an industry resistance to change that makes ocean carriers reluctant to be the first one to make a major investment in a door-to-door container tracking system in international commerce. However, we feel that these barriers will be overcome in the near future.
- Putting a satellite-tracking unit on the container is not the only possible solution. Another alternative is to place the satellite-tracking unit on the chassis and use a simpler technology to match the container to the chassis.

TOPIC: INTERMODAL TRANSPORTATION

TITLE 16. U.S. DOT, ITS America. *Intermodal Freight technology Workshops "Advanced Freight Alliances"* Document Compendium July 7, 2000, CD-ROM, [30].

DISCUSSION:

In 1998, U.S. DOT and ITS America initiated the development of a collaborative forum to address the needs of this diverse intermodal community, and to investigate the applicability and viability of emerging technologies to the movement of intermodal freight. In June 1998, the first *Intermodal Freight Identification Technology Workshop* was held with participation from a broad cross section of public and private sector stakeholders. At this first workshop the participants sought to identify opportunities for collective benefits through technical interoperability and institutional partnerships. The principal recommendation from the participants was the establishment of the Intermodal Freight Technology Working Group (IFTWG), made up of a broad-based group of industry representatives, to coordinate the action agenda from the workshop: build the cost/benefit case for more coordinated use of intermodal technology explore the feasibility of identifying a common set of information to be shared across modes to facilitate the transfer process without delaying freight shipment conduct impartial analyses of whether specific technologies are cost effective, improve utilization or efficiency, and/or add value to customers that could generate additional revenue or efficiency improvement.

The IFTWG has pursued three major initiatives since the last workshop. The first is mapping a representative end-to-end intermodal freight business process based on private sector inputs. The business process map includes functions, stakeholders, assets and data flows. The remaining two initiatives are technology scanning and operational technology demonstrations.

The ability of the industry to successfully respond to the challenges facing it today will depend on collaborative endeavors. The key stakeholders, public sector, shippers, carriers, technology providers and intermediaries each bring unique perspectives that must be accommodated. A number of public/private initiatives are helping to communicate a common understanding leading to these collaborative endeavors. Based on this shared understanding, the outcomes promote the common good and ultimately provide real value to individual companies. With a better understanding of industry operations, the public sector can be more effective in setting policies. Shippers functioning in a global economy can be more sophisticated in managing their supply.

TOPIC: PORT LANDSIDE ACCESS

TITLE 17. R.L.Walker, J.S.Helmick. *Port Access and Productivity: A Systems Approach.* Ports'98, Vol.Two, American Society of Civil Engineers, [31].

DISCUSSION:

The movement of international freight in today's trading environment requires a competitive logistic system that emphasizes quality of service and lower total logistic costs. The importance of such a system lies in the strategic value of its operation, in which freight moves through an integrated origin-to-destination "pipeline". Liner ports and terminals are pivotal links in the freight logistics chain.

Intermodal performance involves not only elements of physical terminal productivity but also dimension such as quality of service. Vital tasks in managing the multiple facets of terminal productivity are to identify bottlenecks in the flow of cargo and to resolve inefficiencies that impair the functioning of the logistic "pipeline". Sometimes this can be done not by the land expansion, but by effective management of the existing facilities with the introduction of new technologies such as Electronic Data Interchange (EDI), and Automatic Equipment Identification (AEI) systems.

Several initiatives have emerged to elevate the consideration of freight mobility at all levels of government and in private sector. Two examples include the U.S. DOT National Freight Partnership (NFP) and the Intermodal Freight Transportation Coalition (IFTC). The national Commission on Intermodal Transportation, mandated by Congress in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) also identified access to ports and marine terminals as a critical issue. The USDOT continues to encourage and support public-private partnerships to address financial resource requirements for large corridor initiatives such as the Alameda Corridor project.

As we approach the 21st century, ports and terminals will continue to be pivotal links in the freight logistics chain. Adequate landside access that supports seamless connections to surface transportation will impact port operations and productivity. The challenge is how to address and fund critical port and terminal infrastructure, including landside and waterside access, to maintain an efficient and competitive logistics system.

TOPIC: PORT FUNDING

TITLE 18. D.Luberoff and J.Walder. *U.S. Ports and the Funding of Intermodal Facilities: An Overview of Key Issues.* Transportation Quarterly, Vol.54, No.4, Fall 2000, [32].

DISCUSSION:

Due to economies of scale, the growing use of containers to move freight had led carriers to use fewer but larger ports. In their efforts to attract and retain carriers, U.S. ports have made or are planning substantial investments. The current port financing system –relied on balance-sheet financing and direct public subsidies – could create several problems by leading to less-than-optimal use of public resources and underestimating risk.

As an alternative true-project based financing shifts risk from public to private entities and leads to improved decision-making about investments in intermodal facilities. The paper provides an overview of the on the changes in container shipping industry, examining how these changes affect ports, detailing how ports have responded, and examining the current funding system the authors suggest some alternative funding models. Ports should move toward true project-based financing mechanisms. Private equity investors might also undertake the construction and operation of those facilities.

TOPIC: MANAGEMENT INFORMATION SYSTEMS IN PORT TERMINALS IN AUSTRALIA AND ASIA

TITLE 19. J.Behera, C.Bhuta, and G.Thorpe. *Management Information Systems: An Overview of Practices at Marine Container Terminals in Australia and Asia.* Transportation Quarterly Vol.54, No.4, Fall 2000, [33].

DISCUSSION:

This paper presents the results of a survey on the correct use of management information systems at major container terminals in Australia and Asia. Management information systems have played a major role in improving the productivity of container handling operations at marine container terminals. The full implementation of information systems not only increases the capacity of terminals, but also reduces the need for investment in infrastructure, particularly storage facilities in yard areas.

Internal pressures common to all container terminal operation business include the need to stay competitive, reduce operating costs, specifically labor, improve profitability, and provide better management information. External pressures are the need to improve the quality of service provided, as well as the increasing requirements for all forms of electronic communication with all the stakeholders. Satisfying these demands requires effective management information systems.

The survey used a questionnaire, sent to 17 container terminals in Australia and 48 in Asia. The results have shown that although the introduction of management information systems has brought about significant advantages in terms of speed, and cost, their application is limited to larger capacity terminals. For example, half of the terminals in Australia and one sixth of the Asian, with handling capacity less than 10,000TEUs per month, do not have computer-integrated operating system. Taking advantage of modern management information systems requires the active participation and integration of all parties involved in container terminal operation and should be considered a primary policy goal of management. Because labor costs are rising and container traffic sizes as well as complexity of problems are increasing, the productivity of container terminals must improve.

TOPIC: INTERMODAL TRANSPORTATION TECHNOLOGY

TITLE 20. Carl D.Martland. *Technological Options for the Intermodal Transportation.* Prepared for the CIT/MIT Cooperartive research Program, July 1996, [34].

DISCUSSION:

The paper provides an overview of intermodal freight operations, focusing on options for transporting trailers and containers by rail and truck. The potential of intermodal transportation lies in the superior level of service that provides by taking advantage of the best features of each mode, and in the reducing of externalities associated with transportation. However, the dominant theme is to minimize the total logistic cost for customers. A comparison between truck and rail makes the rail more attractive for the longer hauls 800-1000 miles. This inherent line haul advantage termed as "gross intermodal advantage" or GIA is offset by the cost of assembling and disassembling the train, i.e. the terminal costs.

Every sector of the intermodal technology – containers, terminals, and trains- is examined for technological option it provides. Certain characteristics for terminal access and location are proposed. The role of information technology in intermodal transportation is also important, addressing systems to reduce the paperwork and processing time and customer service systems. Intermodal transportation offers an opportunity to improve the efficiency and environmental impacts of the overall transportation system through the coordinated use of two or more modes.

The major problems related to intermodal facilities are as follows:

- Efficient operation of low volume intermodal freight terminals
- Increasing the throughput of and the level of service provided by high volume intermodal freight terminals
- Increasing the efficiency of the drayage system
- Location and construction of new intermodal freight terminals
- Limited capacity on certain critical rail line segments

Specific research opportunities are as follows:

a. System Issues:

- Theory of location, size, design, and scope of intermodal freight terminals
- Demonstration of the "optimization" of intermodal terminals through the use of the best available technologies
- Determination of better ways to balance time and terminal capabilities

b. Specific Technologies:

- Development and deployment of advanced rail line control technologies, including "positive train separation" and "advanced train control systems".

- Continued evolution of intermodal freight equipment in response to market forces

c. Basic Research on enabling technologies
- Development of stronger, lighter, more durable materials for intermodal equipment

TOPIC: FREIGHT TERMINALS

TITLE 21. Summary of Selected Presentations to the MIT CTS Affiliates Seminar. *Freight Terminals: Operations and Customer Service.* February 12-13, 1997, [35].

DISCUSSION:

This paper summarizes five of the presentations, given at a seminar on freight transportation, on February 1997, sponsored by the MIT Center for Transportation Studies. The first four presentations provide insights into LTL terminals, a UPS air hub, and rail freight classification yards. The final presentation provides some comparisons and conclusions about the role of terminals as related to customer service.

1. *Terminal Operations – LTL Freight.*
   John Braklow, Director, Operations and Network Support, Yellow Freight Systems

The yellow freight Systems has a hub and spoke structure, where terminals at the hubs are distribution centers and the terminals at the end of the spokes are end of line EOL terminals. Location and size of terminals are determined appropriately. Shipments are moved manually within small terminals, but large ones use automated movement systems, e.g. drag lines and conveyor systems. They use bar codes on shipments and the system knows the location of all trailers. With such capacity control, there is considerable flexibility in routing and scheduling.

2. *Flexible Intermodal Operations at UPS Air Hubs.*
   Jack Blaisdell, Plant Engineering Deployment Manager, UPS

To deal with the capacity concerns UPS undertook a 3-month design study for upgrading the Louisville Hub. The issues that were crucial were: better balance of geographic distribution, minimizing the cost per piece, flexibility, minimizing the knowledge required for sorting, and accommodate wide variances of flows.

3. *Meeting the Demands for Terminal Capacity through Continuous Improvement.*
   Arno Dimmling, VP Terminals, Sea Land

Dimmling described Sealand has achieved substantial improvements in terminal operations through a continuous improvement process. To illustrate differences among terminals, he contrasted the Sea Land terminals in Hong Kong and in Elizabeth, New Jersey. With 20% of the berths and land area and only 60% of the cranes, Hong Kong handles traffic volumes equivalent to what is handled in Elizabeth, NJ. Sealand used a 10-step process to improve terminal performance. They focused on the 52% of terminal costs that were controlled within the terminal. They then proceed into a very detailed analysis of each process, identifying the best practices. The end result was the significant improvements in key terminals. Gantry crane productivity for all North American terminals rose from low 20s to 30 gmph.

4. *Rail terminal Capacity Analysis and Corridor Planning.*
   Richard Gray, Director operations analysis, Union Pacific Railroad

At UP, transportation planning has focused on five critical resources: line capacity, terminal capacity, power utilization, crew utilization, and car utilization. Concentrated planning efforts are underway under by the Network Planning group that addresses corridor planning (linkages among terminals), resource capabilities (terminal capacity), and terminal optimization (dwell minimization). The desired result is an achievable operating plan and the best use of resources.

The planning process first applied in 1995 to a new hump yard in Livonia, MI, and provided a 5-6 hour reduction in the planned car dwell time at each terminal. Actual performance so far has been even better than the planned reduction.

5. *Terminals and Customer Service.*
   Carl Martland, Senior Research Associate, MIT Dept. of Civil & Environmental Engineering.

Several points can be made relative to customer service:

1. Terminals are critical to customer service.
2. Specialized demands cause terminal operating problems.
3. A focus on utilization and terminal productivity is not the same as a focus on customer.
4. The conditions faced by the different modes vary widely.
5. Market segmentation is critical, and the container dwell times are very long.
6. The key to automation may be in revamping the supply chain, not in automating the traditional terminal operations.

TOPIC: PERFORMANCE IN U.S. FREIGHT TRANSPORTATION

TITLE 22. FHWA, Office of Freight Management and Operations. *Performance Trends in U.S. Freight Transportation,* [36].

DISCUSSION

Over the past two decades, freight transportation has been a leading factor in terms of productivity improvements. Technological, institutional, and structural changes have allowed the industry (if not all carriers) to remain profitable while changing lower prices in current dollars.

However, there are disturbing signals that the industry will have difficulty in sustaining its impressive productivity gains. Capacity is a great concern. Rising costs pose another problem. Finally, technological opportunities today seem to be less promising than they were 25 years ago. Information Technology certainly offers the most opportunities.

This is not to say that the industry cannot improve its productivity. The point is that problems are emerging, and new public and private strategies may be necessary to identify and follow a new path toward productivity.

Looking over the past 20-30 years for example the U.S. Rail Industry benefited from productivity improvements from the shift to heavy haul operations with bigger cars and more unit trains, from network rationalization and reductions in track costs, from reductions in clerical costs and reductions in crew, and finally from improvements in fuel efficiency.

These productivity improvements resulted in general from using cheaper or better inputs to provide the same or increased output. A Discussion of Potential Problems in Achieving Further Productivity Improvements according to FHWA should include:

1. New sources of productivity improvement
2. Concern about the Capacity growth
3. Overcoming Congestion
4. New approaches to Local Distribution
5. Expanding Role for the Railway Network
6. Railroad Rationalization will continue – But toward what end?
7. Vehicle design
8. Role of the Third-Party intermediaries

The report concludes that capacity and costs are likely to become more serious problems in the near future. The freight industry cannot live off past investments, and major capacity additions will be needed to keep up with freight demand. Economic trends in labor, fuel, and capital costs that were favorable appear to be reversing.

TOPIC: OPERATIONS RESEARCH IN RAILROAD INDUSTRY

TITLE 23. Carl D.Martland. *Modeling & Managing Railroad Terminal Performance.* Presentation to the Rail Applications special Interest Group INFORMS, November 5, 2000, [37].

DISCUSSION:

The presentation provides a rough catalog on state of terminal modeling and performance evaluation in order to provoke a discussion for Operations Research (OR) approaches to Railroad Industry. Currently the railroads do not use OR in managing terminals and OR practitioners focus more on mechanics (routing and scheduling simulation). However, there is a major role in understanding, monitoring and improving terminal performance. The elements of terminal performance include cost, service quality, capacity, velocity, safety, and environment. Each element is examined separately. Improvement in terminal performance can be achieved by rationalization of facilities, introduction of new technologies, better planning, and better control. The role of OR is in:

- Clarifying the objectives
- Understanding performance: estimating levels of cost, service, and utilization
- Service design and operations planning: car scheduling, yard performance.
- Capacity planning: the yard facilities that are needed
- Real-time decision support.

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