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Double-stack unit train container service: its commercial impact and value to the military skipper

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DOUBLE-STACK UNIT TRAIN CONTAINER SERVICE:
ITS COMMERCIAL IMPACT AND VALUE TO THE
MILITARY SHIPPER

by

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DD FORM 1473, 84 MAR   83 APR edition may be used until exhausted. All other editions are obsolete   SECURITY CLASSIFICATION OF THIS PAGE provided an early opportunity for a thorough review of its development, the impact upon the containerized freight industry, and the stack trains' potential value to the military.

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Double-Stack Unit Train Container Service: Its Commercial Impact and Value To The Military Shipper

by

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ABSTRACT

Double-stack container train service was successfully introduced in 1984 and has expanded rapidly since. The newly designed five-platform articulated well railroad car serves as the vehicle. Space-age computer-assisted design has helped to engineer a radical departure from conventional railcar configuration and produce significant weight and rolling resistance reductions. Commensurate with introduction of this new generation of equipment, the ocean carriers and railroads have developed new cooperative train scheduling procedures and container railcar handling methods. Additionally, the higher volume of containers per stack train has forced a redesign of railyards and marine terminals. Opportunities for unique military application of stack train technology and possible container rate reductions await the military transporter. The expedient maturation of stack train technology has provided an early opportunity for a thorough review of its development, the impact upon the containerized freight industry, and the stack trains' potential value to the military.

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I. INTRODUCTION

A. BACKGROUND

A sweeping change has manifested itself in the manner in which ocean carriers and railroads are conducting business, best embodied through examination of the new railroad double-stack unit train container service first successfully introduced by American President Lines in April 1984.

Innovations in intermodal cooperation, service contracts, new rolling stock, and container handling methods create the demonstrated potential for container rate reductions, more prompt and reliable service, less shipper involvment, and improved shipment traceability through door-to-door service and shorter scheduled train transit times.

Sufficient progress has been reached over the past two years to enable a thorough examination of the state-of-the-art operations of double-stack trains by the railroads, ocean terminal operators, and ocean carriers. Consequently, its present and future impact on the military shipper can be assessed. Further, military service applications will be explored in view of the unique double-stack equipment technology.

B. OBJECTIVES

The main objective of this thesis is to rigorously acquaint the military transporter to the new double-stack train industry, and to the new service procedures, container handling processes, and business arrangements that have accompanied its introduction. In so doing, a comprehensive description of the innovations in railroad operations, terminal operations, coordination between railroad and steamship lines for both service and contractual arrangements, and equipment design will be presented. Implications for the military shipper regarding feasibility of unique service application for stack equipment and container rate reductions will be reviewed. Peripheral issues such as railroad track wear will also be addressed.

C. RESEARCH QUESTIONS

Implicit to the aforementioned issues, the following primary research question has been postulated:

What is double-stack unit train container service, how has it developed, and what unique service applications and potential for container rate reductions appear feasible?

Secondary questions pertinent to the subject include:

1) How is double-stack container train service different from conventional container-on-flatcar (COFC) service and what efficiencies does it provide operators and shippers?

2) What service applications and container rate reductions are foreseen utilizing the unique advantages of double-stack unit train container equipment and service?

3) What service handling and equipment changes have taken place and are planned at railroad yards and ocean terminals to best take advantage of double-stack container unit trains?

4) What effect has double-stack container train service had upon competing transportation modes and what coordination cooperation has evolved between them?

D. SCOPE

This case study will examine the development of double-stack unit train container service to date; its impact upon the manner in which railroads, ocean carriers, and ocean terminals conduct business; and its current and projected impact upon the shipper. Also, military applications of the new types of equipment fielded by the railroads will be researched.

The scope will include double-stack train effect upon rates, service, cargo traceability and loss and damage, container handling procedures, and market niche (limited to non-proprietary and unclassified data).

Existing rail costing models may be applied as necessary. No attempt will be made to develop any new empirical container rate structure, but it will seek to identify any obvious changes in container rates wrought by the economies of double-stack trains.

E. ASSUMPTIONS

It is anticipated that the character of this study will remain general enough to provide thought provoking reading for a broad audience. However, limitations prevent expanding the background to encompass a review of the entire intermodal freight transportation industry. Naturally, the greatest benefit will be to the military transporter with some foundation in container cargo movements.

F. METHODOLOGY

Accumulation of data for the double-stack container train industry will include a comprehensive review of published literature with complementary telephone and personal interviews of representatives in the ocean carrier, ocean terminal, and railroad companies.

The impact of double-stack technology upon military cargo container rates will be assessed through analysis of the MSC Container Agreement and Rate Guide and through interviews with MSC contracting personnel and ocean carrier government sales representatives.

Equipment manufactures will be solicited for engineering data concerning equipment capacities and service specifications. Future technological innovations will be reviewed as well as possible adaptation of equipment for unique military applications. The Transportation Engineering Agency (TEA) of the Military Traffic Management Command (MTMC) has provided their plan for research efforts involving double-stack railcars.

Published information will be limited to non-proprietary and unclassified data.

G. ORGANIZATION

This thesis incorporates nine chapters. Chapter II provides general background regarding legislative developments, market forces, and the intermodal industry. Chapter III will discuss the embryonic development of the double-stack concept by the ocean carriers and railroads. Chapter IV will describe the introduction of the double-stack service and the current double-stack network. Chapter V will thoroughly describe available stack equipment, the differences between competing brands, and their advertised cost-saving features and potential for further improvement. Chapter VI will describe and interpret a representative exempt rail transportation agreement. Chapter VII explores military service considerations. Chapter VIII investigates terminal efficiency as it relates to double-stack service. Chapter IX presents a summary, conclusions, and recommendations.

II. INTERMODAL INDUSTRY BACKGROUND

A. INTRODUCTION

A burst of technological innovations has swept the intermodal freight industry in the past five years, one result of which has been the successful introduction of articulated container-on-container railroad train cars. Figure 2.1 provides a representative comparison between conventional trailer-on-flatcar (TOFC), conventional container-on-flatcar (COFC), and the new double-stack COFC.

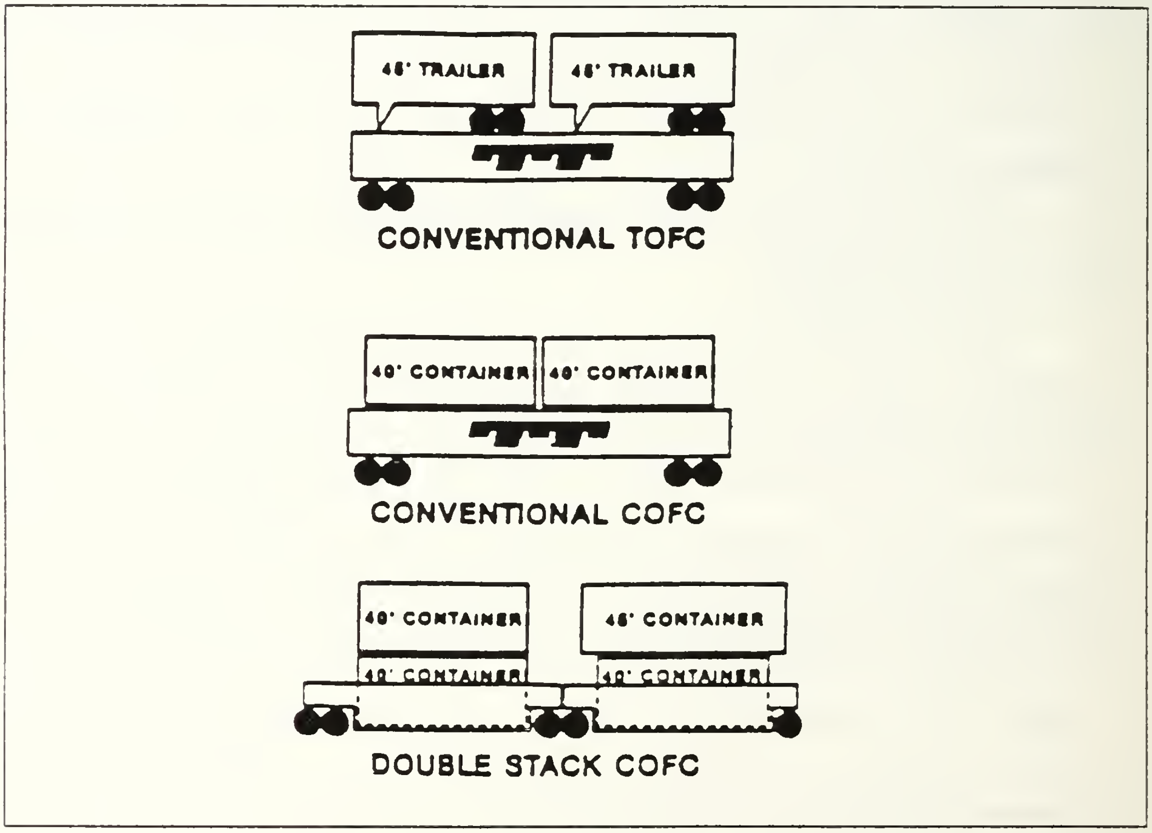

Figure 2.1 Intermodal Configurations.

This equipment, operated in unit trains of 20 cars hauling 200 containers per trainload, is being initiated with increasing frequency by railroads in high-volume corridors for both scheduled and nonscheduled service, and also both in fixed contract movements for ocean carriers or direct retail hauls for commercial shippers. Transit times are tightly managed and unit train movements are flexibly coordinated directly to vessel sailings with steamship line representatives and thereby avoiding interchange delay. Dramatic fuel savings of 20 to 40 percent have been reported with significant overall operating cost reductions resulting from union labor concessions and equipment efficiencies. The dramatic expansion of double-stack container service since April, 1984 has had a noted impact upon all aspects of intermodal container service to U.S. shippers, both import/export and more recently in domestic container freight traffic development.

The implications for the shipper and the industry from just this one evolution are so great as to engender investigation of new opportunities for the military shipper/logistician into discounts for existing service, new and faster service, and unique service applications resulting from double-stack train equipment features.

Because double-stack train service is a recent development (American President Lines first introduced successful coast-to-coast double-stack service with the Union Pacific Railroad in April 1984), comprehensive literature is just at this time reaching print. Because a large segment of military transportation personnel have had little opportunity to familiarize themselves with double-stack container trains this justifies a primer covering the background, existing service, and potential for unique military applications of the container-on-container articulated well train industry. A major postulation will be supported by this review that interprets the host of technological and procedural innovations surrounding double-stack train service as having been brought about through analysis of the traditional transportation system from new angles and enactment of enlightened legislation. In other words, the precept being promoted here incorporates the belief that, through enabling legislation, the spontaneous introduction of double-stack container service has acted as a catalyst in innovative thought and helped open the door for other complementary and novel container handling procedures and business concepts (cycle loading/unloading of containers at railyards, improved telecommunications between ocean carriers and railroads, shifted emphasis upon coordination of larger container unit trains toward vessel sailing schedules, etc.).

Ready acknowledgement is paid to the fact that the double-stack container boom has mushroomed so in the past two years as to make any comprehensive review dated literally within weeks. This treatise can best serve the reader as background, definition, and fertile material for creative thought. As such, this chapter is intended to provide both an explanation of legislative origin and industrial equipment evolution to steer the reader into a better understanding of the intermodal container segments of both the railroads and ocean carriers.

The intermodal container industry has developed as an entity all its own, crossing all transportation modes in a vertical integration effect. A feeling for this maturing segment of the international transportation industry strongly complements an understanding of recent stack train activity.

A note at this point about terminology is in order. Twin-stack, double-stack, Lo-Pac 2000, Fuel-Foiler, two-tier, Twin-Pak, and container-on-container are just some of the industry nomenclature or brand names gaining popularity for describing the stacking of one container atop another onto a redesigned, articulated, well flatcar or skeletonized railcar. Of these, it seems double-stack has been adopted most readily by the press as industry terminolgy. The sensitivity of many equipment manufacturers and intermodal service companies towards association of their product or service to one or more of these terms is acknowledged. However, without discriminatory or promotional intent, the term double-stack, as popularized by the media, will hereinafter generically describe the act of placing one container atop another onboard a railcar.

B. EARLY INTERMODAL EFFORTS

In order to properly understand the developments surrounding the evolution of the double-stack concept in the 1980s, a comprehensive background review is necessary to focus upon those events leading up to the introduction of the stack train. The discusion in this section draws heavily from John H. Mahoney's publication, Intermodal Freight Transportation, as prepared in 1985 for the ENO Foundation For Transportation, Inc. in Westport, Connecticut. [Ref. 1]

The double-stack train concept is an extension of the intermodal, container revolution that gained popularity in the 1950s. Interestingly, the first recorded carriage of freight by intermodal truck trailers on railroad flatcars was in 1926 on the Chicago North Shore and Milwaukee Railroad. Piggyback services, as both container or truck-on-flatcar services were then called, grew slowly but steadily until the middle 1950s, when the pace quickened. The development of long-haul rail-truck intermodality was hampered between the 1920s and the mid-1950s by the growing rail-truck competition for long-haul traffic and by inflexible government regulations. The present expanding intermodal operations are attributed to the relaxation of regulatory restraints beginning in the mid-1950s.

In addition to the parochial attitudes of the railroads and the aggressive over-the-road truck competition, the Interstate Commerce Commission (ICC) in 1931 issued a decision to a container service case which placed an additional roadblock before faster rail-motor intermodal development. The decision required that rail rates for intermodal containers be related to the class rate structure in that it required no container move at less than the carload rate or more than one class lower than the any-quantity basis applicable to the commodities in question. The carload rate on the highest-rated commodity would have to be applied to the whole containerload if it was higher than third class. Plus, varying rates with minimum weights in the 4000 to 10000 pound range were prohibited. This effectively put a floor under piggyback rates and made rate calculation much more complicated. The final act limiting intermodal development was a 1935 Association of American Railroads (AAR) resolution against through routes and joint rail-truck rates except where such arrangements would not constitute invasion of another railroad's territory.

A major precursor to stack train technology was the introduction of piggyback trailer-on-flatcar (TOFC) and container-on-flatcar (COFC) service. Development of TOFC service remained tentative as the New Haven Railroad petitioned the ICC in 1953 for a declaratory judgement on the legal status of piggyback services in many of its ramifications. In the spirit of The Transportation Act of 1940 which recommended ". . . developing, coordinating, and preserving a national transportation system . . .", the ICC issued findings in 1954 that generally favored piggyback development as an intermodal instrument. It found that through rates and joint rates between railroads and motor common carriers were permissible and further delineated the roles of railroads, private carriers, contract carriers, freight forwarders, shippers, and others in relation to piggyback carriage.

Five major piggyback plans eventually developed from these ICC actions. In 1955, the Pennsylvania Railroad inaugurated a Plan I type service (railroads line-haul motor carrier's trailer with no shipper/railroad contact) for trucklines. Plan II service (railroad service at rates competitive with motor carrier rates) was also authorized. Plans III and IV service (less complete services involving flat rates per trailer regardless of contents), useful mostly to freight forwarders, were not cleared until 1962 by affirming decision of the Supreme Court. In 1964, the ICC issued Ex Parte 230, a new set of rules clearly delineating the five plans, declaring I and V to be "joint intermodal" and II, III, and IV as " open tariff ", permitting the latter's use by all types of carriers and shippers. The railroads' challenge to the "open tariff" aspect was denied by the Supreme Court in 1967 and, thereupon, piggyback service plans were solidified and became one of the developmental cornerstones leading to the eventual introduction of stack trains.

In the business arena, a major milestone occured in 1956 as the Trailer Train Company began railroad car leasing operations. A major catalyst in the ready availability of flatcar rolling stock for TOFC/COFC operations, Trailer Train presently operates approximately 120,000 cars for use by most railroads and aggressively pursues development of new rolling stock technology, such as articulated and stand-alone well flatcars.

Another cornerstone to stack train development occured on April 26, 1956, when a converted tanker carrying 58 trailer vans on its specially adapted decks, sailed from Newark, New Jersey to Houston, Texas, thereby touching off the container revolution. Actually, this event demonstrated three principles necessary to support an industry that incorporates large-volume unit movements of containers by rail. These included movement of cargo in standardized containers, oceanborne movement of containers, and efficient land-sea interchange of containerized cargo. Malcom Mclean, a trucking executive, used the operating rights of the Pan Atlantic Steamship Corporation as his medium to support, in 1956, the initial sea-land experiment. The service was successful from the beginning. At the outset he used converted tankers, the Ideal X and the Alema, each with a capacity of 58 20-foot containers. The fleet was soon expanded by two more converted tankers. In 1957, the company took delivery of the first ten containerships, each with a capacity of 226 35-foot containers and equipped with ship mounted cranes. The company name subsequently changed to Sea-Land Services. Today Sea-Land Services is the world's largest containership line.

Moving from the demonstration phase to institutionalization was another matter indeed. The U.S. Navy's Military Sea Transport Service (MSTS) began experimenting with 6x6x6-foot steel containers for military shipments on commercial vessels shortly after World War II and quickly developed as a result of the Korean War. these military containers were referred to as container express boxes, or more popularly as CONEX boxes. By 1967 there were over 100,000 CONEX containers in use worldwide, and the success of this system led to later development of intermodal ocean containers.

During the 1950s almost every major steamship line invested in containers similar to CONEX containers. However, containerized shipments constituted only a very small fraction of the load on any one sailing. Containers ranged in size from approximately 250 cubic-foot to approximately 500 cubic-foot capacity. Leasing firms, such as CONTRANS, invested in these square shaped containers and steamship lines employed them mostly on a pier-to-pier basis, not intermodally.

The CONEX box reached its peak popularity in 1965 and then, except for military use, faded rapidly, being replaced by the standard 8x8x20-foot dry cargo intermodal container. It is used as a basic measuring stick in many statistical comparisons and is referred to as a TEU, a twenty-foot-equivalent-unit. An 8x8x40-foot container is equal to two TEUs.

The land-sea intermodality aspect progressed slowly, mainly as a result of competitive animosity between land and sea modes combined with institutional lethargy. Intermodality was confined primarily to local pickup and delivery of containers by trucks. Even though trailers were hauled by TOFC in the early 1960s, the individual shipments were rehandled at truck terminals, railroad pier stations, or steamship piers. Few unitized shipments went overseas intact until transatlantic container service mushroomed in the later 1960s.

One major obstacle to containerization was the heavy initial investment in containers, vessel conversion, and terminal facilities. Full cost savings could only be achieved through uncompromised fully converted containership operation. The subsidy system did not encourage U.S. ocean carriers to make capital investments for profit enhancement. The United States shipbuilding subsidy program was based on potential ton-miles produced per dollar spent, rather than on operating efficiency or profitability of ships produced. As a result the program continued to crank out obsolete breakbulk vessels long after the container revolution had proven its point. Labor unions fought containerization because of the negative impact upon the total number of future union jobs.

Conference carriers, were especially insulated from any new ideas. The framework within which they operated was a share-of-the-market allocation system among themselves. Having operated on a subsidized basis within this allocation system for many years, they had dispensed with research and planning departments as unneeded, and therefore did not have an internal alarm system that might have alerted them to the need for change. Successful containership operators currently engage in "load-centering", or limiting the number of ports of call, funneling the freight through just a few major ports, and serving other ports by local land or sea connecting carriers.

In the 1960s, though, load-centering would have altered the conference's established share-of-market allocations, thereby pitting conference members against each other in an unwelcome competitive struggle.

Additionally, the conference rate-making system was based on commodity rating, which allowed the conferences to set prices on the basis of "what the traffic will bear". Containership pricing, by contrast, is based on a flat per container or per ton rate, regardless of the commodities packed inside of the containers. Because conference carriers felt their margin of profit came from the high-rated commodities, it was difficult for them to accept the possibility that lost revenue from this source would be offset by the efficiencies of containership operation.

However, in early 1966, Sea-Land Service inaugurated the first transatlantic containership service, and by 1973 virtually all transatlantic trade was carried by containerships and ro-ro (roll on-roll off) vessels, albeit dominated increasingly by foreign carriers.

One noted change to the ocean carrier's financial makeup is that the container revolution made an already capital-intensive business even more capital-intensive by reducing dockside labor costs and increasing capital equipment costs. Double-stack train equipment and expected innovative crew reductions continue that trend for the railroads.

C. DEREGULATION

One of the principle benefits resulting from the deregulatory legislation enacted in the 1970s and 1980s was the liberalized permission for carriers of one mode to own and operate carriers of another mode. In a decision under the new legislation, the ICC, effective January 6, 1983, eliminated regulatory restrictions enacted in 1935 to protect the then infant trucking industry from the railroads. This new flexibility was greeted warmly by the rail and ocean carriers but with some dismay by the trucklines because rail carriers have greater inherent financial clout to buy out many of the smaller motor carriers.

Another important deregulatory boost to intermodality was to free rail piggyback carriage from all ICC regulations. This was accomplished, not alone by legislation, but through an exemption promulgated in an ICC rulemaking procedure under the umbrella of the Staggers Rail Act of 1980. The ICC proceeding was entitled Ex Parte No. 230 (Sub. 5), the results of which became effective March 23, 1981. Ex Parte No.

230 (Sub. 5) was actually instituted on August 21, 1978, prior to passage of the legislation, but it was not pursued vigorously by the Commission until late in 1980, after both the Motor Act and Staggers Rail Act became law. This action has afforded the railroads greater flexibility to price piggyback competitively against truck hauls, as well as wider latitude for routing traffic on joint rail-piggyback hauls involving rail-owned trucklines. A more recent rulemaking proceeding, Ex Parte No. 230 (Sub. 6), decided 20 September, 1984, extends piggyback deregulation to exemption of truck rates from regulation in joint piggyback operations with the railroads.

Piggyback has grown considerably since its inception in the 1950s as noted. In 1977 piggyback traffic represented seven percent of all rail revenues, second only to the carriage of coal. From 1969 to 1977 rail piggyback tonnage grew by 40 percent, while rail tonnage generally dropped by six percent. In spite of the increase in piggyback tonnage, it had not reached forecasted volumes, amounting to less than one percent of all intercity freight movements by all modes at the end of its initial period of growth.

Less-than-anticipated volumes were attributed in part to the federal regulatory structure preventing flexibility and inhibiting creative marketing. Further, a lack of aggressiveness on the part of the railroads to promote piggyback was blamed again on regulatory inhibitions, a reluctance to cooperate with truckers, and a perception that piggyback was only marginally profitable. Also, the shippers felt that the service was complicated by lack of coordination among modes and noncompetitive in terms of flexibility and transit times.

However, in 1977 the deregulatory process began and carrier reluctance about cooperation with other modes, and lack of enthusiasm for new intermodal piggyback services, changed significantly for the better.

Simultaneously, the interstate highway system began to fall into a state of disrepair in the late 1970s, after years of neglect, thereby furnishing rail piggyback services with a boost in competitive image. Highway fuel and truck tax increases further contributed, but were offset somewhat by subsequent liberalization of weight and size limitations for highway trucks and trailers.

In 1983, piggyback volume accounted for 12.4 percent of all rail carloadings, ranking second to coal (27 percent). That same year, 2.3 million flatcars carried almost four million trailers or containers by rail. In May 1984, Trailer Train reported that its piggyback operations had grown 18 to 19 percent over the previous year. Final figures for all rail carriers in 1984 showed that trailers and containers loaded rose 11.7 percent, to 4,569,094, while the number of cars loaded with trailers and containers rose 14.6 percent to 2,690,659.

D. BRIDGE SERVICES

This dramatic increase in piggyback service as brought about by deregulation contributed strongly to the development of stack trains in so far as the growing pressure by rail carriers to serve a burgeoning conventional COFC market led them to explore new ways to more efficiently accommodate the higher container volumes through a finite number of increasingly busy rail corridors. The answer was to increase the container unit train carrying capacity through stack train technology and keep the number of trains operated from skyrocketing. Another vital market force receiving widespread credit as a primary motivation in fostering double-stack unit train service is the expansion of "bridge" services that cross the U.S. continent. Landbridge, minibridge, and microbridge are terms used to describe rates for the land portion of certain intermodal movements of freight across the United States or Canada, or to and from points within these countries.

1. Landbridge Service

First conceived in the 1960s as a more efficient means of shipping between the Far East and Europe, the U.S./Canadian landbridge uses transatlantic and transpacific water transport combined with rail piggyback to move goods across the North American continent. Two distinguishing characteristics of this landbridge are: (1) the entire movement between the Far East and Europe is covered by a single bill of lading issued by a steamship company or an NVOCC (non-vessel operating common carrier), and (2) the goods remain in the same container for the entire movement. In spite of the publicity given landbridge, volumes moved have not been significant. The U.S./Canadian landbridge was intended to compete against the all-water route via India at a time when the Suez Canal was closed and the Siberian landbridge was not yet in full operation.

2. Minibridge Service

U.S. minibridge was created shortly after landbridge. It applies to shipments moving between foreign and U.S. (and Canadian) points. The rate is calculated as if through all-water transportation were used to or from a port near the U.S. (Canadian) city of origin or destination.

The shipment actually moves via the designated U.S. (Canadian) port, but by surface transport. For example, a minibridge shipment from Japan to Wilkes Barre, Pennsylvania could use the all-water rate from Japan to the port of Philadelphia, then a rail or truck rate from Philadelphia to Wilkes Barre, even though the cargo actually arrived by sea at Los Angeles and moved by rail to Wilkes Barre via Philadelphia.

As in the case of landbridge, minibridge shipments are covered by a single bill of lading, and the goods remain in the same container for the entire movement. Minibridge tariffs are published by the steamship lines, and the proportional divisions of the revenues are negotiated by steamship lines with other intermodal carriers.

There are minibridge systems linking the Far East with U.S. points via West Coast and East Coast ports (as in the Japan-Wilkes Barre example), and linking the Far East with U.S. points via West Coast and Gulf ports. An example of the latter is a shipment from Montgomery, Alabama moving by rail to New Orleans, then to the port of Los Angeles, and by ocean carrier to the port of Pusan, Korea. There are also systems linking Europe with U.S. points via East Coast and West Coast ports (for example, Hamburg, Germany via New York and San Francisco to Sacramento), and also systems linking Europe with U.S. points via East Coast and Gulf ports (Dallas to Copenhagen via Houston and Baltimore).

3. Microbridge Service

Microbridge service and rates were devised in 1970 to apply directly between interior U.S. (and Canadian) cities and foreign cities via a single port, avoiding double-port transits of minibridge systems. Modifying the minibridge Japan to Wilkes Barre example, the microbridge movement would be from Japan to a West Coast port such as Oakland and then direct via rail piggyback to Wilkes Barre, avoiding the port of Philadelphia. The movement would be charged a through rate, possibly discounted below the combination of rates via the port utilized. A microbridge shipment also is covered by a single bill of lading issued by a steamship company or an NVOCC, the cargo remains in the same container for the entire movement, and tariffs are published by the steamship lines, which negotiate proportional divisions of the revenues with their intermodal partners. Neither shippers nor consignees have control in determining routings or port gateways to be used in microbridge movements.

4. All-Water Versus Bridge Route Competition

Minibridge and microbridge rates and services, especially microbridge, have had a considerable overall market impact. Deregulation by the ICC and FMC

(Federal Maritime Commission) has given aggressive carriers greater freedom to use these systems to undercut existing rate structures, to direct cargo from ocean rate conferences, to negotiate rates with shippers, and to implement through rates without notice or explanation of the proportional division of revenues between participating intermodal carriers. In effect, it has caused a significant change from the environment of the 1916 Shipping Act that permitted ocean carriers to join together to fix and enforce rates and conditions of service.

One of the most significant deregulatory moves by the ICC was to eliminate piggyback rate regulations, permitting ocean carriers to establish through intermodal rates using piggyback at almost any rate level that they wished. The ICC move was soon followed by FMC action permitting publication by ocean carriers of intermodal through rates without separating the portion representing the ocean carriage.

As the bridge traffic became more susceptable to flexible pricing schemes ocean carriers became more interested in cutting operating costs and maximizing profit while at the same competing aggressively with the all-water routes. Concomittent to the significant savings in overall transit times (for example, U.S. Lines' Yokohama-Chicago bridge transit times by containership via the all-water route to a Savannah port call), the bridge rate need only be comparably priced as a result of the double-stack economies in fuel and labor savings. It is significant to note at this point that initial probings by APL (American President Lines) in 1982 towards railroad development of double-stack technology resulted in only rebuffs [Ref. 2: pp. 30-31]. It is interesting to observe that an ocean carrier had the vision to see value in reducing the overland movement costs for competitively shifting cargo market share from all-ocean to ocean-rail movement. One would logically have expected the railroads to advance technology themselves that would capture cargo market share from a competing transportation mode, a sensitive topic with railroad management.

Intermodalism became a popular "in" word in the United States in 1985. However, the idea was strongly promoted in the early 1970's when McKinsey was advocating main port to main port marine transport, and the more farsighted operators in Europe saw the advantage of using integrated transport sytems and developed them slowly taking full advantage of existing railroad and inland waterway routes. Development of intermodalism remained stunted for a decade because [Ref. 3: p. 13]:

1) Relatively few containers moved to the hinterland.
2) Ship operators had to maintain their position in the conference system by calling at a full range of ports.

3) Ports fought to maintain status by insisting on direct calls.

4) Road transport was relatively expensive in view of the long distances to be covered.

5) Above all, regulatory agencies controlled the terms under which the railroads could accept cargo.

The opportunities resulting from reaching new inter-corporate agreements and restructuring multi-modal corporations came into reach in the 1980's commensurate with enacted deregulations necessary to facilitate these business arrangements. The speed and efficiency that has become synonymous with double-stack unit train operations have allowed this new technology to become a major link necessary for intermodalism to blossom.

In relation to the bridge services previously described, stack trains have been reported to reduce transit times betweeen the Far East and the U. S. Midwest by three days and New York by four days when compared with conventional COFC flatcar service. Overall, there is a savings of nine days compared with the all water route between the Far East and New York [Ref. 3: p. 14]. Rail officials additionally claim a reduction of between one and three days on transit times between Europe and the Middle East to the U. S. west coast compared with the all water route [Ref. 3: p. 14]. Quantified savings have been more controversial and less publicized. Some shipping lines have expressed overall savings of between 15 and 20 percent compared with conventional COFC flatcars but no comparisons between the all water and rail routes have yet been published. [Ref. 3: p. 14]

III. MARKET FORCES AFFECTING THE STACK TRAIN

A. INTRODUCTION

Existing reviews that describe the double-stack container train phenomenon all cite one or another of a host of economic and market driven forces as the progenitors of the twin-stack innovation. In fact, its appearance is tightly interwoven with the development of new cargo movement control and handling methods that are encompassed within intermodalism and incorporate the "just in time" philosophy of inventory level management.

The events described in the previous chapter provided the latitude for exploration of new cost saving technology and different methods that would lead to service improvement. But what need would drive a carrier to such development efforts, and what mode would initiate development of the stack train concept? A look at the economic market conditions of the past decade is in order.

B. DEPRESSED RATES

An excess of "bottoms" (as cargo-carrying ocean vessels are typically referred to in industry slang) has become a virtual fact of life for the steamship lines in the latter 70's and 80's, as overconstruction and a worldwide general economic recession brought the rapid expansion of international container movements to a halt. Instantaneously, two other trends of major importance surfaced. Imports to the United States from Pacific Rim countries rose sharply, and the U. S. industrial base was evidencing a shift from heavy industries of the "rust belt" to service industries of the "sun belt" specializing in soft high value, vulnerable, and non-transportable offerings (services requiring only international electronic communications and no movement of cargo). Further, European consumers were expressing a new interest in Japanese manufactured goods, posing a challenge to the European businessman. This trend has caused an increase in containerized cargo moving form the Far East to European markets, either via our all-ocean round-the-world carrier or utilizing the U. S., Canadian landbridge.

C. LOAD CENTERS

The glut in container service, by keeping container rates depressed, has denied steamship lines any profit-taking opportunity that could have resulted from the escalating value-of-goods shipped in containers. That has caused a greater emphasis on cost control and saw the early demise in the 70's of Sea-Land's SL-7 super-containerships that had high speed capabilities and fuel-gobbling habits. This has further forced the construction of "low-cost-per-container-slot" 4400-plus TEU containerships that operate economically through low fuel consumption diesel propulsion at a disadvantage to the former containerships' speed. This speed reduction, complete with their gigantic size, has brought on the new intermodal concept of load-centering in which all ports are identified by steamship lines as load centers or feeder ports. Their superships, in round-the-world transit, call only at load centers, and containers are then shuttled to and from the other feeder ports for the final inland delivery. In this way, the superships call only at ports capable of efficiently handling the unloading and onward movement/distribution of such large quantities of containers all at once. They also minimize the total time that the container is involved in its slowest portion of the journey, the over-the-ocean leg. The ability to quickly and economically move large quantities of goods around the world has aided the emergence of a "global" economy. Concentrating production or heavy industry in the southern regions of the world has allowed the focus to shift from an industrial to an information society in the northern regions. This places a new burden upon efficient interval movement of containers in bridge, minibridge, microbridge and even domestic movements in the United States, being a conveniently located "island" between the fast developing Far East and the Euro-Mediterranean land mass. Political exigencies continue to prevent the Siberian landbridge from opening up to its full potential, although an increase in traffic has been experienced.

The imminent fruition of load centers, conceptually not a new idea, the inevitable focus on total transportation system cost control, and the soaring emphasis on the time factor brought on by high-value goods has in the last few years generated strong competition between U.S./Canadian bridge traffic and the all-water Panama Canal route. The advent of unit stack trains in landbridge traffic in April 1984 by American President Lines has provided a further divergence in coast-to-coast transit times (three days quicker over conventional COFC service) between landbridge and the all-water route. This has allowed the already depressed bridge rates to remain, but at an improved profit to the ocean carrier. The ocean carriers are reaping the majority of profit by engineering fixed contracts with the railroads to haul containers via stack trains based on a flat container charge and not value-of-shipment variable rates. The ocean carriers are interfacing directly with the shipper and not, with some domestic cargo and backhaul traffic exceptions, the railroads. Further, the coast-to-coast transit time improvements stem from an insistence by the ocean carriers for railroad stack train service, instead of conventional COFC. They have linked with the railroads a new philosophy of managing the departure, movement, and arrival of stack trains in a much more closely coordinated fashion. Ocean carriers are routinely in a constant interface with railroads via ocean carrier representatives stationed in railroad yards and via computer hookup. This allows the railroads to schedule and control through movements of double-stack unit trains directly to vessel arrivals and departures.

D. RAILROADS RESIST STACK DEVELOPMENT

In essence, the need for economical stack train service was funneled through steamship lines as a direct result of the increased need to compete effectively with all-water service (United States Lines, Evergreen, etc.) to and from the Far East. Although the economics are obvious, the volume trend was predictable, and the technology was at hand, APL executives who approached various segments of the railroad industry seeking a partner in the development of the double-stack were turned down. It was labeled a "boutique train", too specialized to be widely accepted for rail use. APL, therefore, developed the stack train concept to fruition. [Ref. 4: p. 46]

Analysis of internal railroad statistics by car-type reveal that other pressures may have caused a resistance to double-stack implementation as well. Two major points bear mentioning. Both rail intermodal and truck traffic have grown in the past three years at the expense of the boxcar. The economics of the double-stack container are such that on long-haul movements neither TOFC nor truck are going to be able to slow the diversion of traffic from their mode. The use of boxcars from plants and distribution centers to wholesalers and shipper-direct is down dramatically. One shipper reported car useage in total was down from 35,000 to 40,000 cars a year in 1978-79 to 18,000 cars a year in 1984 with nearly all cars now used in 1984 in inter-plant service. A second shipper reported that customer direct shipments by boxcars were down from 95 percent boxcar to a point where, within 90 days of the interview, there would be no boxcar loads to the customers. However, there would be 7000 to 7500 intermodal customer moves in 1984. The "trailer freight" pool of the domestic surface transportation industry is most vulnerable to diversion to containers operating on stack trains. Most shippers do not differentiate between intermodal and truck in defining "trailer freight"; it is simply total freight moved. As stack train service (combined with hub to ultimate consignee delivery by truck) proves the equal of TOFC or over-the-road truck, its cost benefits will lure more and more shippers to it. Assuming a "ramp-to-ramp" intermodal charge to the shipper of approximately $.70 to $.80 a mile, it is clear that on a stack train where power, fuel, and labor are held virtually constant at the conventional COFC level, a container ramp-to-ramp rate of approximately $.40 to $.50 may be possible. Figure 3.1 compares estimated linehaul costs for various intermodal configurations and graphically illustrates the overall economic advantage that double-stack technology encompasses. By pricing the backhaul container space at the margin, $.40 a mile, ramp-to-ramp domestic container freight has become a reality, as American President Company's (APC, the new parent of all AP companies) subsidiary American President Domestic Transportation Company (APD) has already experienced in their efforts to concentrate solely on developing the domestic container freight market. [Ref. 5: pp. 249-253]

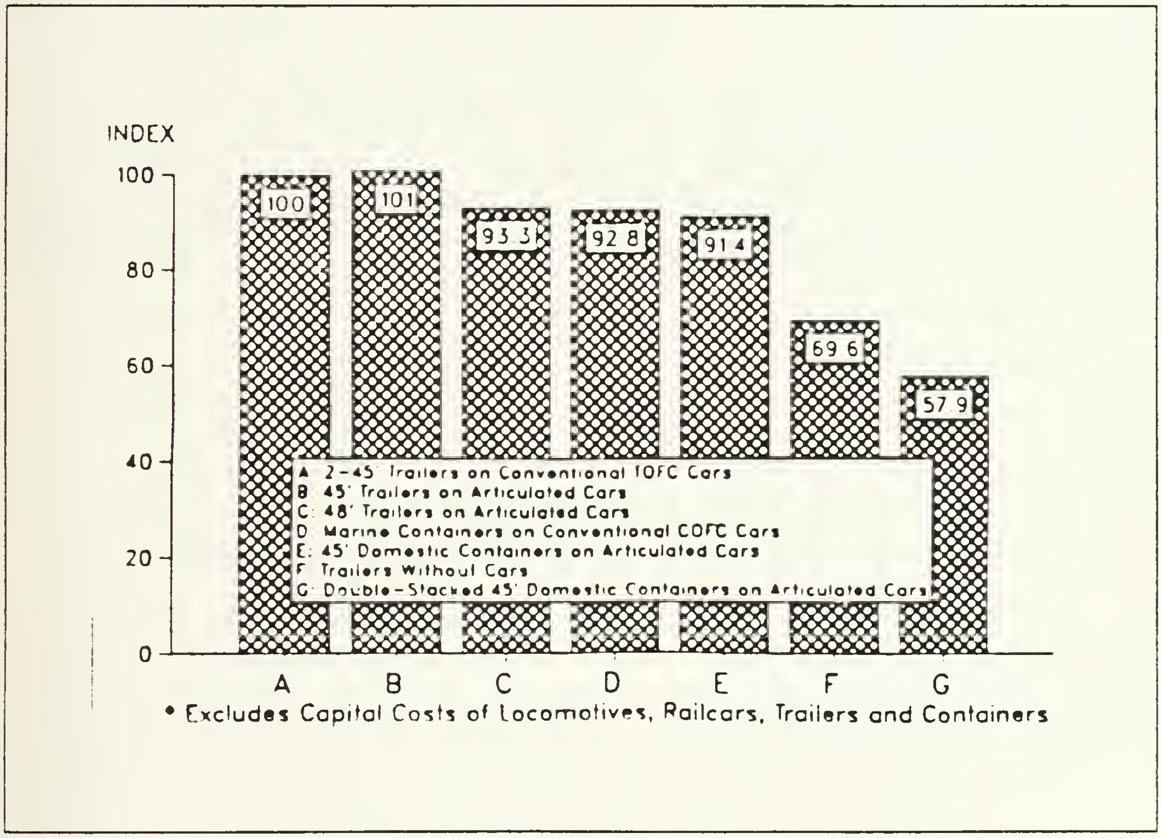

Figure 3.1 Estimated Linehaul Cost Comparison.

The "Achilles heel" for railroads in diversion of traffic from conventional COFC/TOFC and boxcar to stack trains is the tremendous potential for underutilization of relatively new, undepreciated rolling stock and the added cost of investing in wholly new unique equipment in order to compete or even just maintain their share of the freight market vis-a-vis other railroad and truck competition. For as the port managers are quickly finding out, deregulation and the increased cargo mobility that stack trains offer are changing their traditional port territories established by conference agreement and, likewise, may allow significant enough shifts in cargo volume between ports serviced by competing railroads to alter a rail carrier's base load from that point. In order to avoid this investment gamble in equipment, railroads have resorted to including in their service contracts with the ocean carrier a clause directly passing along the car hire and mileage charges for the new equipment and locking the ocean carrier into penalty payments for tonnage shortfalls or early contract termination. This has essentially passed the stack train equipment rental risks onto the ocean carrier [Ref. 6: pp. 3-4]. In short, by putting many of the world economic, steamship line, and domestic railroad trends together, it has been shown that the development of double-stack trains came about concurrently with, and, in turn, proved a catalyst for further development of the new global intermodal transportation system.

Each facet of the double-stack industry and related events surrounding the stack train involvement with the new intermodal expansion will be reviewed next in further detail.

IV. DOUBLE-STACKS: PIONEER EFFORTS TO DEVELOPED NETWORK

A. DOUBLE-STACKS: THE FIRST EFFORTS

1. Southern Pacific

The first scheduled double-stack trains were inaugurated by Southern Pacific Railroad in 1981 with service between California and Texas. A total of 42 bulkhead retainer type cars were constructed by ACF Industries, Inc. The concept, however, didn't have an immediate impact upon the COFC/TOFC market. [Ref. 7: p. 10]

2. American President Lines

The next entrant was American President Lines, which had pioneered the use of container unit trains using conventional flatcars in 1979 with its Linertrain service. APL, an Oakland-based trans-pacific ocean carrier, began testing a double-stack prototype of its own in the summer of 1983 with a combined movement of 19 Southern Pacific double-stack cars from Los Angeles to Kansas City and to Chicago via the Burlington Northern Railroad. All of the cars, part of APL's Linertrain service from Los Angeles, were filled with Asian import containers carried by APL vessels. On the backhaul to Los Angeles, most of APL's containers were filled with domestic westbound freight to California for customers of Merchant-Stor Dor Freight System Inc. of Chicago and Western Carloading Co. Inc. of Los Angeles, both subsidiaries of Transway International Corp. of New York with which APL has an agreement for domestic freight backhaul forwarding. [Ref. 2: p. 30]

As a precursor to its success with double-stacks, Transway and APL had concluded a series of landmark agreements with each other and with the railroads in 1981 to resolve their own transportation flow imbalances and secure certain service guarantees. Transway has a preponderance of westbound domestic freight, and APL, with 20 cargo vessels in the Pacific, accounts for heavy flows of import cargo from Asia which must move cross-country from West Coast ports. This allowed a refinement of their cargo balancing programs and has contributed to APL's success with its double-stack service by ensuring backhaul utilization. [Ref. 2: p. 31]

In April 1984, APL began replacing its conventional Linertrains of single-stacked containers on railroad-owned conventional flatcars with articulated, five-unit well cars, owned and managed by APL. The initial investment was for $12 million. By mid-1985 further investment shot their total to over $20 million. A concurrent reorganization that placed APL subordinate to a new parent, American President Company, added American President Intermodal (API), and American President Domestic Transportation Company (a combination of three former Brae Corp. subsidiaries; National Piggyback Services, Inc., National Piggyback Specialized Commodities, and IntermodaL Brokerage Services, Inc.). API owns and controls the new equipment and APD is designed to provide westbound shipments in domestic containers from the East and Midwest. Westbound Linertrains had been 85 percent loaded and risen above 90 percent since. Eastbound, the trains have been approximately 98 percent loaded. [Ref. 8: p. 62]

APL's stack cars were introduced by the Budd Co. and redesigned and built by the Thrall Car Co. at Chicago Heights, Ill. One of APL's five-platform stack cars can be seen undergoing loading in Figure 4.1. Initially, the cars held 40-foot containers in the wells and 20-foot to 45-foot boxes on top of them, held together by interbox connectors (IBC's). The IBCs are clamp devices just like the ones used to securely hold containers to each other by their flanges on the weather decks of ocean vessels and were chosen to reduce the overall weight of the stack car. Recent development efforts have resulted in well cars accommodating 45-foot boxes in the well and 48-foot domestic containers on top of either 40 or 45-foot boxes. [Ref. 8: p. 62]

The light, floorless cars have American Steel Foundries 70-ton trucks at each end, and three American Steel Foundries (ASF) 100-ton trucks in between supporting the joinings of units with ASF articulated connectors. A 100-ton ASF truck is shown in Figure 4.2. The boxes snuggle into well flanges and the car undersides have six inches of clearance above the rail, including allowance for three and one quarter inches for wear and spring deflection. There are 20 easily insertable and removable steel connectors or IBCs per car that are strong enough to hold stacked containers six high onboard ocean vessels. [Ref. 8: p. 62]

Donald C. Orris, currently president of API and formerly vice president-inland transportsation services for APL, is credited with fathering the successful introduction of double-stacks. Before moving to APL in 1977, Orris was manager of intermodal services for the Denver & Rio Grande Western Railroad, where he first proposed that one box could ride on top of another. Lacking the cooperation of connecting railroads, the idea was then shelved. Since, the current development of stack trains involved mechanical officers of Union Pacific System, Chicago & North Western, and Conrail after APL had taken the initiative. [Ref. 8: pp. 62-63]

Figure 4.1 An APL Double-Stack Railcar.

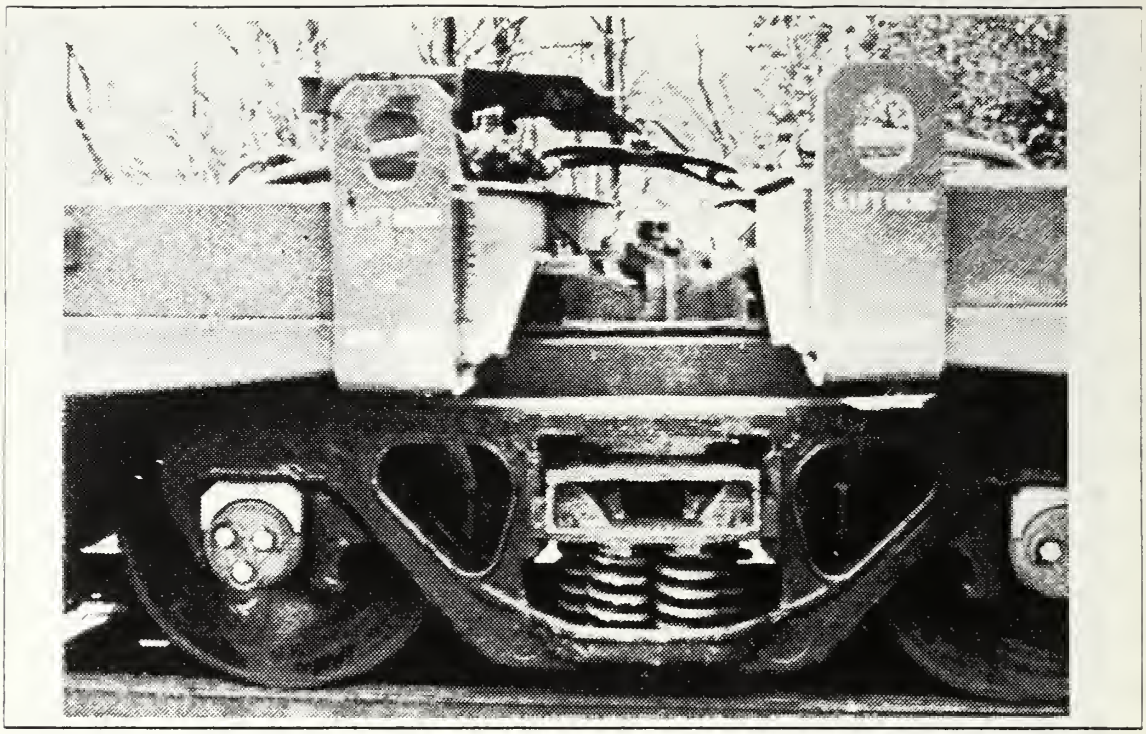

Figure 4.2 A 100-Ton ASF Truck.

Initial service experience with the equipment tied into mile long trains (each Thrall car set is 269 feet long) that weigh over 5000 tons loaded was outstanding. Minor improvements such as stronger brackets to guide boxes into wells, two full-length stringers in the open well-bottoms to protect against floor failure, reinforcing plates on intermediate unit side guides, and relocated car-end walkways for yard personnel to work further from the open wells, have enhanced the resiliency of the cars. End-of-car cushioning with 15-inch-travel gear was found to be unnecessary and a switch was made to Cardwell Westinghouse H60 hydraulic draft gear with three and one quarter inches of travel. Early problems with the truck mounted brakes were quickly resolved and the Davis Brake Beam "Truc-Pac" has been performing well. [Ref. 8: p. 63]

Managing the logistics for the equipment required unexpected effort. APL underestimated the complexity of the operation, which involves coordinating ship unloading with train loading on the West Coast, load shuffling at Chicago, and unloading on the East Coast, in addition to scheduling of trainsets and finding backhaul loads [Ref. 8: p. 63]. APL staff at Los Angeles, Seattle, Chicago, and New

York maintain daily contact through three conference calls that involve location, quantity, and balancing of containers, chassis, and rolling stock. In addition, computer programs help managers develop train consists to prevent clearance and well car overload problems. [Ref. 9]

By providing priority scheduling and priority loading and unloading of container trains in the railyards, the railroads have achieved an average 53 hour transit time from Chicago to Los Angeles and back. C&NW, whose yard at Wood Street has been central to feeding of containers between the Los Angeles-Chicago round trips and the Chicago-Kearny, New Jersey round trips, was required to make major accommodations to its all-piggyback yard and reserve one of its five Piggy Packer loading devices exclusively for APL's double-stack trains. Initially its track sections were so short that it could only handle 20 standard Trailer Train flatcars. And C&NW's port of entry into Chicago is the Proviso Yard, which required a secondary route of three hours running time to transit to Wood Street. In July 1985, C&NW relocated its piggyback operations a short distance to the Canal Street Yard (formerly owned by the Missouri Pacific), making Wood Street an exclusive double-stack facility. In addition, the adjacent, unused Robey Street Yard was acquired from the Baltimore & Ohio Chicago Terminal Railroad, thus giving C&NW a total of 110 acres for development of its entirely new facility, christened Global I, scheduled for completion in November 1986. Global I was designed in close cooperation with the steamship lines in the realization that the facility will be handling the ocean carriers' trains, business, and containers. [Ref. 10: p. 33]

B. DOUBLE-STACK TRAIN NETWORK

As of 1 May 1986, more than 30 double-stack movements a week including 12 railroads and 11 steamship lines were in service as illustrated in Figure 4.3. A year earlier, in 1985, fewer than half those movements involving only four railroads and two vessel operators were in operation. [Ref. 11: p. 36]

Double-stack frequencies vary from six to one per week. Cars run in solid trains or as blocks in solid intermodal trains that generally consist of 20 five-well articulated stack cars that hold approximately 200 FEUs, 10 to a car set. Unit trains, however, have been assembled to 28 cars in length. With each train towing a capacity almost one-half greater than conventional COFC unit trains, speculation abounds concerning the service network's continued growth. Domestic containerization may absorb

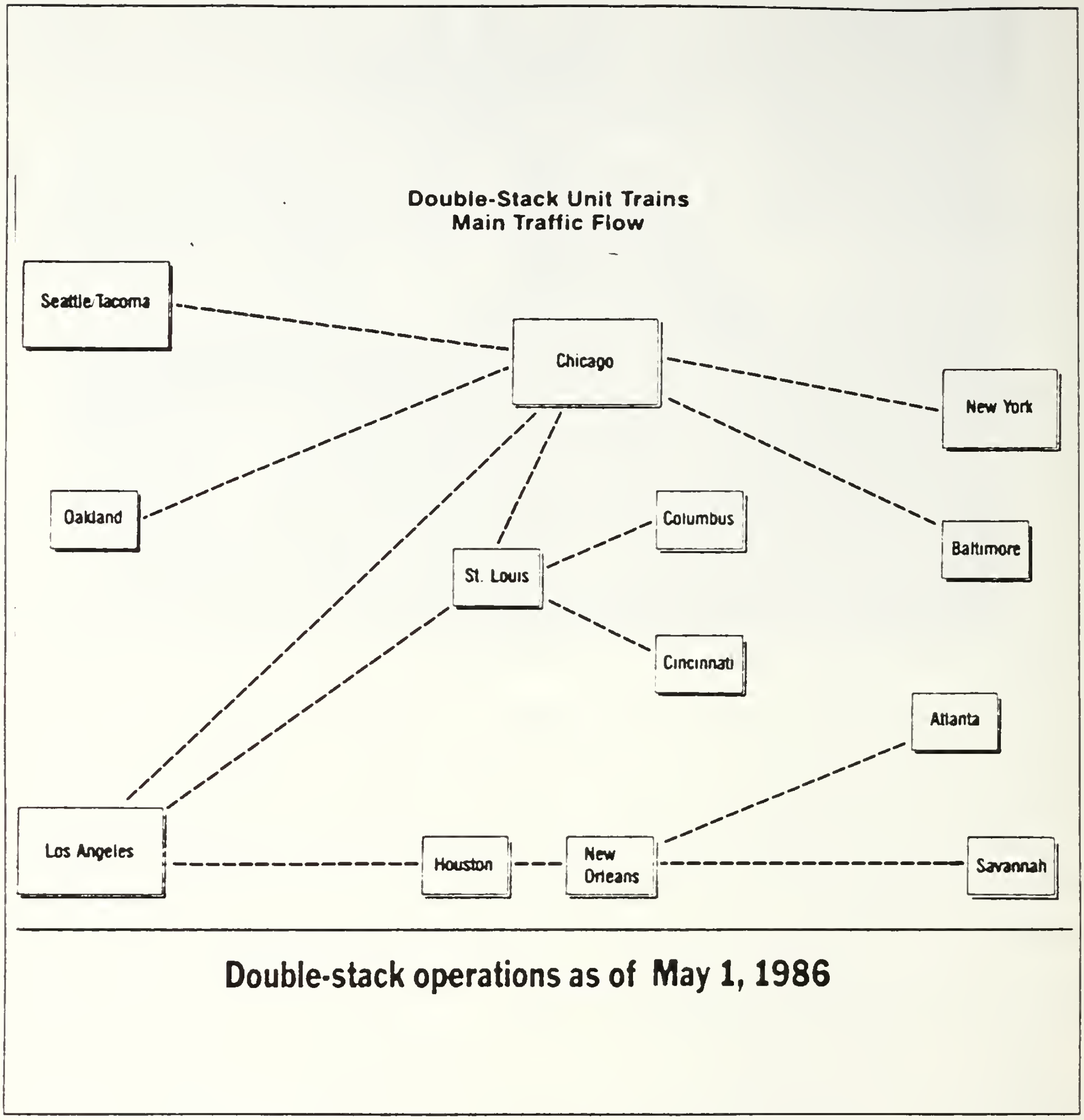

Figure 4.3 Double-Stack Train Main Traffic Flows.

enough freight in developing fronthaul movements to allow some industry optimists to speculate that continued growth will cause an increase of 40 more weekly double-stack movements (from 30 currently to 70 per week) by the summer of 1987. [Ref. 11: p. 36]

Making up these new trains are 161 five-unit articulated cars from Thrall and 204 cars from Gunderson, all owned by Trailer Train; 313 cars from Thrall with 60 more on order owned by American President Lines; 83 Gunderson cars with up to 80 more on order owned by Sea-Land; and 43 early bulkhead units built by ACF (no longer manufacturing double-stacks) and owned by Southern Pacific. These figures are from mid-April 1986 and have been climbing steadily since. American President and Sea-Land both lease to supplement their fleet. The double-stack unit train main traffic flows are depicted in figure . Currently, Sea-Land deploys 163 double-stack cars a week. Many of them run in solid trains making a "huge figure eight" with Los Angeles and Tacoma on one side, Chicago in the middle, and Little Ferry, New Jersey, on the other side, with both Tacoma and Little Ferry being Sea-Land operated terminals. For Sea-Land moves from Tacoma, Burlington Northern (BN) is the carrier, while Santa Fe handles them from Los Angeles. At Avard, Oklahoma, Santa Fe delivers a block to BN for movement to the Southeast through Memphis. In Chicago, Santa Fe and BN turn over their Sea-Land traffic to Chessie, which delivers it to the Delaware & Hudson (D&H) at Buffalo. D&H moves it on to Binghampton, New York, where the New York, Susquehanna & Western Railroad takes over for the run to Little Ferry. Sea-Land also uses SP for a Los Angeles-New Orleans movement. American President relies on UP, C&NW, and Conrail (CR) for double-stack movements from the West Coast to South Kearny, N.J. To Jersey City, Conrail handles Maersk and K Line double-stacks originating on the West Coast and moving to Chicago over UP and C&NW. Conrail, as of April 1986, had spent $10.8 million to raise clearances on its water-level route alone. [Ref. 11: pp. 38-39]

Conrail also handles a double-stack Mitsui move to Columbus, Ohio. This traffic originates at Los Angeles as a solid train handled by SP. At St. Louis, the Illinois Central Gulf Railroad takes a block for delivery to Chicago, and CR takes the rest to Columbus. The double-stack Mitsui traffic reaches Columbus mixed with single-stack cars in all intermodal trains in furtherance of Conrail's policy of combining stack traffic with other intermodal business or several steamship line's business into one stack train whenever the volume of one ocean carrier is insufficient to warrant a full double-stack train. On the eastern fringe of Conrail's ex-Pennsy Chicago-New York route, clearances prohibit stacks, thereby requiring a breakdown of Seattle/Tacoma originated double-stack containers. At Chicago, these loads are drayed between BN and Conrail and U.S. Lines stack traffic from Oakland also is broken down. [Ref. 11: p. 39]

As more and more high-value retail merchandise freight finds its way into domestic containers, the double-stack network is bound to expand further. The current fad craze that stack trains are enjoying is luring many new customers to experiment, such as North Carolina furniture makers, appliance manufacturers, and so forth. This may lead to a permanent growth or a later retrenchment if service standards fail to meet expectations of first time rail customers. Also, high density, or weight-limited goods should soon be accommodated upon completion of testing and production of a successful stand-alone car that, with heavier tonnage double-axle trucks, can reach container weight load limits. With this equipment eventually in place, the outer envelope of containerizable cargo can be reached with double-stack train service. It will then only be a question of how rigorously the other nodes of the intermodal system are developed and how creatively the new equipment is managed and the service is marketed.

V. EQUIPMENT

A. RAILCAR DESCRIPTION

Articulated well railcars capable of transporting one container on top of another represent a technological breakthrough in design. Without the limitations that conventional railcar construction impose upon designers seeking strength and durability that the traditional heavy, solid railroad cars provide, computer assisted designers at the Budd Co. and Gunderson Inc. have developed two competing space-aged "drop-frame" flatcars that incorporate tremendous weight and rolling resistance gains over conventional COFC equipment. A third manufacturer, ACF Industries, Inc., actually provided the first examples of double-stack equipment to Southern Pacific in 1981. However, the failure of the Southern Pacific design to substantially reduce tare weight prevented significant economic advantages from materializing and limited its impact upon the COFC market. [Ref. 4: p. 46]

The two successful manufacturers of stack train rolling stock essentially have split the market evenly. The Budd Co. designed car is marketed as the LOPAC 2000 by the Thrall Car Manufacturing Company of Chicago Heights, Illinois (full address: P.O.Box 218, Chicago Heights, Illinois 60411; phone 312/757-5900) and has undergone several design improvements since inception of service with APL in April 1984. The more recent competition, Gunderson Inc. of Portland Oregon, entered the business on 1 March 1985 and has experienced an immediate flurry of orders (4350 N.W. Front Avenue, Portland, Oregon, 97210; phone 503/228-9281). [Ref. 11: p. 38]

The intent is to fully and accurately describe both manufacturer's equipment offerings, including the advantages and disadvantages touted by each builder. However, no inference is made concluding that one design is to be promoted as better than the other in this thesis. Descriptions of one car's benefits over the other have been, for the most part, provided by the vendors, and that should be kept in mind as this chapter is reviewed.

There are a number of similarities in the railcars offered by these manufacturers. Both designs involve a five-platform configuration to make up one railcar. These platforms are joined by semipermanent connectors that tremendously reduce the slack typically found between railroad cars. The platform sets incorporate eight fewer axles per set, 12 total versus 20 for five conventional flatcars [Ref. 12: p. 2-3]. Both platform types use "drop-frame" construction with open wells reinforced with stringers for weight savings. The 12 axle positions are clearly illustrated in the drawing of a complete Gunderson railcar set in Figure 5.1. The open well designs of both car types can be compared in Figure 5.2 and Figure 5.3.

One key difference between Thrall cars and those of Gunderson is the means by which the upper container is secured. Similar to the first stack train designs built by ACF, Gunderson cars feature bulkheads at the end of each articulated unit, thereby eliminating the need for interbox connectors used in the Thrall units. Both bulkheads and interbox connectors retain the top containers in place satisfactorily. The bulkhead cars are slightly heavier than the IBC cars but allow the containers to be positioned onto the car by a crane operator without the assistance of ground personnel that are necessary for the IBC equipped car in order to remove IBC clamps to securely anchor the top box at loading. Illustrations of the two car types clearly show the difference in design. [Ref. 11: p. 38]

Both manufacturers have made slight improvements in their designs and, notably in Thrall's literature, slight variations in dimension and tow weight are noted in their descriptions of the 40-foot well platform, 45-foot well platform, and for both manufacturers comparing end platforms with center platforms [Ref. 13: p. 1]. Generally, Gunderson's Twin-Stack car is 265 feet 1 1/2 inches in length and 9 feet 11 1/2 inches wide. The height from the rail to the bottom of the platform (empty) is 8 1/2 inches. The height of two empty 9-foot 6-inch super-cube containers is 19-feet 11 1/2 inches from the rail and loaded 19 feet 9 3/4 inches. To insure clearance for 20 foot right-of-ways, a standard height 8-foot 6-inch or 9-foot high container must be mixed in for safe transit. The Twin-Stack railcar is shown completing a loading operation in Figure 5.4. [Ref. 12: p. 4]

The Thrall car, in comparison is 291 feet 1 1/2 inches in length and has an inside width of well of 8-feet 1/2 inch. Its height from the rail to the bottom of car sill is 9 1/4 inches. Its total height from the rail with two super-cube containers is then 19 feet 9 1/4 inches empty, very similar in repects to the Gunderson car. The nominal capacity per platform is 101,500 pounds. The estimated tow weight per platform is 32,400 pounds. [Ref. 14: p. 1]

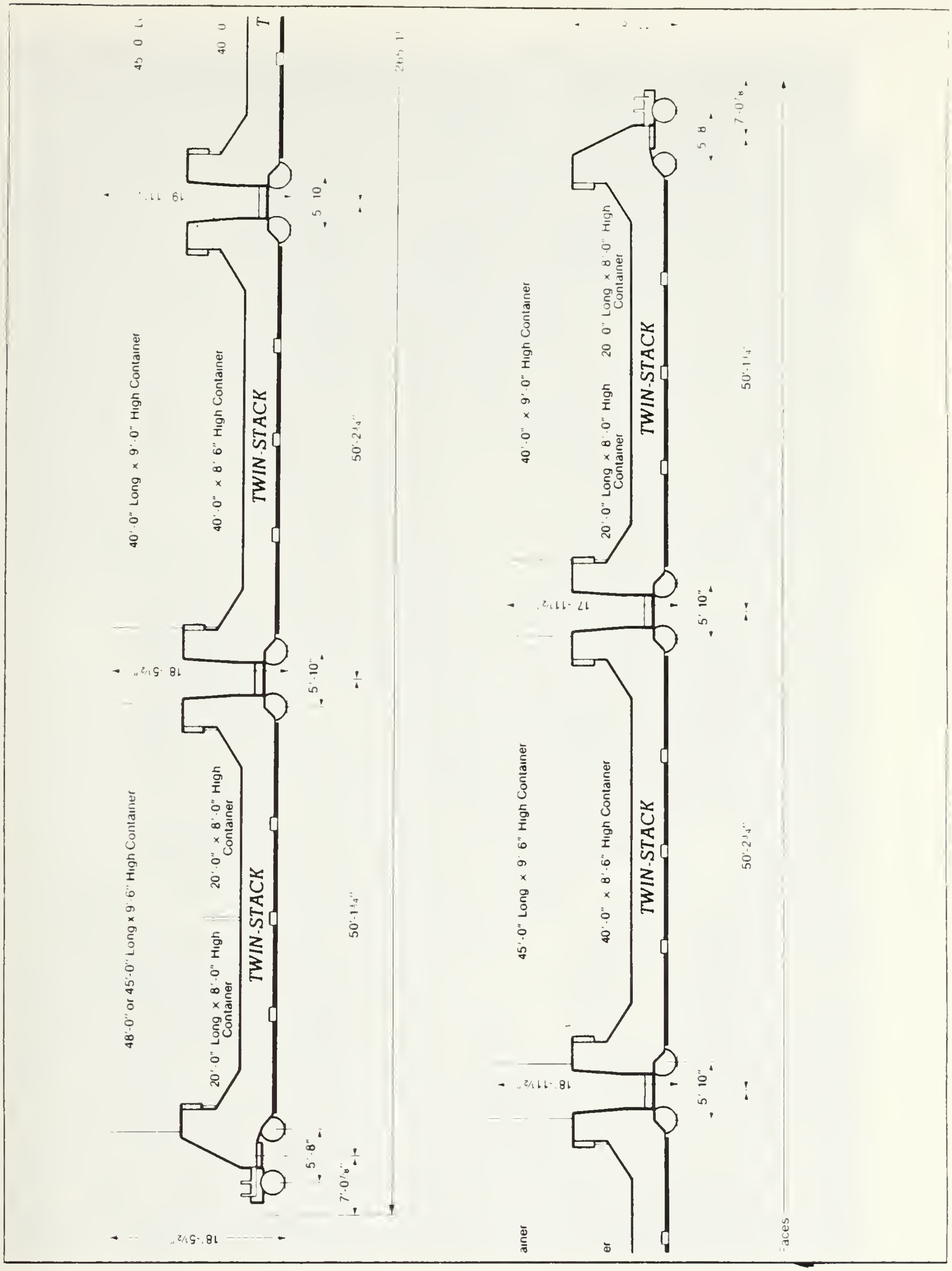

Figure 5.1 Gunderson Five-Platform Railcar Set.

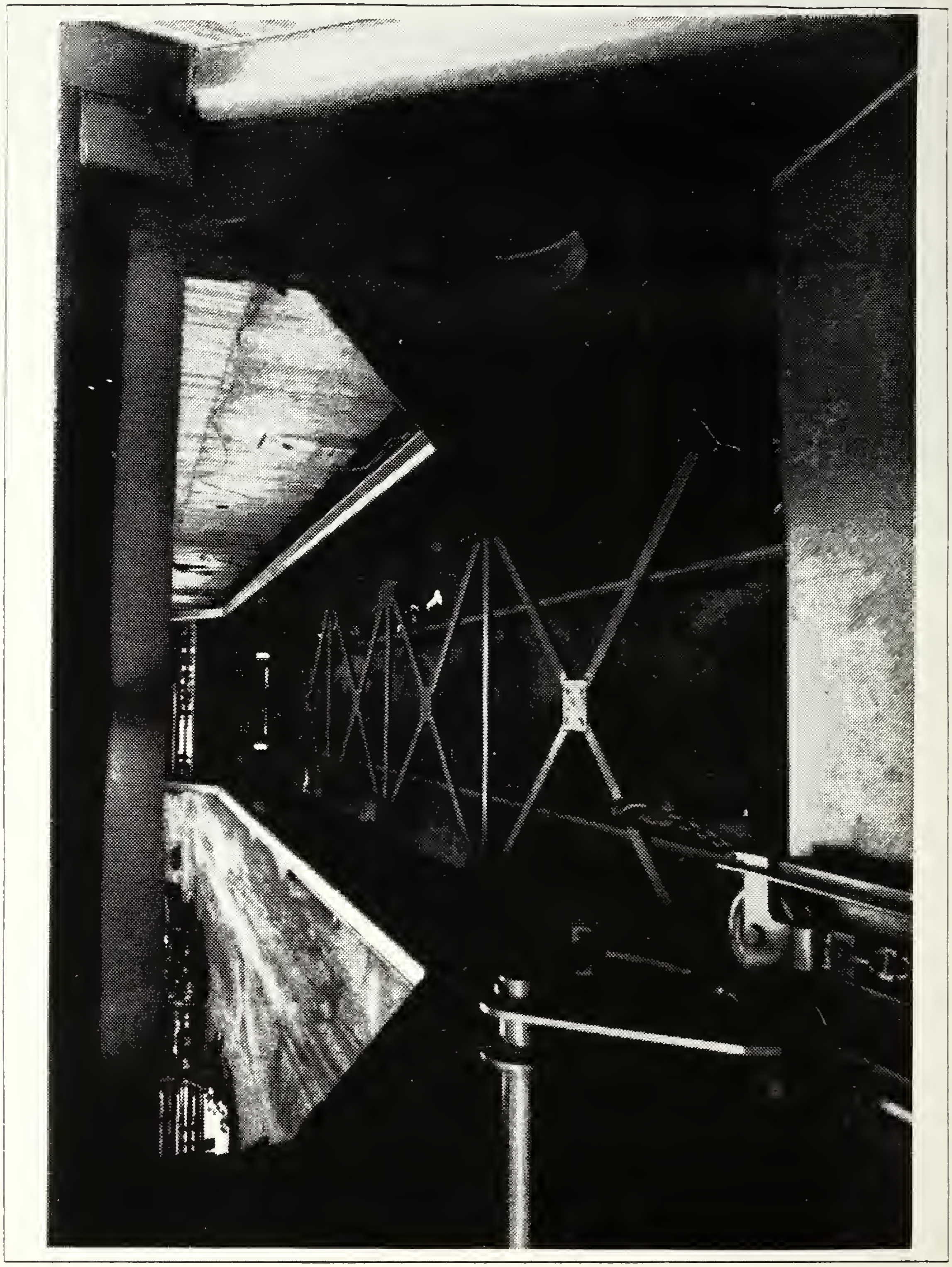

Figure 5.2 View of Gunderson Railcar's Open Well.

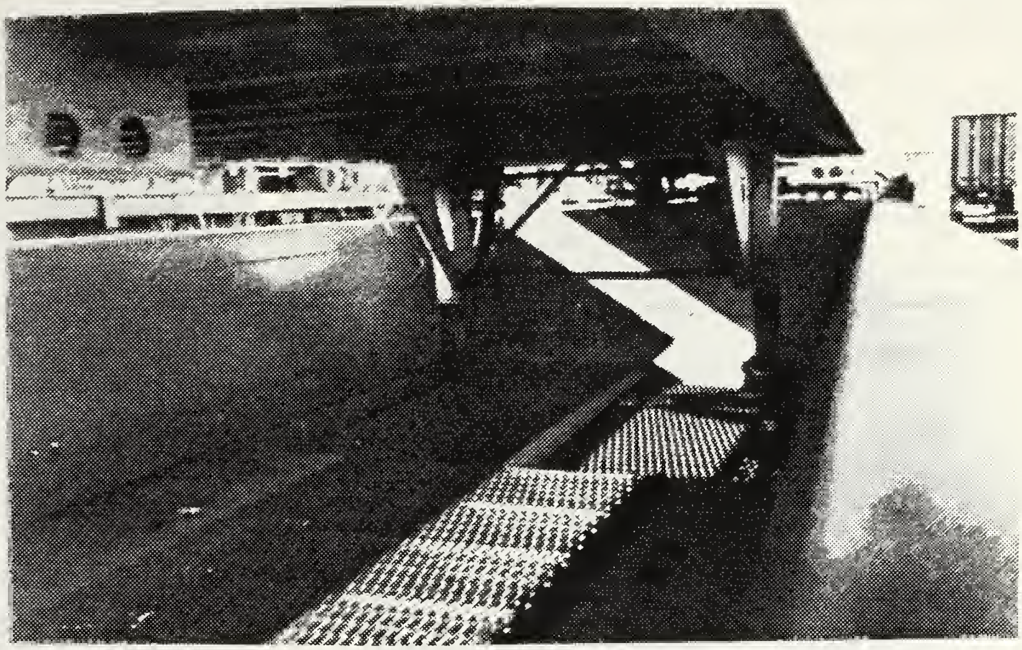

Figure 5.3 View of Thrall Railcar's Open Well.

B. DYNAMIC FORCES

1. Longitudinal

There are three basic types of movement that are seen in rail transportation: longitudinal, lateral, and vertical. APL offers a brief explanation of the benefits of their car (and, one would think, similarly equipped cars) in reducing the movement and forces in each of these directions as compared to movement on conventional intermodal cars. An understanding of these dynamic forces allows a better insight for the prospective customer when examining the new stack train rolling stock. [Ref. 15]

Longitudinal movement is created in switching rail cars for train make up and may occur at intermediate locations from the rail origin and destination when conventional cars are added. This also occurs due to the run-in and run-out of trains while they are in transit. This run-in and run-out is created due to standard intermodal rail cars having 15-inch end-of-car cushioning at the ends of each car consequeuntly, when the train is going downhill, it will contract so that nearly all of this extension is gone. This force is also seen when the train engineer is braking the train with the locomotive only rather than using the brakes on the rail cars. This is normally called

Figure 5.4 The Gunderson Twin-Stack Railcar.

dynamic braking and causes the train to contract when braking. If the engineer is not careful this contraction can be rapid and can create fairly significant logitudinal forces.

The normal size standard intermodal train is approximately 50 cars. In theory, at this size of train it is possible to see 125 feet of slack action when the end of car cushioning goes from the fully extended to the fully contracted position.

APL's (and Gunderson's) rail cars used in the stack train service are five-platform articulated rail cars. The articulated connection, which takes place at the intermediate ends of each platform is a fixed semi-permanent attachment. There is no slack to speak of at these locations. At the end of each car is 15-inch end-of-car cushioning (since changed to Cordwell Westinghouse H60 hydraulic draft gear with only 3 1/4 inches of travel.) The stack trains are normally operated with 20 of these five-platform articulated cars. In comparison to the standard intermodal train, these double-stack trains only have a theoretical slack distance of 50 feet. This significantly reduced slack distance also retards the longitudinal forces seen while trains are in transit.

2. APL Innovation

Recognizing that longitudinal forces created by run-in and run-out in train service can be a primary cause of lading damage during rail transportation, APL went one step further. The end of car cushioning is created by hydraulic fluid being transferred from one chamber to the next through 12 ports (or holes). Lock-out valves have been installed in 10 of these 12 ports which significantly reduces the flow of the hydraulic fluid between the chambers at low forces as experienced during in-train service created by the run-in and run-out of slack action. These valves make the end of car cushioning much stiffer at the lower forces and allows the run-in and run-out to be much slower and controlled as opposed to being relatively free and sloppy which can create quite a jarring effect at the ends of the travel of the end of car cushioning. The valves, on the other hand, will open up at higher impact forces which might be seen in train make up or while switching and allows the end of car cushioning to work as intended. To the best of their knowledge, the APL stack cars are only the second application of these valves in rail cars, due in large part to the expense of having them installed. Their use is widely recognized as an effort to reduce longitudinal forces created by slack action.

3. Rolling Movement

There is a rolling movement, known as lateral movement which is common in rail transportation and is created by the variation in height from one side of the track compared to the other side. In any rail service there is naturally a certain amount of roll that takes place. APL's stack train rail car, because of its articulated connectors at the intermediate ends of the platforms, significantly reduces this rolling movement as one platform rolls one direction and next one is rolling the opposite direction and the result is that the platforms counteract each other and tend to dampen the rolling effect. This is a condition that is well known for any articulated rail car design and does not apply specifically to APL's cars.

Results of tests performed at the Transportation Test Center in Pueblo, Colorado over the rock and roll section of trackage were very impressive. The car was loaded in a worst case configuration which had every other platform loaded to a very high combined center of gravity with the alternate platform loaded to a low center of gravity.

In this manner it was thought that the heavier and higher center of gravity platforms would not be affected as much by the lower center of gravity and lighter loaded platforms and, as a result, a higher degree of roll would result. Even under this severe condition the rolling movement was minimal.

4. Vertical Movement

Insofar as vertical movement of rail cars is concerned, no data are available for conventional flatcars to allow comparison with articulated stack cars. It is believed, however, by APL that a stack car would create a superior ride because the truck centers are 50 feet 6 inches and standard intermodal rail car truck centers are approximately 80 feet. This plus the reduced camber in the car body on APL cars should minimize the vertical accelerations or bouncing.

C. MANUFACTURER PROFILE

Gunderson, Inc. has had some media exposure and serves as a convenient example from which to sketch an industry profile. A member of the Greenbriar Leasing Corporation, which includes the subsidiaries Greenbrier Intermodal, Greenbrier Capital, and Gunderson, Inc., produced 1450 container carrying platforms in 1985 since its startup March 1 and purchase of FMC Corp's Marine and Rail Equipment Division in Portland, Oregon. An advantage is the fact that Gunderson's fellow subsidiary, Greenbriar Intermodal, is dedicated to developing the market for the Twin-Stack container rail car, having had total sales for the period exceeding $45 million. Located along the Willamette River in Portland, Gunderson's 75 acre facility has 750,000 square feet of manufacturing space and a capacity of 6,000 cars per year. Greenbriar Leasing was Gunderson's first Twin-Stack customer for 100 platforms. These were, in turn, provided under short term lease to Burlington Northern and Sea-Land. Greenbriar also uses their cars as marketing tools to aquaint prospective customers with Twin-Stack performance. At its peak backlog last summer, Gunderson was constructing Twin-Stack cars at the rate of 12 platforms per day to meet early delivery schedules required by customers anxious to implement or expand their double-stack transportation programs. [Ref. 16: pp. 30,32]

D. COMPARISON BETWEEN CONTAINER RESTRAINING SYSTEMS

1. Similarities

As previously mentioned, the primary difference between the Thrall car and the Gunderson car is the use of IBC's and bulkheads, respectively, for holding the top containers in place. Since both cars are reasonably close in dimension (with some length and aerodynamic considerations addressed later), load bearing capacity, and adaptability to all container sizes (20, 40, 45, 48-foot), the two different container restraining systems bear further attention.

2. Groundsmen

An Arthur D. Little, Inc. study dated March 7, 1986 and commissioned by Greenbriar offers an examination of the differences between car types [Ref. 17: pp. 1-8]. The source of their study consisted of observations made at ten terminal locations, two operating only IBC cars, seven operating only bulkhead cars, and one operating both. Loading and unloading operations were observed. Groundsmen were employed at 80 per cent of observed double-stack terminal operations that included all IBC car operations and five of eight bulkhead car operations. These goundsmen are essential for operating the IBC car because the top containers on these cars must be secured by four inter-box connecting devices, and groundmen are required to manually install, lock, unlock, and remove the IBCs at the corners of the bottom box. The groundsmen are not required for bulkhead car operation. At the five bulkhead car operations, Arthur D. Little, Inc. reports that they were there due to work rules or because they were working on other conventional equipment. The number of groundsmen used with the one IBC car ranges from one to three per crew. Potential cost savings due to the extra crewmens' wages and reduced liability were noted. The actual figures noted by Arthur D. Little are omitted here because, without more complete cost data for other areas of operation and exact equipment purchase prices, listing partial data to promote a particular vendor's equipment would be unfair.

3. **Theft Protection**

The study further notes that the issue of protection from container theft was repeatedly raised in their interviews. When containers are placed on a bulkhead equipped car, the container doors become very difficult to break open because of the presence of bulkheads and flippers (needed as spacers to accomodate different container lengths with one car size). With the IBC equipped car, it was noted, the platform used by groundmen in loading and unloading is also convenient for thiefs and vandals in removing lading. There are no bulkheads to protect the container doors from being opened. Their report notes that the assistant terminal manager of a Chicago terminal cites weekly break-ins, while terminals using bulkhead cars reported little or no theft, largely attributed to the bulkheads.

4. **Cycle Loading**

A new type of container loading and unloading technique has been linked to car type as well. Cycle loading is claimed to significantly enhance the value of double-stack cars. After initial unloading to create space, each platform level (both upper and lower) is unloaded and then the same platform is reloaded again, as equipment is moved rapidly down a block-loaded train. The conventional loading/unloading method requires that the entire train is first stripped prior to any reloading. Loader crews travel twice the distance as they have to traverse the entire length of the train to reload, a considerable distance when contemplating mile-long stack trains. In cycle loading, chassis are never empty, and only slightly more than half the number of chassis and drays required for conventional loading are used. This is a critical consideration in maintaining tight chassis pool management and aids in the balancing of available chassis. Cycle loading can be used with both IBC and bulkhead cars, resulting in lower costs for the steamship lines. However, Arthur D. Little, Inc. found that terminal operators are not cycle loading with the IBC car, ostensibly because cycle loading was found not to be as cost effective using IBC railcars. This conclusion was unsubstantiated in the report and, therefore, may be discounted as the conclusive reason for not cycle loading IBC equipped railcars. In conclusion, it was found from the study that the bulkhead car eliminates ground personnel costs, reduces exposure to liability, minimizes the liklihood of pilferage, and is more cost effectively utilized through cycle loading.

E. LINE-HAUL OPERATING EFFICIENCIES

1. Fuel Consumption

The next area for review concerns double-stack equipment line-haul operating efficiency. Several recent studies warrant mention. The first, by John H. Williams and Judith H. Roberts of the Woodside Consulting Group, generated comparative data between hypothetical intermodal runs from Los Angeles to Chicago for double-stack equipment, conventional COFC, TOFC, and trailer and container-on-lightweight car utilizing a computerized rail cost model to determine each of the variable operating costs. Fuel consumption was shown to be 32 percent of over-the-road truck fuel consumption, 16 percent better than conventional COFC and 12 percent better than lightweight COFC (lightweight COFC/TOFC represent the new skeletonized ultralight single container or trailer on flatcar technology). Double-stack rail service was also found to be competitive in total trip time, 53 hours (includes loading unloading) versus 50.3 hours for over-the-road truck. Without unnecessary detail, primary cost components for double-stacks were found to be 59 percent of total conventional COFC costs. The study concluded that, as service speed had become competitive with over-the-road truck, COFC double-stack service can effectively divert a greater share of the truck freight market. Although actual costs in cents per mile were not shown in this study they will be addressed at a later chapter. [Ref. 18: pp. 242-248]

2. Streamlining, Weight Reduction, and Articulation

Also of interest is the effect streamlining, weight reduction, and articulation have upon train sets of intermodal cars and how much double-stack cars have advanced in fuel savings as a result of each factor. A study Fuel Use Simulations of High Productivity Container Trains by Daniel S. Smith of Manalytics, Inc., has taken an engineered rail cost model (RCM) to estimate round trip fuel consumption for existing double-stack container trains and hypothetical integral intermodal trains between Los Angeles and Chicago [Ref. 19: pp. 236-241]. The observations and conclusions reached concerning double-stack train design and the efficiency value of each type of improvement are of greatest concern. The base case selected for the analysis was a double-stack, cabooseless container train similar to those in use by

American President Lines and Sea-Land Service, i.e., the Thrall and Gunderson cars respectively. The base case train consisted of 20 cars, each composed of five articulated platforms or wells carrying stacked 45-foot marine containers. Platform tare was set at 28,000 pounds, container tare at 8,550 pounds each, and lading at the average highway load restriction load limit of 43,000 pounds each. The total loaded car, therefore, came to 131,000 pounds with two stacked 45-foot containers. The net tare ratio, by the way, is an impressive 86,000/45,100 or 1.91, as compared to a conventional piggyback net/tare ratio of just .67. Model runs were made by changing one factor and holding the others constant. One pass was used to guage the influence of articulating the entire train (as if the whole train were one car) saving one truck per car or a total of 20 trucks per train. One run was conducted just to show the effects of streamlining by using an equation coefficient simulating trailing cars in a passenger train. This was compared to a base case coefficient that represents boxcar wind resistance as no coefficient has been scientifically developed for stack trains and, logically, loaded stack train cars most closely simulate boxcars. The impact on tare weight was analyzed by comparing the 28,000 pound current double-stack conventional average with a 23,000 and 18,000 pound theoretically improved car model. Other runs were made with integration of motive power (power units on platforms instead of separate conventional locomotives) and multiple combinations of the aforementioned changes.

The results were as expected. Car weight had the greatest impact (3.6 percent fuel saved), followed by streamlining (1.1 percent), and lastly, full articulation, contributing only .7 percent fuel savings. The actual percentages are valuable in that they can be compared to each other to see how much each contributed relative to fuel savings. The actual numbers are meaningless in this thesis, however, for determining fuel savings of double-stacks vis-a-vis conventional COFC since the computer runs were designed to determine how much further an integral train would benefit fuel savings beyond a base case stack train. The effect of integration or articulation which reduced the number of axles was very small. The savings accrued through streamlining were equally modest. The effect of streamlining varies with the square of velocity. The base case and streamlined trains were modelled averaging 48 to 49 MPH when moving. Speed limits varied between 50 and 70 MPH, depending on terrain, but the train did not always reach the limit when running upgrade. Also, some railroads have restricted double-stack trains to 60 MPH due to their high gross weight per operating brake. If the average speed were raised to 60 MPH, according to Mr. Smith, air resistance would increase by 53 percent and streamlining would be more important.

One conclusion that this study has made clear is that double-stack container trains are dominated by their loads. The containers and lading account for 85 percent of the weight and 92 percent of the air resistance in the lightest-car model (18,000 pound tare). The requirements for motive power are determined by the train's load, not its tare. In fact, the double-stack car design is already so spartan that its sole function is to keep the containers over the railroad wheels and connected together in a train. It offers no protection from the elements, and no support or containment for the lading itself. Aside from some additional minor weight savings, it seems reasonable to conclude that the double-stack equipment currently being offered represents a new constant in efficiency that will set a benchmark for the industry.

3. Streamlining Improvements

Although the paring of tare weight from stack car designs has nearly reached its practical limit, further efforts are still underway to squeeze more fuel efficiency from streamlining. Airflow Sciences Corporation of Livonia, Michigan has performed wind tunnel tests with scale models of Gunderson's Twin-Stack articulated well cars that have measured air resistance to their standard units as well as to modified units with the addition of thick and thin spacer blocks attached to the tops of the bulkheads to reduce the between car voids and associated wind turbulance. [Ref. 20: pp. 1-4]

Wind tunnel work at Lockheed-Georgia in 1983 found that, for well cars carrying containers, the size of the gap between loads on adjacent cars was the major variable. Streamlining of the containers themselves was shown to be of minor significance. At 60 MPH, a sharp break in resistance occured between gaps of 75 and 45 inches, with the reduced gap lowering air resistance by as much as 50 percent. The wheelbase of a standard 100-ton truck is 70 inches. Therefore, containers in articulated well-type cars cannot be closer than about 100 inches, especially if both upper and lower containers are the same length. Reduction or virtual elimination of this gap with filler is the aim of the thick block thin sheet experiments at Airflow Sciences Corp.

The testing was accomplished assuming an average yaw angle of five degrees to simulate typical cross-wind conditions. Base on a study by Dr. Frank Buckley of the University of Maryland, it was concluded that five degrees is a representative average yaw angle for vehicles travelling at 55 MPH in the continental United States. The tests were performed upon scale models at 120 MPH winds which translated to true scale speeds of 19.2 MPH. Three car arrangements were used to allow the fore and aft cars to produce a first-order representation of the remaining train's interference effect. Data were also compared to a 1983 Thrall car test at Lockheed using 30 percent scale models. Conversion calculations were performed to align their data to parallel the 16 percent Airflow Sciences Corp. tests.

The drag area between end-of-car units was found to be more than double the drag area between intermediate articulated units (45.8 square feet versus 21.5 square feet). The difference was due to the increased gap distance between 40-foot container faces. Between intermediate units, a gap distance of 10 feet exists between 40-foot container faces whereas, between end units, a gap distance as large as 25 foot exists.

The estimated drag area for a five-platform Thrall car (as converted from the 1983 test) is 166.7 square feet, 26 percent greater than the Twin-Stack car without aerodynamic modification (131.8 square feet) and 77 percent greater than the Twin-Stack's best aerodynamic modification for 45-foot containers (93.9 square feet).

Drawbar force calculations utilizing car weights of 31,000 pounds for the Thrall car, 35,000 pounds for the Twin-Stack without aero, and 36,000 pounds for the Twin-Stack with aero modification reveal almost equal drawbar pull at 40 MPH between the Thrall and Twin-Stack cars (1620 pounds versus 1507 pounds) but a quickly growing advantage for the Gunderson car at 60 MPH due to the apparent advantages of reduced air turbulance between container platforms (Twin Stack 2181 pounds versus Thrall car 2472 pounds).

Using an equation to determine gallons of fuel consumed per 100,000 miles that takes into account the drag area variations and a function for fuel use in hill climbing, braking, and acceleration, Airflow Sciences Corp. determined that at 60 MPH a Twin-Stack car would require 53,520 gallons per 100,000 miles whereas a Thrall car would use 59,160 gallons, or an increase of 5,640 gallons per car. The 45-foot aerodynamic modifications would enhance fuel savings by an amazing 6,870 additional gallons, or 46,650 gallons total. Considering the earlier work by Manalytics in highlighting the emphasis car weight appeared to have over the effects of streamlining, the difference in car weight of 4,000 pounds (31,000 pounds for the Thrall car versus 35,000 pounds for the Twin-Stack) apparently did not influence the Airflow Sciences Corp.'s calculations as much as expected. However incredulous one may be of the results the wind tunnel rests also ascertain the value of streamlining at higher speeds and the potential for improvement that the Gunderson car has in that area.

F. STAND-ALONE RAILCAR DESIGNS

Over the near horizan, car manufacturers and marketing leasing firms are keenly examining the development of "stand-alone" well cars designed to couple platform to platform without articulation. The primary motivation for this last area of opportunity is to enable carriers to haul two weighed-out containers at the same time. Present well car load limits either require cutting off loading containers to their limits of about 67,000 pounds or mixing one 'light' and one 'heavy' container per platform (as most current loading procedures call for) to prevent overstressing. As aggressive marketing of double-stack service seeks to attract the weight-limited commodity groups such as canned goods, wine, dry prepared foods, and so forth, carriers will want to be ready to offer this service safely. As top loads of domestic 48-foot boxes become more popular, weight limitations will more readily present themselves. Trailer Train has developed designs for three different stand-alone double-stack cars capable of handling two 48-foot containers. [Ref. 21: p. 22]

Thrall Car Manufacturing Company has delivered the first prototype to undergo static, dynamic, and field testing at Hammond, Indiana, and at the Transportation Test Center at Pueblo, Colorado. It is expected for the wells to permit load limits above 135,000 pounds. The lightweight trucks of the first prototype are a frame structure guiding two single axles under each end of the car. By letting the axles support the car at the sides instead of through a center pin, stability should be improved. The axles are 32 inches apart and carry 28 inch wheels. Swing hangars and leaf springs are used as suspension, and a damper spring or hydraulic device will be used to control 'truck hunting' (the phenomenon in which the slack between the wheel flanges and track width allow the truck to twist as it is guided down the track). The first prototype uses 15-inch end-of-car cushioning and comes in at a tare weight of 50,000 pounds (possibly cut to 45,000 pounds with some design modifications). The first and second prototype car use IBCs, with a third to use bulkheads. [Ref. 21: p. 22]

G. ACCELERATED TRACKWEAR

One very important issue of industry-wide concern to the railroads is the potential for accelerated track wear or even damage posed by the introduction and widespread use of heavy load-bearing stand-alone stack cars. Time was when the movement of 79,000-pound-per-axle equipment was confined to isolated unit coal operations which could be safely ignored with respect to potential for widespread uncontrolled use. But with 40-foot double-stacked containers, each loaded to its 67,000 pound maximum cargo, the load on one truck (including tare) would be over 168,000 pounds (articulated unit), equivalent to a load of 330,000 pounds on a four-axle car and well over the 125-ton capacity heavy coal cars presently in limited route use. Further, 20-foot containers could be loaded to 52,800 pounds. If four were seated on an intermediate platform of a five-unit articulated car the total load would be 241,200-pounds on one truck, the same as over 480,000-pounds on four axles and far beyond any railroad's experience. If load-capable stack cars are fitted with 125-ton trucks, that possibility could be achieved. [Ref. 22: p. 39]

One example of long-term heavy equipment use is that of Detroit Edison's unit train operations on Conrail's Waynesburg Southern line of the Monongahela Railway. Since 1969, steady use of their 125-ton capacity coal hoppers has led Conrail to determine that rail life was reduced two to seven times what it would have been under normal 100-ton car operations. Only by installing a premium class of track and instituting a high level of inspection has the use of this captive equipment become feasible. [Ref. 22: p. 39]

The rail deterioration apparently stems from fatigue rather than wear, in which a 'nominal' increase in wheel load produces a very large reduction in rail life owing to the highly elastic character of the fatigue factor. Below 28,000-pound axle loads (80-ton car), rail life is determined by wear life (i.e., 1100 million gross tons (MGTs) at 28,000-pounds and not much higher as loads drop). Above 28,000-pound axle loads (greater than 80-ton cars), rail life is determined by fatigue (i.e., rail life drops rapidly with little increase in axle loads as, for example, 33,000-pound axle load (100-ton car) fatigues rail after just 300 MGTs). [Ref. 22: p. 40]

The quick answer to head off such decline would be to use heat-treated, special metallurgy rail in the relevant stretches together with the newer profiling techniques of the rail head that maintain centered wheel loads. These approaches, however, will not protect track structures against fast deterioration, where in isolated cases, it has been estimated that bridge life has been reduced from decades to less than 20 years due only to the effect of higher wheel loadings. [Ref. 22: p. 40]

The rail life issue should promise to add a measure of complexity to the evolution of the next generation of double-stack rail equipment insofar as it will bring the railroads, interested in preserving their track and not investing heavily in upgrading their entire network, into conflict with the ocean carriers, hell-bent on squeezing maximum efficiency out of their contracted overland rail partners.

VI. EXEMPT RAIL TRANSPORTATION AGREEMENTS

The exempt rail transportation agreement is the legal precedent upon which the economic vitality of the new ocean carrier-double-stack-rail intermodal organization is founded. Without this cooperative agreement, the many traditional encumbrances previously sacrosant in interstate commerce regulation would have prevented either mode of carrier from taking advantage of the efficiencies inherent therein.

Proprietary data rights prevent publishing the actual carrier's names in the analysis of the following recently negotiated contract between an ocean carrier and several railroads. Close inspection of a typical steamship line/railroad contract provides significant insight into the parameters that mold the scheduling, frequency, and management of the double-stack service network.

The railroads have agreed to provide round trip rail transportation of loaded or empty containers ("or empty" i.e., no loading of cargo at the convenience of the rail carrier without control of the ocean carrier) between major listed cities. Such round trip shipments shall move in multiplatform railcar trains ("multiplatform railcar" spcifically demanded, implying expedited handling of containers in express, tightly coordinated unit trains as associated with that equipment). [Ref. 6: p. 1]

The transportation services are provided by the railroads in exchange for a commitment by the ocean carrier to tender certain minimum numbers of round trip movements for linehaul via the railroads and pay the tariff schedules listed in the contract. Tendering of the minimum volume is considered a material consideration and inducement, without which the railroads would not agree to give up their marketing rights to a large volume of container cubes traveling over their rails. [Ref. 6: p. 1]

In addition to rail linehaul services, the railroads agree to load onto, secure, and unload from multiplatform railcars the ocean carrier's containers. Any paperwork and terminal movement of containers will also be handled by the railroads. [Ref. 6: pp. 2-3]

The railroad shall furnish the ocean carrier a specified quantity of multiplatform railcars built for Trailer Train and assigned to that railroad. Mileage and car hire charges are to be paid by the ocean carrier to the railroad for the railroad's use in hauling the ocean carrier's containers. However, should the ocean carrier's volumes of traffic tendered fall below contract minimum or should the ocean carrier terminate the contract prior to the agreed upon termination date, the ocean carrier shall be liable for all car hire charges up to the previously agreed upon contract termination date, with credit applied toward the account for any alternative use the railroads or Trailer Train can find for the cars (this means that the ocean carrier is liable for the rental of the railcar equipment at onset of the contract through termination regardless of outcome, freeing the railroads from any financial risk whatsoever in this venture). [Ref. 6: pp. 3-4]

Additionally, the ocean carrier must tender the railroad cars to the railroads for a minimum of 45 round trips per twelve month period or be subject to a "shortage" charge for not allowing the railroads to meet the minimum transportation requirement. [Ref. 6: p. 4]

In exchange for the rail transportation furnished by the railroads under the agreement, the ocean carrier shall pay a rate per round trip per multiplatform railcar based on 100 percent loaded containers eastbound and 0 percent loaded containers westbound with small additive charges assessed for westbound loaded containers. These rates are then escalated based upon price indexes for fuel and non-fuel, wages, wage supplements, materials and supplies, and other operating expenses. [Ref. 6: pp. 5-7,12]

Under deregulation, the terms of the agreements and the rates are considered confidential between negotiating parties. The same ocean carrier can, therefore, earnestly negotiate with each regional rail carrier for the most favorable provisions and rates. This leads to one carrier paying different rates and working within differing sets of restrictions with each participating rail carrier.

It appears, then, that the railroads have essentially traded their control of marketing the cube of available empty containers directly to retail customers in exchange for a no-risk multiplatform railcar hauling contract for transporting their (i.e., ocean carriers') containers. Given that a particular railroad's organization has a finite capacity for engaging in business activity, the decision to concentrate on fixed fee contracts with ocean carriers has signaled a migration in strategy from a competitive, high-risk, value-of-goods pricing scheme in the retail marketing of transportation services to a relatively low-risk environment involving wholesale marketing of transportation services at a fixed return. The railroads involving themselves heavily in steamship line contracts, therefore, have given up the 'opportunity' for large profits (which the railroads haven't seen since carpetbagger days anyway) in exchange for guaranteed volume and a reasonable profit.

The ocean carrier has gained a measure of control and influence over the rail carrier that enables the steamship line to influence the manner in which the rail carriers handle their containers in their yards and how they prioritize their train schedules to meet vessel sailings. In this way, for a certain fixed profit, the railroads become an arm, albeit loosely affiliated, of the ocean carrier.

VII. MILITARY SERVICE CONSIDERATIONS

A. MILITARY CARGO RATE CONSIDERATIONS

In conjunction with researching the development and make-up of double-stack container train service, an opinion survey of personnel at the Military Traffic Management Command-Western Area's (MTMC-WA) Military Export Cargo Offering Booking Office, the Military Sealift Command-Pacific's (MSC-PAC) Contracting Office, and American President Line's military cargo sales representative, revealed that intermodal container rates, as provided for the military shipper in the MSC Container Agreement & Rate Guide, had not changed significantly as a result of the introduction of double-stack train service. Military cargo being primarily werstbound for export to overseas bases, the container space had been and continues to be priced at or near marginal costs (floor price that covers only variable costs). Furthermore, the depressing effect upon rates of the ongoing excess of Pacific Basin container service has had an overshadowing effect on any potential impact that stack train economics may have had. The result, therefore, is that personnel working with the Container Rate Guide have noticed no drop in rates due to introduction of double-stack train service.

B. MILITARY SERVICE APPLICATIONS OF STACK TRAIN TECHNOLOGY

Military service applications of double-stack technology are awaiting a rigorous comparison of the stack car's unique features with the military service's peacetime and mobilization requirements. Although the primary force behind its development was efficient and economic bulk transport of containers, certain features, such as the car's shorter length over conventional flatcars that carry two containers end to end, may allow stack cars to perform military missions. Perhaps during a mobilization scenario, a certain port's yard space would not have allowed two hundred containers carried conventionally to be offloaded from two long trains at once. But a single stack train would concentrate more containers to be offloaded per section of pier apron and help widen a logistics bottleneck.

Unique features, such as the Gunderson car's Twin-Stack bulkheads, would make containerized ammunition shipments more pilfer proof, for example. The Military Traffic Management Command's (MTMC) Transportation Engineering Agency (TEA) in Newport News, Virginia has been commissioned to study the impact of double-stacking railcars on the defense transportation system. The study will also determine optimal utilization of double-stacking railcars for military applications.

VIII. TERMINAL EFFICIENCY ISSUES CONCERNING STACK TRAINS

A. INTRODUCTION

The issue of terminal efficiency has been raised by the double-stack train's increased ability to dump large volumes of containers into a rail or marine yard at one time. An examination of the issues and developments in rail and marine terminal design are valuable at this point.

B. RAILROAD YARDS

1. Global I

First, the issues related to development of the intermodal container system will be discussed. Global I, as mentioned in Chapter IV, is the Chicago & North Western Railroad's new double-stack-only railroad container train handling facility located at the former Wood Street and Robey Street Yards. Named Global I in recognition of the international cargo movement through the yard, the railroads have been coming to the realization that, with the current state of affairs, even the Chicago facility is nothing more than an extension of an ocean carrier's turning basin for containers. Steamship lines were consulted to aid in the most efficient design of the ultramodern facility. [Ref. 10: pp. 32-33]

Innovative track configuration is central to the yard's operation. Having three parallel tracks will simplify the unloading of double-stack trains through a process called "stop and swap" as illustrated in Figure 8.1. With a double-stack train on the middle track, and conventional TOFC cars on the two tracks alongside, containers can be transferred from the double-stack track to the other trains with a minimal amount of handling. An overhead crane, with an inside clearance of 66 feet, will straddle the three tracks, as well as one chassis lane on each side. It can transfer containers from the stack train onto chassis, either for road delivery or to be placed on one of the TOFC cars for rail delivery. [Ref. 10: p. 33]

Roughly 30 percent of the yard's container volume leaves by rail, with the remainder departing over-the-road. The majority of outbound containers are distributed to final destination within 300 miles of Chicago. This makes the ease of container transfer feature of the new facility layout so important. [Ref. 10: p. 33]

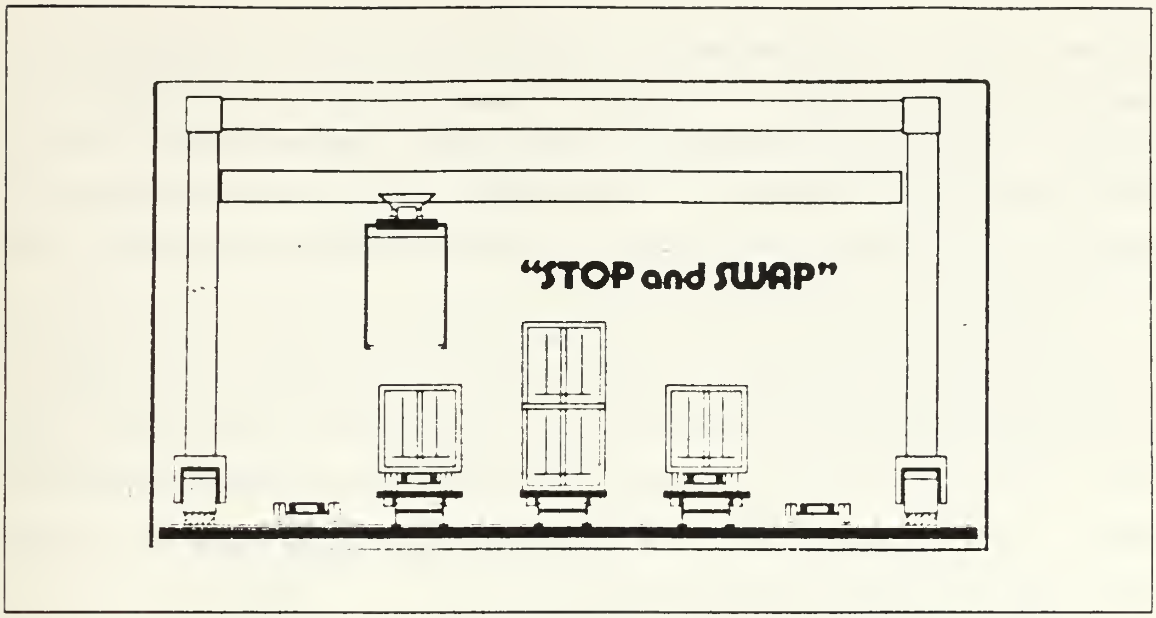

Figure 8.1 New Global I Gantry Crane.

Four sets of tracks equipped with the new gantry cranes, model MJ1000DS built by Mi-Jack, can accommodate 10 five-unit cars each. An additional area can handle another 22 cars with existing overhead cranes and conventional side loaders. [Ref. 10: p. 33]

Another feature of the new yard is the fact that containers aren't stacked. All containers are on chassis and are driven out of or around the yard by tractors. This highlights the continuous flow goal of new terminal design. The majority of containers are expected to cycle through the yard within hours of arrival, assuring the fast turnaround necessary for a seven day Chicago/West Coast round trip schedule. Any delay in round trip time would have required the acquisition of additional expensive railcar sets to meet vessel sailing schedules. [Ref. 10: p. 33]

Interestingly, efficiency more than speed has been the result of the Global I facility. The unload/load time for one stack train remains 12 hours, but at a much lower cost with the new capital intensive equipment. Also, with the ability to simultaneously handle three 200 container stack trains in 12 hours, the yard now boasts an annual throughput capacity of 876,000 containers. The true operational limitation has been shifted to the speed and capacity constraints of the other segments of the transportation system, i.e., the port loading facilities at one end and the customer's ability to handle his freight and get it out the door at the other end. The stack train has had the effect of enlarging the conduit diameter in the journey leg by enabling a larger slug of containers to be delivered more quickly than before and puts greater emphasis upon terminal handling facilities. As terminals are upgraded, the network constraints will continually shift to whichever is the most antiquated and inefficient facility. [Ref. 10: pp. 33-34]

This quickened container transfer pace has required more intensive management control of operations and tighter coordination between carriers. Weekly, the C&NW management at Global I meets with vessel operators to map out a game plan. Computer links with western ports allow C&NW to know the exact makeup of trains two days before they arrive and any modifications to port calls based on storms at sea or other constraints. [Ref. 10: p. 34]

Electronic advance-receipt of paperwork and processing the driver's outbound paperwork at check-in time all help to remove stop points in the container's travel through the yard. [Ref. 10: p. 34]

Preloading is done whenever a shipper buys spare sets of cars and leaves them at the yard. Some pre-load as much as one-half to three-quarters of a train consist. This dramatically cuts turnaround time. All these techniques have been developed to reduce the chance of vessel delays in port. In essence, the influence of the ocean carrier has now been felt by railroads as far inland as Chicago insofar as the justification for the $36 million expenditure for these improvements stems from the high cost of vessel delay incurred by the steamship operator, not the railroad. The insulation between the two modes of transportation has finally been broken, wherein the potential penalty costs of vessel delay are traded for a smaller additional charge for more intensive, expedited railroad equipment operation. [Ref. 10: p. 34]

Just like a false floor beneath a computer installation, the C&NW yard is asphalt paved, not cemented, to allow for inexpensive remodelling as improvements are already envisioned. Fully computerized loading gantries that are guided by imbedded wire, and computerized sorting, watching, and positioning of trailers are just two of many hands off container handling innovations foreseen in the future. [Ref. 10: p. 34]

2. Hub And Spoke Route System

Another disappearing entity is the "circus ramp" style terminal for TOFC and container-on-chassis-on-flatcar unloading. Named for the method used by circus trains to unload their cars, a ramp would be constructed at a spur and car crossover plates would allow tractors to drive off trailers over connected flatcars to one exit ramp. The requirement for speedy delivery, as exemplified by tight stack train schedules, has doomed the circus ramp terminals to obsolescence. The many stops required by an intermodal train to service the multitude of circus ramps tremendously slows delivery of the final destination trailers. What has replaced circus ramps is the new "hub and spoke" system whereby express trains deliver to a few major hub terminals from which final delivery by truck is arranged. Although the truck leg maybe slightly longer, the rail leg has been dramatically shortened in time. This concept further clears the way for stack trains to service a greater number of routes in the developing domestic containerized freight network. [Ref. 23: p. 58]

C. MARINE TERMINALS

1. Introduction

In addition to the inland railyard having to become more efficient to accommodate stack trains, so too must marine terminals handling the new 4500-TEU ships. In effect, the marine terminal must quickly and efficiently convert a 4500-TEU mega-ship load of containers into a string of outbound 200 container (400-TEU) mini-ship loads onboard stack trains.

Most significant in this trend has been the activity along the Pacific Coast wherein railroads and port authorities are cooperating in establishing large railyards at or near the port areas. The impetus appears to be the crucial solicitation of domestic cargo via price, service, or a combination for the westbound trip in order to make the concept overwhelmingly attractive to shippers as well as carriers. The meshing of import and domestic traffic in the form of containers at these facilities is causing many handling problems for the yards that possess neither the storage areas required nor the room to expand. This has already developed pressures toward fewer but larger terminals and more efficient handling equipment at Seattle, Tacoma, Oakland, and most recently Los Angeles. [Ref. 24: p. 39]

2. Intermodal Container Transfer Facility

The most notable example of these new facilities is the Intermodal Container Transfer Facility (ICTF), a $62 million joint project of Southern Pacific and the ports of Los Angeles and Long Beach. When completed, the 150-acre facility is expected to handle 360,000 containers annually. It has five operating tracks, center-aisle parking and two run-around tracks, a combination that will permit the prestaging of loads for an 84-car double-stack train. The complex will include 10 buildings, a six-story control tower and a 16-lane inspection building with Customs accommodations. The entire terminal will be radio-and TV-monitored for 24 hours, seven days a week operation. A view of the ICTF is shown in Figure 8.2. [Ref. 24: p. 40]

Such "load centers" are ideal in that they: [Ref. 24: p. 40]

1) Serve a large metropolitan population market.
2) Have a well-located harbor with good port facilities.
3) Feature a suitable inland infrastructure for trucks and railroads.
4) Can call on nearby support from freight forwarders, brokers, and banks.

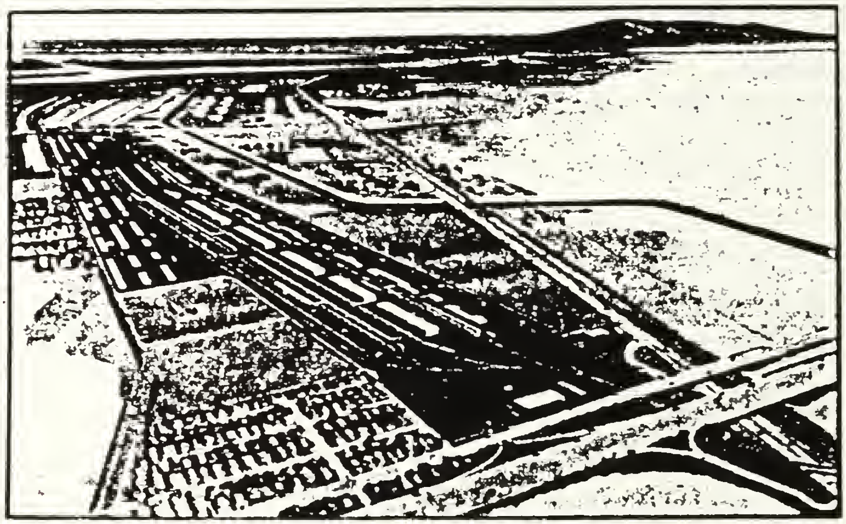

Figure 8.2 The Intermodal Container Transfer Facility.

Dockside water depths will allow access by future 5500-TEU vessels. Ship loading gantry cranes will be able to reach over 16 rows of containers stacked four high on a ship's deck, with 12 rows stacked nine high in the hold. That means an outreach to 140-feet or more in which multiple boxes are transferred at high throughput rates. These "fourth generation" cranes will be rated at 40 long tons in capacity. [Ref. 24: p. 40]

Such productivity rates extend to a capability for loading and unloading 800 to 1000 40- to 45-foot containers every 24 hours. By comparison, inland terminals such as the old C&NW yard in Chicago are rated highly efficient in handling 600 boxes per day (the new Global I rate translates theoretically to 1200 containers per 24 hour period). [Refs. 24,10: pp. 40,36]

3. On-Dock Transfer

The new facilities can be expected to eventually incorporate direct vessel-to-rail movements, overcoming, in the process, "place of rest" concerns. The number of movements, or steps, a container must go through from lift out of the vessel container slot to the final load onto an over-the-road truck chassis or rail is the most important determinant in measuring terminal efficiency. Both containerships and double-stack trains are highly specialized systems for container transportation. Getting the most efficiency out of both systems from a single terminal is a difficult process. [Ref. 24: p. 40]

Current terminal buffer operations typically require at least two lifts and a drayage. One lift off the vessel to a yard chassis, then a temporary storage followed by a dray out of the gate to a rail terminal for lift onto an intermodal railcar are the minimum steps currently taken. Some port facilities have additional storage or a long dray as additional inconveniences. No North American port has maintained a direct ship-to-rail transfer of significant volume or duration. A properly sorted rail train consist cannot be practically loaded under a vessel container lift crane without significant jockeying of an unwieldly train set. The on-dock transfer systems use either a vehicle or ground storage as an intermediary between the ship and the railroad cars. [Ref. 25: pp. 1-2]

The objective of on-dock transfer is to reduce the cost, time, and administrative effort required to shift containers between the ship and the railroad. The major cost elements in container transfer are terminal space and facilities, container lifting and moving equipment, the number of container lifts, and the number of drayage hookups and drops. The time taken for each operation affects both cost and service quality. The theoretical advantages of on-dock transfer lie in the complete elimination of one or more operations from the chain of lifts and moves required between ship and rail. However, the advent of dedicated double-stack trains has encouraged railroads to expand off-dock ICTFs to avoid separating the mile-long trains. The railroads want to minimize switching and sorting, and so might be amenable to handling a full train on-dock, if it would fit. Perhaps blocks of six to ten double-stack cars dedicated to specific customers may allow railroads to serve less-than-trainload, single user terminals while keeping switching and sorting costs to a minimum. [Ref. 25: pp. 2,10]

Because of various limitations, the physical dray between ship and rail cannot be readily eliminated. What can be eliminated by co-locating rail facilities, for example, are the gate barriers, the use of highway licensed and equipped drayage equipment, and the loading restrictions imposed by highway weight limits. Double-stack trains, or sets of dedicated double-stack cars, can be efficiently handled at on-dock transfers where sufficient volume is available to outweigh the rail switching costs and minimize any re-sorting or topping-off requirements. [Ref. 25: pp. 14,17]

D. CONCLUSION

It has been shown that vast sums of money and significant design efforts are being expended in the development of rail and marine terminal efficiency. When complete and fine-tuned to accept the volumes of containers that mega-ships and double-stack trains can surge through their facilities, a network will emerge that will consist of just a handful of super-high volume, super-efficient, container handling facilities through which the vast majority of U.S. import/export and transcontinental domestic container cargo will move. Double-stack development has helped point out the absolute necessity for investment in these facilities, the lack of which would generate massive inefficiencies to counter the potential of stack trains.

IX. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

It has been conclusively presented, with rigorous background data, that emergence of the double-stack container train resulted from three major influences. The first, enabling legislation through deregulation of the railroads and the ocean carriers, has legally allowed binding contractual arrangements between the rail carriers and steamship lines. The second influence entailed a focus on cost saving techniques and equipment such as double-stack Linertrains that intense market competition forced upon the ocean carriers and the rail carriers reluctantly acquiesced to. Stack trains are a cost saving device rather than a revenue enhancement innovation in that the stack train performs an identical service to conventional COFC equipment, but at a significant savings in fuel and labor resources. The third influence came as a result of the keen competition in worldwide intermodal container carriage. U.S. landbridge advocates chose the double-stack container train to use as a weapon in challenging the all-water carriers for the increasingly lucrative eastbound import traffic originating in the Far East and destined either for the U.S. market or landbridged to the growing European markets.

Following a brief historical recounting of the first stack train service and a description of the current service network, a thorough analysis of the stack train manufacturers and their equipment offerings helped to conceptualize what a double-stack train looks like and what benefits it provides for the operator in saving precious resources in fuel and manpower. Further, an exacting description of competing designs helped to focus on their differences and similarities in the hopes that such rigorous analysis might spawn creative adaptation of the equipment for some unique military service application.

A rare view of an actual ocean carrier/railroad contract followed, providing insight into the actual clauses that shape how the railroad receives a certain revenue in exchange for equipment leasing and minimum volume requirements for container offerings by the steamship lines to the railroads. Depending on the actual profitability to the railroads of the fixed fee service provided, a clear-cut winner may prove hard to select.

A general view holds that double-stack container trains have been somewhat more profitable to the railroads than conventional COFC has been. Caution is urged, though, in that financial operating data on stack trains is not generally available from railroad carriers sincerely interested in protecting proprietarty data and expanding their share of the market with just the right fine-tuned contractual arrangements to be competitive.

The development of the new intermodal container freight network has led to more quickly exposing the inefficient links in the fast evolving time-sensitive logistics network. Larger container ships and more tightly scheduled 200-container stack trains impose mounting pressure on both rail and marine container handling yards to move these large volume container surges through their systems efficiently and quickly, without mishap. Just-in-time inventory management techniques and the increasingly high-value nature of the goods shipped in containers make it paramount that terminals cease being short-term warehouse facilities for containers and become just a buffer zone for interchange of containers between modes. Global I and the Intermodal Container Transfer Facility total up as a $98 million investment in the newest techniques for terminal handling of containers and double-stack container trains.

B. CONCLUSION

A whole new worldwide intermodal container freight transportation system is fast developing that promises to radically replace traditional views of handling and moving cargo. The parochial viewpoints of each mode (water, rail, truck) in which a defiant attitude prevented cooperative efforts have of necessity been replaced by a strong desire to posture themselves to fit into their niche in the intermodal transportation network.

Double-stack container trains have undoubtedly become the major links between vastly improved marine and rail mega-terminals. A philosophical aura, of sorts, has evolved around stack train operations that imbue a spirit of prompt, tightly controlled and monitored, highly expedited service that appears to go far beyond the mere mechanical differences between stack train well cars and conventional COFC equipment. It seems as though first the steamship lines, and then the railroad operators, have taken the opportunity to use the stack train innovation as a convenient symbol to attach onto the new ways of thinking about cargo handling and movement control. With the stack trains already inherent physical attributes of fuel and manpower savings, its success and greater market penetration through improved service is ensured as well.

The fallout, then, of the double-stack development, far exceeds merely improved efficiency of traditional operations. The ocean carriers and railroads have pushed forward to actually enhance service through new management techniques and cargo control and, as a result of widespread publicity for the stack train, have linked its appearance with dramatic transportation system improvements.

C. RECOMMENDATIONS

As the equipment manufacturers are flush with success and enthusiastic about further technological improvements to their new cars, the military services would be wise to take advantage of this state of affairs and thoroughly examine their cargo and unique equipment transport requirements for possible special adaptation of these cars. The Gunderson bulkhead cars could be tested for safe and more secure ammunition movements as just one example. Perhaps a future 125-ton truck-equipped stand-alone stack car could provide compact transport of heavy military cargo in a mobilization scenario to port facilities with limited railroad siding accommodations.

As for the commercial movement of military cargo, the awareness to the presence of double-stack train routes might open a new avenue of negotiation for volume point-to-point rates in which the knowledge of lower carrier costs through stack car service along a particular route may enable the government negotiator to hold out for lower margin rates. At least it would provide service improvements in the form of reduced transit times and reduced loss and damage claims as a result of faster, more tightly monitored train movements.

A greater awareness of the benefits available from double-stack train service and its equipment is highly recommended for all military personnel involved in or dealing with the transportation industry. Military cargo shippers must also understand the benefits of stack trains if they are to protect the taxpayer's dollar in military containerized cargo movement.

LIST OF REFERENCES

1. Mahoney, John H., *Intermodal Freight Transportation*, ENO Foundation Ror Transportation, Inc., Westport, Connecticut, 1985.

2. Johnson, B.,"Double Stack Railcars Planned By APL," *Container News*, v. 18, pp. 30-31, October 1983.

3. Fcit, P.F., *Jane's Freight Containers*, 18th ed., pp. 13-14, Jane's Publishing Company Limited, London, England, 1986.

4. Hesterman, M. T., "Double-Stacking: A Maritime View," *Railway Age*, v. 186, pp. 46-48,90, May 1985.

5. Hudson, J.F. and Baker, F., "The Current Surface Transport Interrelationships Affecting Intermodal Growth," *Transportation Research Forum*, v. 26, pp. 249-256, 1985.

6. *Exempt Rail Transportation Agreement*, Ocean Carrier Prepared Draft, pp. 1-13, 1986.

7. Horner, D.H., Jr., CPT and Marcus, H.S., "Adventures In Intermodalism Double-stacking Container Trains," *Translog*, v. 17, pp. 10-13, June 1986.

8. Malone, F., "APL Linertrains Stack Up Profits," *Railway Age*, v. 185, pp. 62-64, April 1985.

9. Guy, L., Intermodal Operations Manager, American President Intermodal, Interview, 23 June 1986.

10. Borzo, G., "Containers Stacked Two High But Handled Only Once," *Modern Railroads*, v. 41, pp. 32-33,36, May 1986.

11. Malone, F., "Double-Stacks: What's Next?" *Railway Age*, v. 186, pp. 36-39, May 1986.

12. *The New Generation Container Car: Twin-Stack*, Sales Brochure, pp. 1-4, Gunderson Inc. 1986.

13. Thrall Car Manufacturing Company, "Blueprints for Double-Stack Articulated Railcar Set," 22 October 1986.

14. Thrall Car Manufacturing Company, "Annual Fact Sheet on Double-Stack Railcar Dimensions and Statistics," 1985.

15. American President Lines, "APL Fact Sheet on Dynamic Forces Affecting Railcars," pp. 1-3, 1985.

16. Johnson, B., "Growth Prospects Good For Double-Stack Cars," *Container News*, v. 21, pp. 30,32,37, April 1986.

17. Arthur D. Little, Inc., *Comparative Analysis Of Terminal Economics For Double-Stack Cars*, pp. 1-8, 7 March 1986.

18. Williams, J.H. and Roberts, J.H., "The Potential Effects Of Improved Railroad Intermodal Technology Within A Competitive Environment," *Transportation Research Forum*, v. 26, pp. 242-248, 1985.

19. Smith, D.S., "Fuel Use Simulations Of High Productivity Container Trains," *Transportation Research Forum*, v. 26, pp. 236-241, 1985.

20. Airflow Sciences Corporation to Gunderson Inc., Subject: *ASC's Wind Tunnel Tests of the Twin-Stack Railcar*, 13 September 1985.

21. "TT Designs Stand-Alone Stack Cars," *Railway Age*, v. 186, p. 22, February 1986.

22. Wesselmann, C., ". . . But What's It Doing To The Track?" *Modern Railroads*, v. 41, pp. 39-40, March 1986.

23. Cooke, J.A., "What's Behind THe Upturn In Service," *Traffic Management*, v. 142, pp. 58-59,61,63, September 1985.

24. Wesselmann, C., "Ship . . . To Shore . . . To Rail," *Modern Railrads*, v. 41, pp. 38-40, May 1986.

25. Smith, D., *On-Dock Transfer: Facing The Issues*, Submitted For the 1986 Annual Meeting of the Canadian Transportation Research Forum, March 1986.

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