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PORTS, WATERWAYS, INTERMODAL TERMINALS AND INTERNATIONAL TRADE TRANSPORTATION ISSUES

PROCEEDINGS OF THE 13TH ANNUAL SUMMER CONFERENCE

The TRB Committee on Ports and Waterways and the Committee on Inland Water Transportation have held joint summer conferences for the past thirteen years. This summer, for the second consecutive year, these committees were joined by the Committee on Intermodal Freight Transportation, Committee on Intermodal Freight Terminal Design and Committee on International Trade and Transportation. Also, for the fourth year, the conference was co-sponsored by the AASHTO Standing Committee on Water Transportation. This expanded 13th edition of the summer conference was held July 19-22, 1988 in Seattle, Washington.

The summer conference is always held at a coastal or inland waterway port city to provide the opportunity for local technical presentations and field trips. The Seattle location was excellent in this regard. The conference program included technical tours of the Port of Tacoma and the Port of Seattle. The Tacoma tour included the on-dock intermodal yards, and the Seattle tour featured an intermodal yard and inspection of warehouse facilities.

The conference attracted 105 participants to hear 21 speakers in five conference sessions and 2 luncheon speakers. The session topics included:

- Responses by Pacific Northwest ports to changing trade and shipping patterns.
- Intermodal terminal operations in a new age of information and control.
- Paving developments in intermodal terminals.
- New developments in international trade and shipping.
- Planning, operations and the future of the inland waterway system.

The luncheon speakers were Lorenz Robinson, Vice President of Operations, American President Lines, speaking on past, present and future developments in intermodalism, and Randy Hanchey, Director of the Institute for Water Resources of the U.S. Army Corps of Engineers, speaking on future trends at West Coast ports. Following are summaries of the two luncheon presentations, and the papers presented at the conference.

CURRENT AND FUTURE OPERATIONAL CHALLENGES OF INTERMODALISM

BY
LORENZ ROBINSON
American President Lines

Any discussion of intermodalism has to recognize that the container is the backbone of the intermodal system. The container industry is only about 30 years old. When containers first came into being, the steamship lines were involved in a very simple type of port-to-port service. The ships would come into the dock and unload the containers. The problems in handling and delivering the containers inland were not the shipowners' problems.

Then there were new innovations like landbridge, transcontinental moves, mini-landbridge from one coast to another, and micro-bridge which took the cargo from a coast to an interior point. We have now evolved to the point in intermodalism where just-in-time service, through bills of lading, and single carrier liability are realities.

Intermodalism has caused changes in the types of ships used to carry containers. The ships have gotten larger, starting off with ships capable of carrying 500 TEU to ships today with capacities of 4,500 TEU (twenty-foot equivalent units), a nine-fold increase. The bridges and engine rooms have been automated, enabling crew reductions of about 50 percent. "Steamship" is a misnomer because just about every ship is now diesel powered. Diesel engines are about 30 to 50 percent more fuel efficient than steam vessels. Instead of just one crane operating on a ship, as many as four cranes operate on a single ship.

Containers themselves have evolved from lengths of 20 feet to lengths of 35, 40, 45, 48 and even 53 feet. The standard width of containers was 96 inches for a long time, but now there are 102-inch wide containers. The height of containers has increased from 8 feet to 9-1/2 feet.

The inland rail shipment of containers evolved from the use of piggyback service to double-stack service. Overnight, the train went from carrying a maximum of 100 FEU (forty-foot equivalent units) to as many as 280 FEU as an average.

The shipping public has benefited from the evolution of intermodalism. The inherent advantages of containerization are reduced theft, damage and cargo handling.

Lower rates to shippers have resulted from economics of scale and improved productivity. For example, a shipment of a 40-foot container from Korea to New York in 1984 would have cost $4,623 Today the average is about $4,003. Domestic service improved as well. In 1980, it would cost about $1,625 to ship a container from the Midwest to Los Angeles. By 1984, the cost was down to $1,350, and to $950 today. Along with costs, transit times have been cut. Shipments from Asia to the East Coast have been reduced from 30 - 35 days to as little as 15 days.

The main thing today is to increase productivity. Intermodalism, with its inherent advantages to shippers and consumers just cannot progress much further without significant productivity improvements.

<u>What are the challenges of the present and future</u>?

Let's first look at the bigger ships, as large as 4,500 TEU. Typically, ships in a liner service would run in a deployment of 4, 5 or 6 matched vessels on a 28, 35, or 42 day turn around, which is 4, 5 or 6 weeks. As ships have gotten bigger, requiring 2,000 - 3,000 container lifts in each port, as many as four cranes are used to work these ships which is perhaps the practical limit.

Despite the larger ships, more containers to be lifted and a limit on the number of cranes, it is still desirable to maintain a 4, 5 or 6 week cycle. To provide this service, labor productivity needs to improve. In Asian ports, they get 30 - 45 container moves per hour as an average. In the U.S., we are lucky to get 25 lifts.

In terms of crane productivity, we are improving the hoist and trolley speeds. Dual hoist systems are being installed with two trolleys working in tandem, one from the ship to a platform and one from the platform to the ground. The entire movement can be automated.

The steamship lines are going to have to introduce operating discipline. Every line has a cargo cut-off, where if your cargo is not at the terminal by a certain day and time, it can not make the ship. Otherwise, you have cargoes dribbling in at all times up to the sailing time.

Better inbound stowage is needed. You often have "cherrypicking" where a crane handles 10 boxes at one hatch, and then it moves to another hatch to get 5 more, and so forth. It takes about 10 minutes each time the crane is moved. This lost time cannot be made up.

The big ships have facility problems. They require that deeper and wider channels be dredged. It takes a Congressional authorization and years to accomplish a project. A ship can wait for the tide, but every hour you wait is costly and may disrupt your sailing schedule.

On the rail side, we need 20 feet of tunnel and bridge clearance. Many ship lines are using greater numbers of 9'6" containers. Stacking two of these containers is 19 feet of boxes. You have 10 inches that the boxes are sitting off the rail. You have to have 20 feet, and there are a lot of major rail routes that do not have 20 feet through tunnels and under bridges.

In some cases, there is self-help going on to improve rail access. APL, UP and the Port of Oakland are each putting up $5 million, or one-third of a $15 million project, for 46 rail improvements between the port and the Nevada border.

Some of the cities in which APL operates, and Los Angeles is the best example, are approaching highway gridlock. If one of our large ships drops off 2,000 containers, 1,400 to 1,500 of those containers may have to go to the railroad.

In L.A., one railroad is four miles away and the other is 25 miles away. A trip to this far yard is a 50-mile roundtrip. We need on-dock or near-dock rail facilities to help relieve the highway gridlock, improve fuel conservation and increase the availability of trucks.

When double-stack service started, loads were increased by up to 400 FEU's per train. We are now looking at this reverse. A lot of the products moving in boxcars and in trucks can be moved in containers on double-stacks. So, to provide faster, more frequent service we are considering running three or four 100 FEU stack trains daily instead of one daily 400 FEU train.

There are trade-offs that have to be looked at in intermodalism. The most obvious one is the cost of land versus the cost of labor and equipment. If you want to store all your containers on wheels in a port, as is typically done in a rail yard, it takes a lot more land in the port. Land is getting more expensive and ports are running out of land, so I think you are going to see movement towards either a lot more ground stacking or a mix of wheel and ground storage. In our case, about 65-70 percent of our traffic is intermodal, and it does not make sense to take a container off the ship, store it on the ground, and then an hour later pick it up to take it to the rail yard. So we are forced to use chassis operations to store containers. But, every chassis takes up room.

For every three loads from Asia that go east of the Rocky Mountains, there is only one export load coming back. What complements this 3 to 1 imbalance in international moves is domestic business which is heavily weighted westbound. But for us to go to on-dock or near dock rail facilities, the rails are going to have to get used to handling the international business, and ports are going to have to adjust to handling domestic business.

Looking to the future, we will have direct ship to train transfers with rails right under the cranes, which will eliminate the need for trucking or storage. Other improvements could involve automated cranes to load and unload trains. Also, there may be automated container freight stations.

INTERMODAL TRENDS AT WEST COAST PORTS AND THE ROLE OF THE U.S. ARMY CORPS OF ENGINEERS

BY
JAMES R. HANCHEY
U.S. Army Engineer Institute for Water Resources

The Corps of Engineers has long been active in developing the nation's harbors and waterways. Studies of improvements for both deep- and shallow-draft navigation projects are directed by the Congress and the Administration, primarily to assist in determining the scope and dimensions of required navigation improvements to assure the continued viability of the nation's excellent system of ports and waterways.

Some of the world's largest and most modern deep-draft ports are found along our nation's West Coast. The principal West Coast ports for container traffic include Seattle/Tacoma, Oakland, and Los Angeles/Long Beach. The rapid growth of the West Coast ports makes them an ideal example to illustrate the revolution that is taking place in the U.S. port industry.

Seattle/Tacoma

The Port of Seattle carried on two-way trade in 1987 worth 26.25 billion dollars with 125 countries. Since Seattle is geographically closer to Asia than its competitors to the south, it's understandable that trade with Asian nations accounted for more than 90 percent of the foreign waterborne cargo moving through the Port of Seattle, and 95 percent of total container cargo. The Port of Seattle handled 1,026,000 TEU of container traffic in 1987, nearly double its 1976 volume.

Existing channel depths at Seattle vary from 30 to 34 feet. A feasibility study recommending a deepening project of 39 feet was passed by the Board of Engineers for Rivers and Harbors in 1983. This project provided for deepening a total of about 4.8 miles of channel at a first cost of about $50 million; however, the port has decided to put the study on hold pending further investigation of port priorities.

Recent growth in container traffic at the ports of Seattle and Tacoma is a function of the locational advantage of the region--260 nautical miles (N.M.) closer to Japan than the San Francisco Bay Area (15 hours sailing time advantage) and 563 N.M. closer to Japan than the LA/LB ports (30 hours sailing time advantage). Ship transit time for a vessel from Asia to Seattle is about 8 days.

Seattle and Tacoma are largely thru-put ports with 70-75% of container imports eventually moving to points east of the Rocky Mountains. Most of this goes by rail, some by truck. A large amount of cargo is warehoused prior to proceeding eastward.

Container traffic in Seattle is served by 7 container terminals equipped with more than 20 container cranes (30-51 LT capacity). Container terminals cover 328 acres. Seattle is served by 40 general cargo steamship lines on a regular basis. Both the Burlington Northern and the Union Pacific provide double-stack train service via three intermodal rail yards.

The Port of Tacoma has existing depths ranging between 35 and 50 feet and an abundance of backup acreage and excellent rail service. Tacoma is already one of the nation's leading container ports, handling nearly 700,000 TEU in 1987. The Corps of Engineers is currently participating in feasibility studies for the Blair Waterway Navigation Project, a $54 million multi-phase project that will open up approximately 300 acres of port terminal lands for container development. Dredged material from the Blair Waterway (existing depth 35 feet) will be used for expansion of the Sea-Land facility. The initial phases of this project are scheduled to begin in 1989.

Oakland

The existing navigation project at the Port of Oakland consists of a 3.4 mile outer harbor and an 8.5 mile inner harbor. The existing project depth is 35 feet. A project to deepen Oakland Harbor was authorized by Congress in October

1986. The Corps of Engineers is presently completing the design and the environmental impact statement. Initial construction, originally scheduled for May 1988, is on hold pending court action on acceptability of the selected ocean disposal site for dredged material.

The deepening project will be constructed in phases, with an initial depth of 38 feet to accommodate the new line of post-Panamax American President Lines (APL) container ships. The recommended plan of improvement will deepen the existing harbor channels to 42 feet and will relocate, deepen, and enlarge the turning basin.

Containers handled at the Port of Oakland reached over 950,000 TEU in 1987, a 50% increase since 1981. The port is projecting a doubling of its container tonnage by the year 2000.

About 40% of Oakland's Pacific Rim imports continue to the East and Gulf coasts by rail. The Port of Oakland is served by 9 container terminals with 22 cranes (capacities 30 LT to 50 LT) including two huge post-Panamax ones. The total TEU capacity on the almost 500 available acres is more than 22,000. Three major railroads--the Union Pacific, Santa Fe and Southern Pacific--provide service to the Bay Area. The UP is currently enlarging several railroad tunnels through the Sierras in order to handle double-stack trains carrying two of the new high cube (9-foot, 6-inch) containers. The project is being jointly funded by UP, the Port of Oakland, and APL.

<u>Los Angeles/Long Beach</u>

One of the most exciting developments at the Ports of Los Angeles and Long Beach is the new Intermodal Container Transfer Facility, which is operated by Southern Pacific and is capable of processing 230 containers per hour. During the first phase of operation the facility will have the capacity to handle 350,000 containers annually, many of them on double-stack container trains. This new facility, costing $70 million and covering 150 acres, was opened by the ports in January 1987 and is considered to be the world's largest intermodal truck/rail yard. It handled over 260,000 containers in its first year of operation.

Over 50% of all West Coast container traffic is handled at the ports of Los Angeles and Long Beach (over 3,000,000 TEU in 1987). About 55% of incoming containers stay in the region, the remaining 45% continue on by rail to destinations east of the Rockies. Together, Asian traffic and petroleum make up about 95% of total business at these ports.

Existing channel depths at the Port of Long Beach vary from 35 feet to 62 feet. Container traffic using the Port of Long Beach is served by seven container terminals equipped with 26 forty-ton container cranes, and two more container terminals are planned for 150 acres of fill. Twenty-nine shipping lines use these facilities.

Of the approximately 20.4 million metric revenue tons (mrt) of container traffic in 1985-86, about 16.4 million mrt, or 80%, were imports. These included textiles (about 70% of all textiles enter U.S. through southern California ports), electronic goods, clothing and shoes from Asia, and spirits, wines and beer from Europe. Currently, a high number of automobiles are imported from Japan and Korea, but future expectations are for growing volumes of containerized auto parts destined for assembly plants at inland U.S. points. Exports to both Asia and Europe consist largely of California agricultural products; seasonal fruits and vegetables in reefer and temperature controlled containers; and cotton.

Existing channel depths at the Port of Los Angeles vary from 35 to 52 feet. A total of seven active container terminals are available, equipped with 29 container cranes. Double-stack train systems operate on the ATSF, SP and UP railroads and are used by Evergreen Lines, APL, NYK, Mitsui-O.S.K. and others. Total container tonnage through the port in 1986-87 was about 27.3 million mrt, representing about 85% of the total general cargo tonnage. This tonnage was transported in about 1.5 million TEU. Chief exports are the same as for Long Beach: seasonal fruits, vegetables and cotton.

Recently, the Corps assisted the ports in the development of their "2020" master plan completed in 1985. Their conceptual plan includes deepening of navigation channels and landfill development within the bay to an ultimate extent of about 2,600 acres to meet the estimated increase in cargo throughput from the present 66 million metric tons to 195 million metric tons.

Section 201(a) of the Water Resources Development Act of 1986 (P.L. 99-662) authorizes the Corps to deepen the entrance channels to Los Angeles and Long Beach harbors to a depth of 70 feet and 76 feet, respectively, including creation of 800 acres of land. The authorization however, is subject to a favorable Chief of Engineers report and the Secretary of the Army's recommendation to the Congress for construction authorization. There are unresolved questions of cost-sharing requirements related to land enhancement, optimal channel depths, etc.

Market Trends

Together, the Pacific Coast ports accounted for over 50% of total U.S. containers (TEU) in 1987, up from just 31% in 1981. Much of the West Coast's growth came at the expense of the North Atlantic port range, whose share of total container traffic dropped from 35% to 26% during the 1981-1987 period. As an illustration of this trend, combined movements through L.A. and Long Beach surpassed New York for the first time in 1985, even while the latter's traffic continued to increase at a modest 5% annual rate through 1985.

The West Coast ports in general, and L.A./Long Beach in particular, have gained ground for several reasons, among them: increasing overall U.S. trade with Pacific basin countries; an increasing share of Asian trade moving through West Coast ports; and increasing rail minibridge penetration of the U.S. interior and East Coast markets.

One factor accelerating minibridge traffic growth is the difference between the amount of time required to move a container from various Asian ports to U.S.

East Coast ports such as New York via either the West Coast (using rail double-stack service), or by the all-water route through the Panama Canal. The all-water route is generally about 10-15 days longer. For higher value and time-sensitive cargoes this time difference can actually result in transportation cost savings using the minibridge alternative.

Projections of container tonnage at West Coast ports by the Pacific Maritime Association for 1990 and 2000 show an increase from 87.4 million revenue tons in 1990 to 171.9 million tons in 2000 based on a 7% growth rate. Using an 11% growth rate, these revenue tonnage figures would be 101.3 million tons in 1990 and 287.5 million tons in 2000.

PORT OF TACOMA: BUILDING THE INTERMODAL ADVANTAGE

BY

CHARLES E. DOAN
Port of Tacoma

In 1981, the Port of Tacoma introduced the original on-dock rail intermodal yard. The Port also introduced the use of the high-speed straddle carrier for loading/unloading containers from rail cars.

Our intermodal traffic increased from 8 lifts per week in 1984, to 1,330 lifts weekly in 1985, to over 3,800 lifts per week at present. We have achieved a total of 937 lifts in an eight-hour shift. That is the equivalent of a 28 car double stack unit train completely unloaded and reloaded.

The Port of Tacoma now operates two on-dock rail intermodal yards where the longest distance from ship to rail is only 1,100 feet. We have the capacity to handle 117 double stack cars. That's 1,170 TEU's (twenty-foot equivalent units) or about 4 unit trains of 28 cars each.

On-dock railroading is not new to Tacoma. Since 1873, when Tacoma was chosen as the western terminus of the Northern Pacific Railroad Co., rails have been important fixtures on our docks. The silk trains of the 1890's originated here. Even today, 10 of our modern general cargo berths have double rail tracks alongside the berth.

Just as speed was important to the silk trade, so is it today. Be it auto parts or electronics, dresses or foodstuffs, the shipper expects to realize the fastest delivery and the most economical. With last port of call from Tokyo, Japan, we can have cargo to Chicago in 12 days and to New York in 15 days which compares to 22 days all-water. That 12 days to Chicago is comprised of 9 days on the water, less than 1 day in port and 3 days on the rails.

Saving a week in-transit over the all-water route to the East Coast means that achieving just-in-time deliveries to a manufacturer's assembly line is closer to reality. It means that consumer goods are on the showroom floor ready for sale a week early. It means real dollar inventory savings, as a container valued at $100,000 would generate about $250 in carrying costs in these 7 days. And finally, it's cheaper. A container of auto parts for diesel engines will cost $200 less going via a landbridge move at $6,348 than via an ocean carrier's slow boat rate of $6,550.

When we built the $6,000,000 intermodal yards, we were primarily serving our ocean carriers, but we also serve the shipper. Our shippers like our ship-to-rail-to-truck program because of four characteristics beyond price:

- Flexibility.
- Greater frequency of ocean carriers.
- Better ship schedules, and
- More reliable train schedules.

Rail deregulation and double stack rail car technology made significant contributions to the port's economics. Deregulation gave the railroads a new competitive posture, particularly with ocean carriers, and double stacks allowed railroads to realize about a 40% operational cost savings.

Tacoma, by eliminating the "intermodal gap" between ocean shipping and rail, has removed the last major un-addressed cost in intermodal transportation. Port terminal efficiencies throughout the United States have reached relative parity. The intermodal Gag, however, can be a key factor in the low margin container business, as Tacoma has discovered. Even if the rail yard is only a few hundred yards away, if it still needs terminal gates, trucking connections, and city streets, the gap is not eliminated. Tacoma's on-dock service can save an ocean carrier's intermodal service a relative cost that equates to about half the profit on a Yokohama-Chicago box move.

In addition to creating highly efficient on-dock facilities, we have also streamlined the administrative side of container movements.

Today, ports, shipping lines, and the railroads must find new ways to expand their marketing potential, foreign and new domestic and international cargo for the intermodal market.

Burlington Northern has experienced tremendous growth in the intermodal area. Six years ago, BN transported 200,000 trailers and containers. This year, they expect to handle 1.1 million. Intermodal traffic now accounts for about 15% of railroad traffic.

While ports, railroads, and shipping lines all expand their Midwest and East Coast marketing efforts to generate new westbound intermodal cargoes, the efforts to generate westbound cargo for doublestack trains should not be viewed as merely a domestic search. It is also an international one. For example, Maersk Line has started moving some of its containerized cargo that comes into the East Coast from Europe out to Tacoma via the doublestack train. From there, it is reloaded on ships.

One of the challenges that the Port of Tacoma, along with all the other ports, faces is how to handle growth. In some cases, our intermodal yards are faced with "The Star Trek" challenge--where Space Really is the Final Frontier. It's great to have huge quantities of containers coming westbound on the doublestack trains, as long as once they arrive at the port, you have enough space and the right equipment and infrastructure to move the containers to their ultimate destination. The challenge is to be able to do this without interfering with what you have going eastbound.

If the shipping world were Utopia, the volume and value of intermodal containerized cargo going eastbound and westbound would be the same. But it's not. A 40-foot container full of linerboard or hay that's exported to Japan doesn't have the same value as a 40-foot container full of VCR's coming in from Japan. Our efforts to balance our intermodal trade must include getting more cargo as well as getting higher value cargo.

While the growth in containerization and intermodalism has been a "Revolution", "Balancing our Trade" in terms of east/west doublestack container traffic will be a slower "Evolution." As ports, railroads, and steamship lines all focus more attention on marketing this aspect of the business, it is expected that they will work out new coalitions and new partnerships to achieve some common goals. And while there may be more cooperation in these areas, it is clear that there will be more competition as well.

The Port of Tacoma has a number of unique selling points--points which we call "The Tacoma Advantage". I have addressed one of these - the modal interface. Our future is linked to it. As we look to the future, I hope you agree with Charles Kettering, who once said, "We should all be concerned about the future, because we will have to spend the rest of our lives there."

PREPARING THE PORT OF SEATTLE FOR THE 21st CENTURY

BY

GORDON NEUMILLER
Port of Seattle

The Port of Seattle got its official start in 1911, when it received a charter from the State of Washington to be a port authority. The first overseas ship called in Seattle in 1890, a vessel operated by NYK Line of Japan.

The port has over $1 billion in assets, and 1,100 employees working both at the seaport and at Sea-Tac Airport. This is the 13th largest airport in the U.S., and we hope to handle about 15 million passengers this year.

The cargo terminals in the port encompass about 700 acres, of which about 400 acres are used for container terminals. The port handled 1 million containers in 1987. We also handle bulk cargo such as grain and break-bulk cargoes such as steel, autos and apples. While we export apples from the State of Washington, we also handle apples imported from New Zealand for distribution throughout the U.S.

To plan for the future, it is sometimes helpful to look at what has happened in the past, to see what worked and what didn't. Seattle has been quite successful, for a few reasons, one of which is geography. Seattle, with sailing via the Great Circle Route, is one of the closest ports to most of the

Asian ports, about a day and one-half or 600 miles closer than the Port of Los Angeles. However, unlike the Port of Los Angeles, we do not have a large population base in the Seattle area, so we had to take a careful look at the markets we can serve. Not surprisingly, our primary market turned out to be the Overland Common Points (O.C.P.) and the area east of the Rocky Mountains.

Once we identified our geographic advantage and the market area to be served, the next step was to determine how to attract cargoes, and how to get importers to discharge at the Port of Seattle. To do that we first needed to develop the cargo facilities, so the port began to develop container facilities and this attracted vessels to the port. In addition to our facilities, we provide value-added services for importers and exporters. For our inland shipments, we began to operate rail pools, truck consolidation, distribution warehousing, all to better serve the importer and to enable the importer to better serve his customers. Since deregulation of the trucking industry, our truck consolidation service has become the Seattle Truck Contract Program. We move about 150 million pounds of freight annually to cities throughout the U.S. and Canada.

If there are lessons to be learned, it seems that providing port facilities and services are important parts of planning. The facilities now cost a lot more than they used to. It now costs the Port of Seattle about $1 million per acre to build a new container yard. The new generation of container cranes with a 100-foot boom, capable of handling post-Panamax vessels, costs $4-5 million each.

Whereas, in the past, a port provided services for importers or exporters, now ports need to provide services for steamship lines. Also, there seems to be a growing battle to see who controls the inland movement of cargo, and the Port of Seattle is willing to work with whoever controls the business.

Other factors need to be considered in planning for the future of a port. These include market and environmental factors such as politics, trade protection, economics, currency exchange rates, and oil prices. While you cannot control these factors, you need to be aware of them so that you can respond as needed. Technology changes must also be considered. You need to be aware of changes that may be induced by the new generation of container vessels and the larger shore cranes to handle the vessels. Because of the large blocks of cargoes involved and the load-centering idea by vessel operators, a port must respond with new technology to remain competitive.

Knowing your competition is an important part of marketing. An interesting part of intermodalism is that it has made all ports compete with each other. That competition may be on a national basis, as East Coast versus Gulf Coast versus West Coast ports. On a regional basis, the West Coast ports compete for the O.C.P. cargoes heading east of the Rockies. On a local basis, there is competition among the ports of Seattle and Tacoma and with the Port of Portland and the Port of Vancouver, British Columbia.

The Port of Seattle is somewhat constrained in its expansion plans to acquire more land, but the port is also looking at efficiency steps to increase cargo productivity. There can be efficiencies in labor/management relations and terminal operations. We are looking at terminal design and mechanical features that can be built to increase cargo handling within the same acreage and without a huge capital investment. The port is also expanding its Electronic Data Interchange (E.D.I.) to eventually link U.S. Customs, cargo terminals, vessels and inland transportation carriers.

COMPETING IN THE PACIFIC NORTHWEST

BY

BONNIE McDADE
Port of Bellingham

The Port of Bellingham is located 90 miles north of Seattle on Interstate 5, in Whatcom County, the most northwestern county in the U.S. excluding Alaska. Bellingham is 23 miles south of the Canadian border.

The port facilities include the Bellingham International Airport, which increased flights from 9 daily to 76 daily in a year and one-half. There are two marinas and a new convention and trade complex. The port has four foreign trade zones, which will grow in relation to trade with Canada. There are two industrial parks, and a shipping facility called Whatcom International Terminal which has 50 acres of cargo terminal and 70 acres of foreign trade zone. The ports cargos include aluminum, wood pulp, chemicals and dried milk.

The port is located closer to the Pacific Rim than the Port of Seattle. The port is competing with the Port of Seattle to locate the southern terminal of the Alaska Ferry. It has the advantage of cutting six hours off the sailing time, and it is only a 1-1/2 hour drive by car from Bellingham to Seattle.

Ports in the State of Washington are mandated by the state legislature to do four things: maintain safe harbors, maintain safe terminals, take a leadership role in economic development, and promote tourism.

THE EMERGING ROLE OF AN INLAND INTERMODAL TRANSPORTATION FACILITY

BY

LARRY BONDERUD
Northern Express Transportation Authority

The Northern Express Transportation Authority (NETA) is located in Shelby, Montana, a town of 3,500 population in a county of 6,000 persons. The concept of the inland intermodal facility is about 10 months old. The authority is a regional port authority under state statutes, the second such authority created in the state.

NETA came into existence to take advantage of its geographic location. It is located about 30 miles from the Canadian border on the Burlington Northern Railroads east-west main line, and on the BN's north-south line which runs from the Canadian border south to Houston, Mobile and Pensacola. About 44 trains per day run through Shelby, of which 12 are intermodal with eight double-stack trains and four single-stack trains.

Another key factor in Shelby's geographic location is that one of the largest Ports of Entry is at Sweetgrass, Montana, at the Canadian border, handling about 750 semi-loads per day through Customs.

The State of Montana provided a big carrot to help bring the project for an intermodal facility together. This was in the form of Exxon overcharge funds that were returned to the state. The state allocated $2.1 million of these funds for development of an intermodal facility. This gave us the incentive to pull our resources together and to hire the expertise and consultants. Although the state funds went to another port authority, in Butte, we were sure of our concept, and we agreed to proceed.

Shelby, Montana is served by 50 transportation companies that have worldwide networks. The key was to access those companies and to make the proper linkages with Pacific Northwest ports, which would lessen our dependence on the BN railroad.

The population of the Province of Alberta now exceeds the State of Colorado, making it a major transportation market. A new transportation authority could act as a gateway between Canada and the U.S. With the large volume of trains, trucks and container movements in this region, the new authority could gain access to some of this traffic.

One concept which could enable the authority to serve as a resource for the BN involves the ongoing study in development of uniform length and load limits for trucks. British Columbia, Alberta and Saskatchewan are going to adopt uniform limits. The maximum gross vehicle weights are going to be 137,500 pounds with 8-axle rigs. The authority is moving those vehicles right now. Between Shelby and the Canadian border, the BN mainline has located "tramp" loading sites. These loading sites allow for transfers between trucks and trains of bulk commodities and containers. Some bulk cargoes are loaded there into containers for export.

At present, NETA is handling 300 forty-foot equivalent container units per month. Many of the containers are U.S. consumer goods coming out of the Midwest via the BN. Canadian export shipments move through NETA to U.S. markets.

We provide warehousing and bulk transloading. NETA provides export cargoes for empty boxcars moving to the West Coast as well as alternative routing and intermodal competition that provides savings for shippers.

One means the authority is working on to extend the range of containers served by NETA involves obtaining permission to exceed the 105-foot length limit on trucks. We could then handle two 40-foot containers in tandem which, along with the cab, would exceed the limit. We will work with the state to determine the placement of trailer axles. The state will be providing scales to weigh trucks at our facility. Sea-Land has agreed to position equipment at the facility.

The NETA is also considering agricultural exports on double-stack trains. At present, we are loading containers with grain products without taking them off the flatcars.

AUTOMATIC INVENTORY SYSTEM AT THE SP INTERMODAL CONTAINER TRANSFER FACILITY

BY
ROGER D. STILES
In-Terminal Services

In August, 1986, In-Terminal Services was chosen as the contractor by the Southern Pacific to operate the newly created Intermodal Container Transfer Facility (ICTF) in Long Beach, California. This modern, fully automated, state of the art facility was built by the SP in conjunction with the Ports of Long Beach and Los Angeles in response to the growing needs of their many international customers. The ICTF is the largest rail container facility in the world.

As this was a totally new and untested facility in almost all operational aspects, many challenges arose in the first two years of operations, not the least of which was inventory control. To illustrate the magnitude of this challenge, consider the following factors. The ICTF currently operates on approximately 230 acres, has 5 working tracks each about 1 mile in length, has 2,300 numbered parking slots, handles 36 double stack trains per week (varying from 6 to 28 cars) and 42 conventional trains per week also of varying sizes, does in excess of 360,000 lifts annually and will have an average of 2,500 containers on chassis and 4,000 bare chassis in the yard at any given time. Ownership of these containers belong to many varied customers utilizing the ICTF.

The dynamic parking scheme of the ICTF was designed to be operated with a real time computerized inventory system, conceived by the SP to utilize their existing TOPS/TCC systems integrated with slot monitors and a mobile inventory system.

There are several key elements that combine to make this a highly effective and efficient operation. First, the drivers delivering the containers or picking them up, must ensure that the container and chassis numbers they give the pre-checker are correct and that they park their container in the assigned parking slot.

The second, is our pre-check clerk working with the slot monitor, communicates directly with the driver and must ensure proper data input as this drives the slot assignment by the slot monitor. The slot monitor maintains a real time inventory of available parking slots. A daily plan is laid out based on the day's projection as to what destinations and/or blocks will be loaded on which tracks. The slot monitor is then programmed with this information, so that when a container comes in for a particular destination, it will provide the pre-check clerk with the next available slot in the area designated for that destination.

The third element is the mobile inventory system. With all elements meshing, the ICTF has the most state of the art, real time inventory system found in today's rail industry. The key to maintaining this real time inventory is the data entry of inventory movement by yard hostling personnel through the use of mobile data terminals.

At the ICTF, all hostling tractors and yard check vehicles are equipped with mobile data terminals. These mobile data terminals (MDT's) are radio linked to a control unit located in the ICTF tower. Data is sent via micro-wave to the central computer located at SP's headquarters in San Francisco.

The need for accurate inventories is critical because:

- Reporting inventory with MDT's results in an accurate inventory.
- Reporting the inventory provides management with a tool to gauge ramp personnel activity and productivity.
- Inventory moves reported via MDT input updates a real time visual monitor used by the ramp manager to monitor hostler activity.

All inventory moves are recorded and stored in a file that provides a historical record to monitor hostler productivity.

The ramp manager is responsible for coordinating all the activity and ensuring that the plan is carried out. He provides the direction and computer input for the ramp crews.

With all elements and systems now functioning we feel that the SP's terminal inventory system at the ICTF sets the industry standards for maintaining a real time inventory and a managerial resource.

SEMI-AUTOMATED CONTAINER/TRAILER CRANES

BY

JIM RALSTON
Provincial Crane Inc.

In order to handle today's cargo at a competitive cost and in good time, new ways of handling the container had to be found, not only in the method of handling the container/trailer itself, but in utilizing the available yard area to the maximum efficiency.

The use of automated machines have been the mainstay of the auto industry, and only in the last 10 years has the automated function been considered in the Intermodal Facility. Automation involves the automatically controlling the operation of an apparatus or system powered by electricity.

What does automation do for the Intermodal Terminal?

<u>It Speeds Up Container Handling</u>

The use of semi-automation on the long-span container gantry cranes provides position operation functions such as X-Y positioning, computerized positioning/locating for containers, and inventory control.

<u>It Reduces Operator Fatigue</u>

With automation of functions of the crane such as BRIDGE, TROLLEY and SPREADER BEAM, the operator can be doing other jobs during the time spent traveling to the container.

The operator selects the container coordinates and the container size, starts the sequence by pressing the selector button and the crane then travels to the position without the aid of the operator. Positioning is accurate to plus or minus 1 inch.

<u>It Reduces Container Damage</u>

With automation, the acceleration and deceleration of the crane is controlled by the on-board computer, thus providing smooth operations. The cranes also have the feature of anti-sway reeving on the hoist which eliminates the sway of the container during movements of the crane.

<u>It Reduces Maintenance Costs</u>

Automation reduces operator abuse of the equipment, and along with the electric powered motors, the high cost of maintaining a diesel engine has been eliminated.

<u>It Interfaces With Yard Computers</u>

With the use of a radio link, the yard computer can talk to the crane computer, giving instructions on what container to select, etc. This feature gives the crane operator the required information on entry into the yard by the trucks. The type of information can be:

- container identification
- location of pick up point
- truck waiting area
- container storage location.

<u>It Increases Equipment Life</u>

Automation not only increases the productivity of the yard but also increases the operating life of the machine. Through the controlled movements of the crane, operator abuse can be virtually eliminated. Also, the use of electric drives, which have been used for over 70 years in the steel-making industry where high reliability is required, has eliminated high maintenance items.

It Reduces Land Utilization

The use of the semi-automated, container handling, long-span gantry crane has also reduced the land usage at terminals that have elected to automate the through-put handling.
The dead-land areas are the two runway rail supports only. On average this would amount to 6 feet per runway support. Cost comparisons can be made between the two runway rails for the long span gantry and the several heavy paved areas required to accommodate the conventional loading equipment.

Features for Automation of a Gantry Crane

The following items are an example of the features that have to be incorporated into the design of the gantry crane in order to have a solid, reliable base for using automation.

Fixed runway rails: The use of fixed runway rails provides the solid base for the bridge travel, which in turn relates to the structural rigidity. These features are the basis in providing the continuity required for an X-Y automated coordinate.

Solid steel rail wheels: The use of the solid-state rail wheels also eliminates the amount of surge movement of the gantry and provides the basic tool for monitoring the bridge travel.

Constant power supply: Having the constant power supply reduces voltage fluctuations and provides continuity for the computer control.

Stabilized reeving: This provides the geometric rigid mast that reduces the time required to spot a container after stopping the gantry.

Solid state drives: The solid state drives provide the interface between the encoders and resolvers used for tracking the movements and the computer for controlling the function.

Reliability: Reliability in the machine is required in the automated gantry so that coordinates can be fixed for an extended period of time without constant reprogramming.

Power

Automation requires that the equipment be run on electricity rather than the liquid fuels presently used in North American intermodal terminals.

With a constant flow of electrical power to the crane, the computer has a non-variable power flow. Another feature of the constant power is that the size of the motors are selected based on the requirement of the crane's duty, i.e., the horsepower required to give the speeds necessary for the crane to handle the terminal through-put can now be selected and incorporated in the design of the crane rather than the horsepowers and speeds being dictated by the available out-put from the diesel generator.

Electric powered equipment can have a positive effect due to reduced noise levels, no use of liquid fuels, night operation in residential areas and reduced air pollution.

Electric powered container handling has been used in Europe for the past 25 years and has proved to be the way to handle containers in a heavily populated community, and to provide reduced costs of handling goods. The advantages of the electric powered machine is found in the operation, efficiency, cost, and life.

The electric powered machine also has the capability to be engineered to the requirements of the Intermodal Terminal so that the required duty cycle of the machine (crane), speeds, acceleration and durability are designed for the through-put.

Benefits of Automation

The automation of the equipment that we use to handle containers and trailers has produced many improvements in the operation of an Intermodal Facility. Some of the advantages are:

Anti-Sway Reeving

During the normal operating movements of the crane, the load is restricted from moving from side to side by the geometry of the hoistering ropes. This provides accurate spotting of the spreader beam over the load and reduces the time required waiting for the beam to stop swaying.

Summary

The automation of the motions of the crane (although the operator can manually override the automation by moving the master switches) provides a system that is better able to consistently position the crane quickly and accurately since the drives always operate at maximum rates of speed and stop in minimum distance during automatic moves. The drives are not limited by visual parallax problems, nor do they become fatigued. The result is that the automated container/trailer handling gantry crane can position itself over the containers with greater speed and accuracy than an operator could consistently provide.

TRANSPONDER/INTERROGATOR SYSTEMS

BY
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Introduction

Transponder/Interrogator systems operate by sending radio frequency signals between an interrogator/antenna and transponders which are attached to objects or in particular locations. Transponder antennas are internal to the transponder itself and interrogator antennas are external to the interrogator.

One example of a transponder/interrogator system uses the interrogator antenna to send an unmodulated radio frequency signal in the direction of the transponder. The transponder is initialized by this signal, slightly modifies it and reflects a modulated signal back to the antenna. The interrogator receives this signal, processes it to determine the identity of the object or the position to which the transponder is attached and provides a serial output interface to the outside world. Transponder readings can either be stored in memory on tape or diskette by the interrogator for later reading or transmitted via radio frequency on a real time basis.

Transponders typically are precoded prior to installation with from 12 to 24 alphanumeric characters of information concerning the location or identification of the object to which the transponder is attached. Some transponders are programmable, and there are two basic types of transponder systems; passive and active.

Passive Transponders

Passive transponder systems consist of:

- A power receiver
- A logic data generator
- A RF transmitter

This type of transponder is inductively activated by a signal from the interrogator. The transponder converts the interrogator signal to a DC voltage, modulates the carrier signal,and transmits pre-coded data back to the interrogator. Once the return signal from the transponder is detected, the interrogator transmits a steady carrier output to provide sustained power source for the transponder.

Active Transponders

Active transponder systems consist of:

- A battery
- A logic data generator
- A RF transmitter

In this type of system the battery is normally in a quiescent state until activated by the radio frequency transmitted by the interrogator. Once activated, the transponder uses the battery for power to transmit pre-programmed information back to the interrogator. The batteries used in this type of system typically last from 10 to 20 years.

Frequencies

The frequencies used in transponder/interrogator systems vary from very low radio wave frequencies in the area of 100 kilohertz up to the high microwave frequencies some of which exceed 900 megahertz. In general, with low frequency systems the transponders must be closer to the interrogator antenna than in high frequency systems.

- Typically 1 to 3 feet for a low frequency system.
- Typically 5 to 100 feet for a high frequency system.

The transponder antenna is built into the transponder package. In general, lower frequency transponders have larger antennas and consequently are larger in overall size. Low frequency transponders will typically range from 15 to 30 inches in length, 8 to 15 inches in width and two to 10 pounds in weight. High frequency transponders will range from 2 to 9 inches in length, 2 to 5 inches in width, and less than 1 pound in weight.

Effects of the Environment

Most of the manufacturers have ruggedized transponders available which have been engineered to minimize or eliminate the effects of the environment on the system. These transponders are not affected by:

Ambient light or darkness
Vibration
Electrical noise
Interfering signals
Temperature
Fog
Rain/water
Snow
Chemicals
Sand, coal, ballast

Microprocessor Control

The interrogator is a microprocessor controlled electronic unit used to process the identification code programmed into the transponder and pass this information on to the outside world. The interrogators receive their data via the antenna which is mounted exterior to the interrogator in a strategic location so as to be able to read the transponders. The antenna is generally connected to the interrogator by coax. On some systems, more than one antenna can be connected to one interrogator.

Size and Weight

Interrogators are generally on a rack mounted chassis and range in size from 11 to 20 inches wide, 20 to 34 inches long and 3 to 9 inches high. The combined weight of the interrogators and their antennas will generally range from 15 to

50 pounds. Also, the lower frequency systems require a larger and heavier antenna. Some interrogators are mobile and can be attached to any movable object.

System Applications

This technology could potentially be applied in an intermodal terminal, through this type of system has not yet been developed. However, several companies are looking at various aspects of the system. The following is a description of an intermodal terminal yard inventory system based on ideal conditions. Some of the issues which need to be resolved before this system can be fully implemented and some of the peripheral applications which can be developed as a result of this system are discussed below.

The ideal system is predicted upon two basic assumptions:

A. All units flowing through the intermodal terminal would be equipped with transponders.

B. Interrogators would be placed within the yard and on any lift equipment to capture the movement of units throughout the terminal:

- o At the gate
- o At the rail/ship entrance to the terminal
- o At strategic locations within the terminal such as individual lots.

At the Gate

All traffic entering or leaving the terminal would pass by an interrogator at the gate and the initial and number of the unit would automatically be entered into the yard inventory system and be displayed to the dispatcher. Depending on whether the movement was entering the terminal or exiting the terminal, the following would be the last activity record displayed on the screen to the dispatcher as shown in Figure 1.

Crane/Piggy Packer

All equipment unloaded from a ship or rail car by a crane or from a rail car by a piggy packer would automatically be entered into the terminal yard inventory. If a pre-arrival exists, this entry will automatically retrieve the appropriate information and place it into the yard inventory.

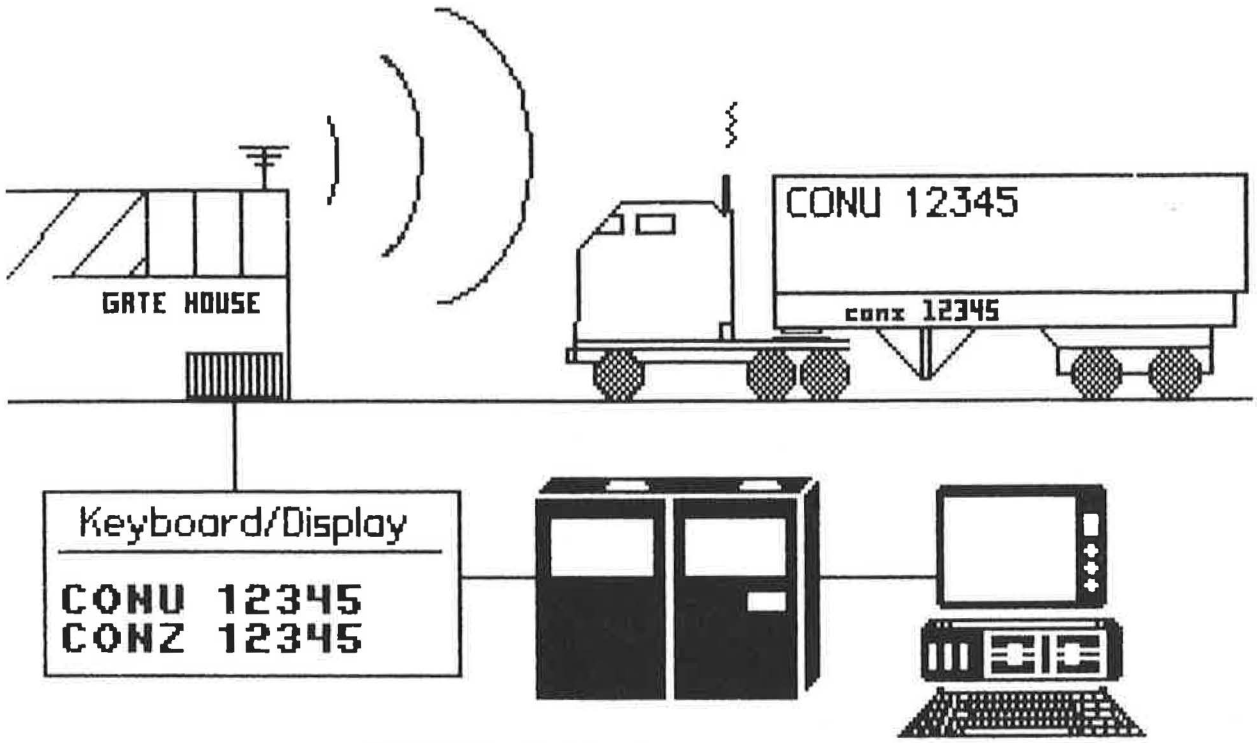

FIGURE 1. Gate house (terminal display)

All equipment loaded onto a rail car or ship would automatically be entered into the terminal yard inventory. If a pre-arrival exists, this entry will automatically retrieve the appropriate information and place it into the yard inventory.

All equipment loaded onto a rail car or ship would be automatically deleted from the inventory. An edit will be made to verify that the unit is destined outside the yard. If not, appropriate warning messages will be generated. In both cases, a computer date stamp will automatically be placed in the record.

Yard Location

Interrogators will be strategically placed in the yard to automatically detect the initial and number of each piece of equipment as it moves throughout the yard. Depending on the degree of accuracy required, interrogators could be placed at the entrance and exit points to the individual lots.

- As the equipment moves from one lot to another, the yard inventory will be automatically updated

- When drivers enter the terminal to pick up loads or empties, they will be directed to the appropriate lot

- The lot location will be automatically shown on the hostle lists

- Equipment unloaded from rail cars/ships will be directed to specific lots and can be monitored enroute to the specific lot

- When lots are at capacity, the yard inventory system will direct the equipment to different lots

- The mobile interrogator on a truck can be used to update inventory location if necessary.

Open Issues

There are several open issues that need to be resolved before a complete system of this type can be implemented:

- When a piece of equipment is lifted by a packer or crane, we need to be able to determine if that piece of equipment is entering the yard or departing the yard. When simultaneously loading and unloading, if a unit is encountered which is not in the pre-arrival inventory or the yard inventory, the computer will not be able to determine whether the unit is inbound or outbound.

- We need to determine how to handle non-tagged equipment which enters the yard. This might involve the use of magnetic serial coded transponders.

Additional opportunities can be derived from the use of a transponder/interrogator system. These include truck fuel inventory records, ramp/deramp/lift productivity records, and chassis inventory.

EXPANSION OF THE SOUTHERN PACIFIC RAILROAD'S DALLAS INTERMODAL FACILITY

BY
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Duval and Associates

Introduction

This project called for the expansion of SP's Dallas Intermodal Facility, a 30-acre freight exchange terminal a few miles south of downtown Dallas. This project can be broken down into basically three separate stages: pipeline installation and subgrade preparation, soil-cement subbase construction, and concrete pavement construction. This presentation focuses mainly on the design, the soil-cement, and concrete portions of the project.

Design

The pavement design considerations included traffic loadings and subgrade conditions. Current and projected traffic consisted of 18-wheel trucks, straddle cranes, and the side packer. Despite these heavy channelized traffic loads, we designed this intermodal paving system as a jointed plain concrete pavement using the latest Portland Cement Association design method. This method is based on non-reinforced concrete. In conjunction with the plain concrete, closer joint spacings on the order of 12 to 15 feet were used to control shrinkage cracking and to develop more efficient load transfer through tighter aggregate interlock.

Three different pavement configurations were used on the project: non-reinforced concrete over an existing crushed stone base and asphalt surface; non-reinforced concrete over 6" soil-cement subbase; and 6" soil-cement subbase with 1-1/2" asphalt wearing surface. Concrete thickness varied according to traffic loading from 6" in loaded trailer parking areas to 8" in channelized traffic lanes to 14-1/2" in straddle crane pathways. The design scheme also allowed the SP more flexibility for future expansions.

In addition to the expansion of existing facilities, the SP wished to improve its deteriorated pavements. The existing crushed stone base was utilized with asphaltic concrete surface as a subbase for a new jointed plain concrete pavement overlay. Taking advantage of the salvage value of the existing pavement permitted the use of a thinner concrete section due to greater load-transfer efficiency provided by the crushed stone. The base also served as an all-weather construction platform and prevented subgrade rutting by construction equipment, so no allowances had to be made for thickness variation. The in-situ soils in the expansion areas proved to be quite tender silty sands when tested in our laboratory, soils susceptible to deep rutting when loaded by even medium-duty construction equipment. Instead of a much thicker concrete section, we chose to take advantage of the soil conditions by designing a soil-cement subbase for the concrete pavement. The soil-cement base provided greater load-transfer efficiency, served as a solid all-weather construction platform for the slipform paver, and prevented subgrade rutting by construction equipment.

Again, this provided greater thickness control for concrete placement and resulted in a thinner concrete section because thickness variation was reduced. For the Northwest Lot, an area in which empty trailers are stored, the structural capacity requirement was less than for the other areas, so a 6" soil-cement subbase with 1-1/2" asphalt wearing course was used as the design section.

To provide uniformity of construction materials, the contractor was encouraged to have an on-site continuous feed soil-cement plant and a concrete batch plant, adding greatly to daily paving production and quality much greater than mixed-in-place soil-cement and ready-mix concrete operations could provide.

Laboratory Testing

Quality control was an essential part of this project and was instrumental in ensuring a top quality pavement. The materials testing laboratory was located on the job site. Once the quality control plan had been developed, daily inspection and testing of the contractor's performance and progress were carried on. Having the testing laboratory on site ensured maximum quality control; test results were given immediately to SP's Project Engineer, allowing for immediate remedial measures to be taken, if necessary.

Soil-Cement Subbase

In order to save time and avoid delaying construction, the Soil-Cement Short Cut Test Procedure for Sandy Soils, as outlined by the Portland Cement Association, was used to determine a safe cement content for each type of soil used on this project. The contractor agreed to abide by these results and even voluntarily added an extra percent of cement to ensure he met the required strengths during the first couple of weeks of operations. Once his production consistently exceeded the specification requirements, he was allowed to decrease the amount of cement used as long as strength requirements were still consistently met. Based on the overall results of the field tests, the Short Cut method proved to be successful.

Once soil-cement operations commenced, several field, laboratory, and plant tests and checks were run every day to ensure good quality soil-cement. Laboratory proctors and strength cylinders were run using that day's stockpile soil and the designated cement content to give an indication of target strengths; field proctors and strength cylinders were also run using soil-cement mixture actually placed on that day to verify compliance with the specifications. Our specifications called for a minimum of 400 psi unconfined compressive strength at 7 days for these strength cylinders.

Rather than dispose of field and laboratory soil-cement Proctor cylinders, they were tested along with the strength cylinders at 7 days to illustrate the effects of moisture content and density on strength. As expected, optimum strength was attained at optimum moisture and maximum dry density. What was dramatically illustrated in the test reports was the rapid loss of strength when moisture contents deviated from optimum moisture an average of 50 psi lost for a +/-2% deviation. Because of this effect, every effort was made by the contractor and inspection team to ensure proper compaction of soil-cement at optimum moisture content.

A sieve analysis was run on the stockpile soil to monitor daily consistency and check for excessive amounts of clay and clay balls. To reduce the amount of clay balls found in the stockpile soil, the contractor placed a 2" screen at an angle over his shaker bin; this combination eliminated all objectionable clay material. To check on the effects this had in the field, we ran in-place material over a 1" and a #4 sieve to check for the amount of clay balls in the mix.

Other daily tests included in-place densities, which were run on the compacted soil-cement using a Troxler nuclear density gauge immediately after final rolling, and thickness checks to check for thickness and uniformity of mix. Cores were taken to check for thickness and laminations, an indication of built-in failure. Areas where we encountered these laminations were removed full depth and replaced. As a final quality check, 4-foot wooden poles were used to "sound" the hardened soil-cement. As areas of dull sounding soil-cement were encountered, they were marked on a map as indications of soft or failed areas. These failed areas were either removed and replaced or removed to good hard soil-cement, and additional concrete was used to make up for the deficient subbase thickness.

The plant had been stockpiling soil for processing for weeks prior to laydown operations. Each area was staked and brought to grade, then the laydown process was brought into full swing. Dump trucks were loaded with the soil-cement mixture from a hopper, then they placed the material in front of the laydown machine. The contractor started off by using an asphalt laydown machine, but his production was low and inefficient. He quickly brought in a Jersey spreader to finish the job, and this increased his production tremendously.

Because rutting was a big problem in some areas, the contractor used a rake to knock down high spots under the dump trucks, and used the roller to recompact the subgrade after each truck delivered its load. The material was then compacted using a steel wheel roller. This roller left compaction planes in the soil-cement, the source of the laminations mentioned earlier, but the amount of material used was enough to leave the compacted section 1"-2" high; the laminations were cut out using a trimming machine. The material trimmed off could then be reused if it was still less than 30 minutes old. Any laminations still in the soil-cement surface were eliminated by using a spring tooth harrow, and final compaction was achieved using a rubber tire roller.

The surface was kept wet to prevent dusting and later hardbladed to eliminate high spots. Finally, a liquid asphalt primer coat was applied as a curing coat.

Having an on-site batch plant greatly improved concrete quality and allowed for greater control of the concrete. The contractor used a slipform paver, which also resulted in higher concrete quality because of the lower slumps necessary for efficient operation. While our specifications called for a maximum slump of 4", the contractor preferred a much lower slump and, indeed, their slumps typically ranged from 1-1/2" to 2-1/2", even when doing hand pours using the Clary machine. This improved the quality of the pavement in both strength and durability resulting in a dense, durable wearing surface of high strength and no problems with scaling.

Specifications called for a maximum 4" slump, entrained air content of 5%, and a 7 day flexural strength of 600 psi at third point loading.

During placement, the subbase was first cleaned off well, then wet down to prevent the subbase from absorbing water from the concrete mix. For finishing, the contractor used 3-foot bull floats and 10-foot straightedges, which produced a much smoother riding surface. For surface texture, wet burlap was dragged along the new concrete, then the white curing compound was applied. The contractor's equipment train was set up so efficiently that the amount of time involved from concrete placement to application of the curing compound was usually less than 30 minutes, thereby preventing plastic shrinkage cracking from occurring during the hot, dry Texas summer days.

Joints were sawed later the same day, as soon as possible without ravelling the green concrete. After inserting a backer rod, these joints were sealed with a cold-poured asphalt emulsion sealer before the pavement was opened to traffic. After all concrete had been placed, cores were taken to check for thickness.

Problems that were encountered during the concrete operations did not come from materials, but from weather. The concrete work was started at the end of the spring rains and although the contractor usually had enough warning before a storm, once he got caught. However, all concrete poured that day was covered with plastic and we did not lose any of that concrete, but the contractor was more cautious from that point on. Concrete operations continued on into July and August, and temperatures soared into the 100's. We became concerned with plastic shrinkage, cracking and flash sets at this point which could result from high mix temperatures. As mentioned earlier, the curing compound was applied immediately after finishing, which eliminated the occurrence of plastic shrinkage cracks. To avoid flash sets, the contractor watered down his coarse aggregate pile to keep it cool and reduce the mix temperature of the concrete. We experienced no problems with flash sets.

The concrete operations were very successful and produced a concrete pavement of exceptionally high quality.

Asphalt

Asphalt had a very limited use on this project. It was used as a level-up to fill in low spots in the existing crushed stone base with asphalt surface which was to be overlaid. It was also used between the railroad tracks to allow crossing the tracks at any point. Finally, and primarily, it was used as the wearing surface over the soil-cement in the Northwest Lot, on which empty trailers were stored.

ASPHALT CONCRETE PAVED YARD FOR THE UNION PACIFIC IN SEATTLE

BY
LELAND B. JONES
Shannon & Wilson, Inc.

The Union Pacific Railroad Company's Seattle Intermodal Facility is located a short distance south of Spokane Street, roughly between 1st and 5th Avenues. A portion south of the 5th Avenue viaduct has been used as an intermodal facility for several years, but the yard needed to be expanded. The expanded area is about 3,300 feet long and up to about 500 feet wide, and extends from 6000 feet northerly from the 1st Avenue viaduct to 700 feet southerly from the 5th Avenue South viaduct. The expanded area has been used for tracks, but did not carry heavy vehicular traffic.

The facility is on the old Duwamish River floodplain. About 80 years ago, to improve the area for development, the river was channeled to its present location, leaving old meanders in the developed area. The old meanders cut through the northerly portion of the intermodal facility and were about 18 feet deep below the present ground surface. In addition, the floodplain was from 2 to 12 feet below the present ground surface.

Initial site investigations consisted of 19 hollow-stem auger borings with Standard Penetration Tests followed by 15 backhoe test pits and 53 Falling Weight Deflectometer tests. Fourteen field California Bearing Ratio (CBR) tests were conducted at selected locations and two plate-bearing tests were performed. Subsurface materials were found to be extremely variable. Until the early 1950's, the old river meanders had been used for disposing of trash consisting of cinders and ashes, glass, various kinds of metals, and chunks of concrete. The rest of the area had been filled with highly variable materials ranging from sand and gravelly sand to very soft clay. The water table was generally only 2 to 3 feet below the ground surface. The old meanders filled with trash were extremely soft, but the rest of the area was inconsistent. Extremely soft areas were found immediately adjacent to firm areas. Some CBR tests had essentially zero strength, and both plate-bearing tests actually failed with loads of less than 50 psi.

One consideration in the design was that the two viaducts restricted the headroom so the final grade could be raised only about 1 foot. This restriction prevented using an overlay of additional fill to solve the stability problem. Based on the subsurface explorations and tests, it became apparent that in certain areas, the pavement could be designed for existing conditions, but in other areas the poor quality material would have to be excavated and replaced with better material. Based on observations and test data, areas not requiring treatment were assigned values for pavement design of K = 100 psi and CRB = 15. The intent was to replace the poor material to the extent that these values could be used throughout the area.

Because it was impractical to delineate the boundaries of unsuitable areas from borings and test pits, it was decided to proof-roll the entire area with a fully loaded 50-ton pneumatic-tired roller with 50 psi tire pressure. This rolling was done after initial site grading was finished. The 50 psi tire pressure was selected because that pressure would approximate the pressure from a loaded Piggy-Packer for 2 feet below the final pavement surface, about the level to be proof-rolled. The roller was operated at a speed of 2 mph for at least 12 passes.

The first few passes did not always show up the soft areas, but by 12 passes the soft areas could be detected and their boundaries delineated. These boundaries were mapped for future excavation.

Two pavement designs were developed for the facility. It was assumed that to obtain a consistent K = 100 psi subgrade value, an average of 3 to 4 feet of material would need to be replaced in the soft areas. To obtain a consistent subgrade for asphalt pavements, 5 to 7 feet of soft material would have to be replaced. The pavement designs prepared were for portland cement concrete and asphaltic concrete (hardest grade) for areas to be used by Piggy-Packers, for trailer traffic, and for parking. No design was prepared for Roller Compacted Concrete (RCC) pavements because of the soft and deformable subgrade likely to be present during construction.

The Union Pacific Railroad Company secured bids from several contractors for both types of pavement (including excavation and replacement of soft areas). As so often happens, much of the work was done during wet fall weather and paving was done in January 1987. The new facility has now been in service about 1-1/2 years.

Frequently, soft spots were long, narrow strips where material has been dumped without compaction, but most often they were in large, irregular areas. Sometimes the very soft material could be removed to firmer soil, but in many places, such as old river meanders, the soft material continued down to greater depths than excavated. Generally, the deeper materials were soft at all locations. The original estimate of 5 to 7 feet of soft material to be removed turned out to be reasonable. In most places, excavation was close to 5 feet and 7 feet was the maximum depth excavated.

In many areas, the soft material was covered by sandy material. This material was stockpiled and used for backfill. Additional pit-run gravel backfill was obtained from a pit located near Kent. That pit generally had a maximum size of about 3 inches and was reasonably well-graded to fine sand sizes. About 35 or 40 percent was finer than the No. 4 sieve; the more silty materials were eliminated by selection at the pit. The same material was used for the gravel base. To keep the backfill from being contaminated, soft areas were covered with a geotextile which made a "sausage" of the backfill.

One problem that developed during construction was that many of the manholes extended downward into the very soft and deep materials, so the weight of the Piggy-Packer or loaded trailer could cause excessive settlement. This problem was solved by constructing concrete slabs about 10 feet by 10 feet in the bottom of excavations to support the manholes.

Since the facility was completed, it has been subjected to high Piggy-Packer and trailer usage. The only known pavement failure has been a small section at the trailer entrance where there was insufficient removal of soft material. Detailed observations have revealed no other failed areas, or even areas that suggest potential failure. Only in the trailer parking areas has there been any distress. In most cases, portland cement concrete strips were constructed to support the trailer dolly pads. These strips were 5-feet wide (except one 3-foot wide pad near the west side of the parking area). Trailers parked 90 degrees to the concrete strips generally have their pads setting on the concrete strips (except many miss on the 3-foot strip), but where angle parking is used a large percent of the pads rest on the asphalt pavement. When the project was first opened, it was quite common for the round pads to sink into the asphalt pavement about 1/4-inch, but since the facility has been in use and the pavement hardened, none of the dolly pads now appear to be causing compression of the pavement. Concrete strips 8 feet wide would solve most of the problem.

Adjacent to some of the manholes, the pavement has settled up to about 1-inch as a result of poor subgrade and base compaction, probably because the roller operated lengthwise over the areas to be paved. At the manholes, the rollers passed outside of the structures leaving V-shaped areas with insufficient compaction.

CONSTRUCTION, PERFORMANCE AND MAINTENANCE OF ROLLER COMPACTED AND OF POURED CONCRETE IN INTERMODAL YARDS AT THE PORT OF TACOMA

BY
CURTIS L. RATCLIFFE
Port of Tacoma

The Port of Tacoma has a North and a South intermodal rail yard. The South yard was constructed in 1985 and was made exclusively of Roller Compacted Concrete (RCC). It covers about 13 acres and was constructed in 120 calendar days and cost $2 million. This was our first experience with RCC. It uses an aggregate with 450 pounds of cement and 100 pounds of flyash.

The North intermodal yard covers 23 acres. We spent $4 million to construct the yard. It has both RCC and cast-in-place surfaces that have performed well.

The two yards are operated differently. Our South yard uses top picks and the North yard uses straddle carriers.

Both RCC and cast-in-place surfaces are extremely different and have their pluses and minuses. In the South yard, the RCC was placed just as you would place asphalt. The contractor had a batch plant on site. We placed crushed rock over the site so we could run machinery on it without rutting the ground surface. We then placed 17 inches of asphalt, 8-1/2 inches at a time.
A problem with RCC is the surface. It is subject to cracking at construction joints mainly. A problem we had at these transverse joints is that the cracks are uncontrolled and always occur at a catch-basin. The way that the yard is designed is that the drainage valley is down the center, and the paving machines do not adjust to the valley in the RCC.

The RCC in the South intermodal yard is presently wearing fairly well. At first, we had some dusting problems, but use of the facility and grinding down some of the RCC surface helped create a good lock on the surface.

An apperance problem, is the edges of the South yard. We were not sure how to handle this during construction, but when you run a straight edge off the paving machine and then roll the surface, then the edge tends to break down at an angle. We had no way to compact the edge, so it is a little loose. Our stopping point is back from the edge, so the condition should not be a problem.

When we first started having problems with the cracks in the joints, we put liquid asphalt in them. This was not pliable, and in the cold weather, it would shrink up and come out. In hot weather, we would patch it. There were places where rubber tires actually picked up the asphalt, but it worked pretty well.

In some joints where the cracks opened up quite a bit, we placed a fine asphalt in the cracks and put the liquid asphalt around them. That has held up pretty well. The North intermodal yard is served mainly by straddle carriers. The "strads" have a tire pressure of 130 psi, and they are abusive to any type of surface.

The RCC on the North yard was placed in 1985. The paving machine used on this project had self-tamping bars which provided 95 percent compaction. The mix of the RCC in the North yard was the same as that in the South yard. The surface was a lot tighter than using traditional methods of pouring concrete. We have not had the cracking in the North yard as we had in the South yard. The machine gave a tighter surface on the edge and produced a sloped edge of about 15 percent.

The RCC was placed in the North yard during the hot season, and I believe that the contractor did not water properly, so the surface dried out. When that occurs, you do not get any matrix on the top of the surface. As tires start running over the RCC, it abrades and self-destructs. This caused quite an alarm at first.

One fix for the problem was to place a coal tar emulsion on the areas that were abraded, along the tracks and where the strads come into the train and turn. We placed two or three coats to see how it held up. The coal tar emulsion has since wore off, but it did its job in preventing cracking.

There are some maintenance problems with RCC, due to the uncontrolled cracking. All things being equal, I would choose cast-in-place over RCC due to the fact that you get a tighter matrix on the surface, better control over cracking and better control over your grade.

RCC EQUIPMENT DEVELOPMENTS AND CONSTRUCTION TECHNIQUES

BY
JON W. DELANEY
Portland Cement Association

Roller Compacted Concrete (RCC) is providing an interesting alternative to many agencies that are in the business of providing hard surfaced areas. It overcomes some of the problems of asphalt while providing the benefits of conventional concrete at a reduced price.

Knowledge of RCC has expanded considerably from the time of its first use in the mid-1970's, but there still is a need for experimentation and more research to make this product even better.

RCC is essentially the same material as conventional concrete. The difference is that it is backed a bit differently and placed differently. RCC typically has a little less cement content than conventional concrete and is rolled into place instead of being cast into place. Because it is a dry mixture, the water content is less. So, RCC is basically a non-plastic or dry mix.

RCC pavement thickness design methods are generally accepted to be the same as conventional concrete. RCC has the idiosyncracy that the initial cracking occurs at very long joint spacing. This produces, as far as cracks go, a very wide or open crack, any where from 1/4 to 1/2 inch.

This poses a problem with pavement design. The criteria for conventional concrete is based on the fact that, at a joint or edge of a crack, we have load transfer across that joint and support by the adjacent panels in all directions. If we take an RCC crack, we have essentially a free edge, and the pavement has to be thicker to sustain the increased stress. To account for the stress, design methods dictate or require that design loads be increased by as much as 20 percent.

If the RCC is batched and constructed properly, the flexible strength of RCC tends to be anywhere from 10 to 30 percent stronger than conventional concrete. So the increase in stress is offset by the increased flexible strength.

Earlier intermodal yards had stacking or picking equipment that protruded beyond the sides of the boxes. This prevented the boxes from being stacked closer together than 15 to 24 inches. With technology, the new picking equipment allows boxes to be stacked butt to butt and side to side. There is no room between the boxes. This gives greater space utilization, but it is a potential disaster for a material on which the containers sit.

Each container typically has a 6"x6" square steel pod in each corner to support the box on the pavement. If we work with containers of 50,000 pounds each and stack them four high, then each bottom corner pad carries a load of 200,000 pounds.

With fully loaded containers stacked four high on rolled compacted concrete or portland cement concrete, spaced about 24 inches between stacks, we would need a pavement thickness of about 18 to 20 inches. With containers stacked with no room between, we need a 28-inch thick section of concrete to hold those boxes without cracking the concrete.

Another area of pavement design that needs attention, which has been overlooked on some projects, is that newer picking equipment may be as much as 15 percent heavier than older equipment, a difference of up to 30,000 to 40,000 pounds.

In discussing construction, RCC pavement can be divided into two categories: those pavements used for dirty operations and those pavements used for clean operation.

A dirty operation is one in which the handled product leaves the pavement covered with a residue, such as when logs or coal are stored on pavement. The RCC surface is covered or only partially visible, thus the surface does not have to be "pretty". In addition, there is not much concern with cracks or minor rattling, and the speed of the operation equipment is relatively slow. So, the surface tolerance can be relatively loose.

A clean operation, typical of an intermodal yard, handles material that is containerized so there is nothing to get the pavement dirty. However, the operating equipment tends to move at a relatively fast speed. Thus, the looks and performance of the surface are more important here, and the surface tolerance is more critical, than that of a dirty operation.

RCC is really an asphalt paving operation using a portland cement bound material rather than using an asphalt cement bound material. Typically, your RCC surfaces have very open texture, and are relatively flat with a slope of maybe 1/2-inch in 10 feet. For a dirty operation, you can use any type of paving equipment for RCC, but for a clean operation, laydown machines with tamping bars should be used. For drainage purposes, a minimum 1 percent slope should be used.

One of the two most important factors in achieving quality in any kind of portland cement is curing. Unfortunately, most contractors putting down RCC do not have an appreciation of the need for curing. Consequently, joint surface rattling problems arise. The U.S. Army Corps of Engineers is experimenting with straight-on curing compounds. Their procedure is to continuously and thoroughly saturate the RCC for the first 24 hours. After that they apply two full strength applications of the curing compound. This seems to work well in keeping a good moist surface that continues to gain strength and durability. This is being considered as a standard procedure for RCC.

To achieve the desired performance of RCC, the density has to be proper. At least 96 percent density should be reached.

RCC is rapidly becoming accepted as the third major method of paving, competing with conventional concrete and with asphalt. It has the potential to become the dominant method of paving, since it provides the quality of conventional concrete, typically at a lower first cost than asphalt.

USE OF UNREINFORCED PORTLAND CEMENT CONCRETE PAVEMENT AT THE BURLINGTON NORTHERN SEATTLE INTERNATIONAL GATEWAY

BY
W. T. McCARTHY
Burlington Northern Railroad Co.

In December 1984, Burlington Northern Railroad (BN) decided to build a new container handling facility at Seattle, Washington. The project was begun in response to a growing intermodal market in the Pacific Northwest and the advent of new double stack equipment technology. The new facility is called the "Seattle International Gateway" (SIG; see Figure 1). This paper discusses the design, construction and performance of the Portland Cement Concrete Pavement used at SIG.

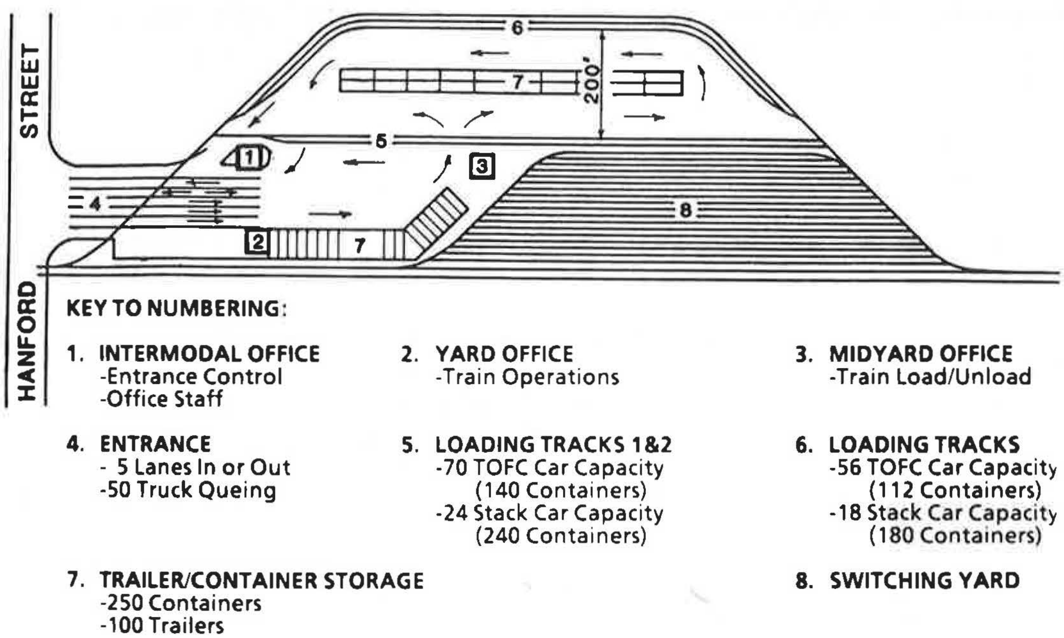

FIGURE 1. Seattle International Gateway: new yard capacity and operation

Until construction of SIG, Seattle had only one intermodal facility which was BN's South Seattle yard. This complex was constructed in the early 1970's to handle trailer on flat car (TOFC) business. In the early 1980's the terminal was expanded to handle container on flat car (COFC) business. The South Seattle yard served Port of Seattle container terminals and industrial warehouses in the Kent Valley. It is located about 10 miles south of the Port and 5 miles north of most warehouses.

Port of Seattle shippers using South Seattle became concerned over increasing rail costs mainly influenced by high drayage costs. In response, a new site was found within one mile of the Port of Seattle which BN made available for a new intermodal yard. Along with yard construction BN acquired new double stack rail cars, state of the art container handling equipment and installed a computerized system for routing containers from dock side to destination. The new intermodal yard is located on a portion of BN's Stacy Street switching yard. The yard has direct rail access to BN's transcontinental and north/south mainlines. In addition, the site provides truck access to Interstate Highways 5 and 90 within one mile of the front gate.

Preliminary surveys showed that the Stacy Street site had the proper dimensions to accommodate loading and switching of intermodal trains. The figure shows the preliminary track layout and operating plan. Site geometry allowed construction of trackage for simultaneous loading of two double stack trains or the equivalent of 400 container loads. The entrance to the site provides necessary queuing space for up to 50 trucks.

In order to meet market demands, BN made plans to complete the new facility as soon as possible. Demolition work was scheduled to start in February 1984 and construction was to begin in March. Based on an ambitious construction schedule, a completion date of July 1, 1985 was established. The decision to start construction in February was made in spite of winter rains common in the Seattle area. Although the schedule did not account for weather delays, construction plans and techniques were designed to minimize such delays.

Pavement Design

Geotechnical studies were performed included using a Falling Weight Deflectometer (FWD) to determine California Bearing Ratio (CBR) and modulus of subgrade reaction (k) values throughout the yard area. Based on these findings and loading conditions from the heaviest types of equipment proposed for use, thickness and other design considerations were determined for asphalt and concrete pavements. Finally, subgrade preparation required prior to placement of the pavement structure was recommended.

Surficial soils across the site were generally weak, consisting of loose mixtures of gravel, fine sands and local areas of wood chips. Underlying the surficial soils was fine, clean sand. The water table was found at an average depth of five feet below natural ground. Areas where the weakest soils might lead to problems during construction were identified so that plans could be made to prevent related delays.

A portable FWD mounted on a trailer was used to collect data on subgrade strengths at 180 points across the site. Based on this data and a statistical analysis of CBR and k-values, the geotechnical consultant developed design parameters for CBR = 5 and for k = 100 pounds per cubic inch (pci). The design CBR value was taken as the 90th percentile value and the k-value as the mean value. These design values were used to develop pavement and base course thicknesses for each alternative.

For design purposes it was assumed that loaded overhead lift devices would operate on paved runways along each pair of loading tracks. It was further assumed that a loaded side lift device and tractor-trailer combinations would operate anywhere within the facility, but most movement would be concentrated near the loading tracks. Wheel loads for fully loaded conditions on both the gantry crane and the piggy packer are about 80,000 pounds, with tire pressures of about 90 pounds per square inch (psi). It was assumed that truck-trailer combinations have two tandem axles of 34,000 pounds each and a single steering axle of 12,000 pounds.

The gantry crane was assumed to be the design vehicle for the runways, the piggy packer for the yard proper and trucks for the facility entrance. Loading conditions for the gantry crane were assumed to be low volume, channelized, and for the piggy packer low volume, unchannelized. For design of the truck lane at the facility entrance, an average daily traffic (ADT) of 175 fully loaded trucks per day was assumed. A durable low-maintenance pavement with a 20-year design life was desired.

Design recommendations were provided for asphalt concrete (AC), Portland Cement Concrete (PCC) and Roller Compacted Concrete (RCC) pavements. A number of alternative pavement sections for each paving material and loading case, were presented, as shown in Table 1. Alternatives for AC pavement are shown as information only since this paper is limited to discussion of rigid pavements.

TABLE 1. PAVEMENT SECTIONS

	Rigid Pavements		AC Pavements	
Alternative	Crane Ways	Yard Areas	Yard Areas	Entrance
1	19-in. PCC 12-in. GB	17-in. PCC 12-in. GB	4-in. AC 10-in. CRB 30-in. GSB	8-in. AC 12-in. GB
2	19-in. RCC 12-in. GB	17-in. RCC 12-in. GB	7-in. AC 8-in. CRB 20-in. GSB	
3	14-in. PCC 10-in. CTB	12.5-in.PCC 10-in. CTB	10-in. AC 6-in. CRB 10-in. GSB	

Note: PCC = Portland Cement Concrete, RCC = Roller Compacted Concrete, AC = Asphalt Concrete, GB = Gravel Base, CTB = Cement Treated Base, CRB = Crushed Rock Base, GSB = Gravel Subbase

A 12-inch thick Granular Base (GB) was recommended for use under rigid pavements in Alternatives 1 and 2. Use of a 12-inch GB in lieu of placing a rigid pavement directly on the subgrade, allows an increase in the design k-value resulting in a thinner rigid pavement section. In addition, the base will minimize pumping and rocking of the slabs and provide a more stable construction surface in the event of wet weather. In general, the granular base was recommended because it would result in lower maintenance of the pavement section throughout its design life.

A 10-inch thick Cement Treated Base (CTB) under rigid pavements was included in Alternative 3. CTB allows the maximum reduction in pavement thickness. In addition, it provides uniform, strong support to the rigid pavement and prevents subgrade from pumping and slab rocking. The process for placing CTB is not unlike that used for a granular base except cement must be mixed with subgrade materials prior to compaction. A danger in using CTB is the possibility of reflective cracking into the rigid pavement caused by inconsistencies in the CTB. After reviewing this alternative, CTB was ruled out for economic reasons.

Besides alternative pavement designs, references to appropriate material and construction specifications along with recommendations for subgrade preparation and treatment of contraction and construction joints were provided. It was recommended that all joints not be more than 25 feet on center. Expansion joints were not necessary except at fixed structures such as buildings and light standards where 3/4 to 1-1/2 inch wide expansion joints were recommended.

Due to concerns about wet weather, proof rolling the existing subgrade was recommended. The proof rolling would identify areas exhibiting pumping or heaving which could not be compacted. Subgrade materials in these areas could either be removed and replaced with sand and gravel fill or allowed to dry out before rolling. This would insure against failure of the subgrade between the placement of gravel base and construction of the pavement even during significant wet spells.

From the proposed alternatives, it was decided to use AC pavement only in the entry way, on parking lots and over the four loading tracks. The use of cement treated base was ruled out as not cost effective. Asphalt concrete pavement could not be used in yard areas since trailer dolly wheels and stacked containers would fail the pavement.

It was not known if roller compacted concrete pavement would prove more economical than PCC pavement in yard areas and for crane ways. Design was provided for both and included as alternate bid items in the contract documents. Even though specifications for RCC were strict, concern was expressed that such pavements are relatively new and, as such, somewhat risky to construct. Inspection of several RCC pavements throughout the Pacific Northwest and Canada showed that construction methods and equipment were still experimental and that service life is unknown.

A pavement section suitable to both PCC and RCC construction was selected. Cross sections of the pavement design loadings by equipment type and by width of the pavement are shown in Figures 2 and 3. Pavement depth in the yard is

17 inches of concrete over a 12-inch gravel base. The concrete depth was increased to 19 inches for overhead crane runways and to 24 inches at the edges of concrete slabs.

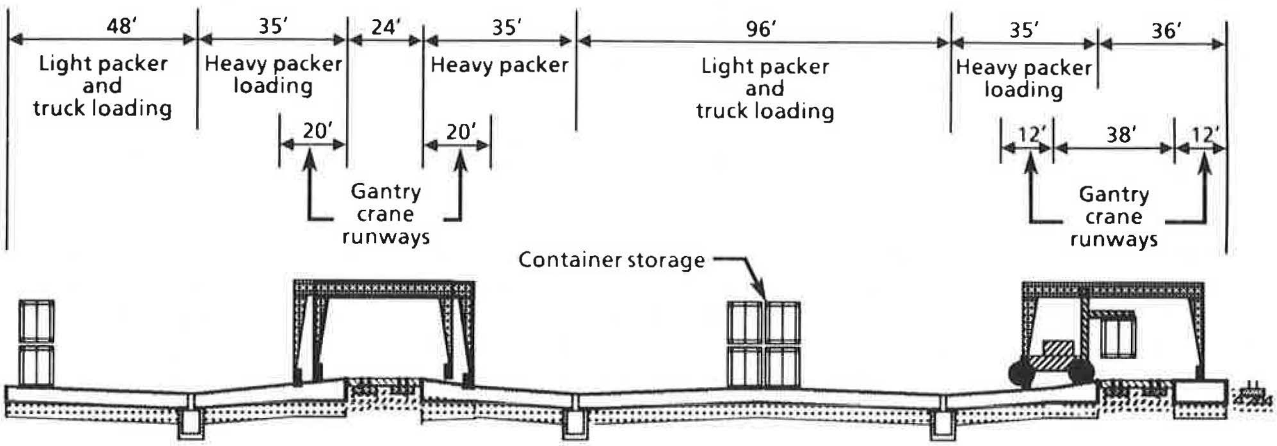

FIGURE 2. Cross section showing design loadings (not to scale).

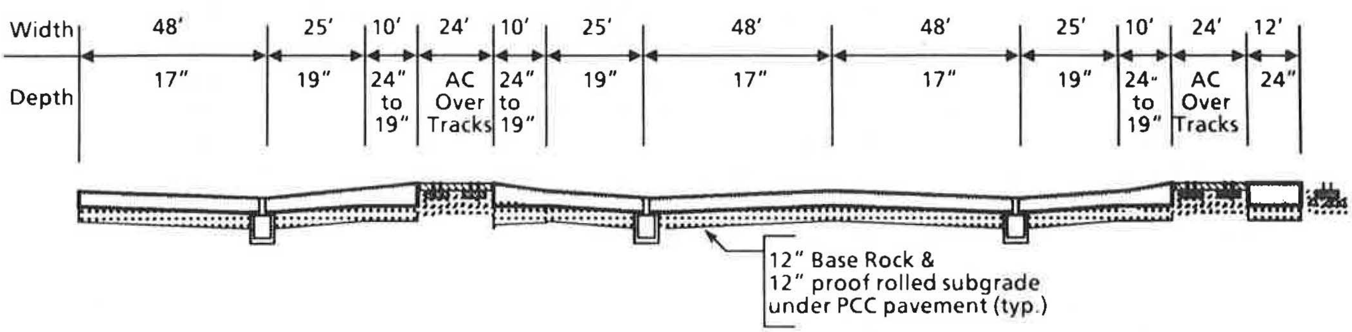

FIGURE 3. Cross section through width of PCC pavement (not to scale).

Although pavement sections are identical, it should be noted that PCC pavement could have been made thinner in some places. PCC pavement has the advantage of being placed as a fluid and can allow abrupt changes in pavement depths. RCC has a disadvantage being placed using conventional asphalt paving equipment since it cannot attain compaction requirements behind the paving train with abrupt changes in pavement depth.

<u>Pavement Construction</u>

A general construction contract was awarded on March 7, 1985 for the PCC pavement alternative. The low bid for RCC pavement was below that of PCC, but not enough in BN's opinion to warrant risking acceptance of RCC.

The contractor moved survey crews onto the site and immediately started planning storm drain construction. Installation of the 3.25 miles of storm drain was an important factor in completing the project. Not only did grading and paving operations hinge on storm drain completion, runoff from winter rains had to be removed from the site as quickly as possible.

In conjunction with storm drainage, the contractor began regrading the site and proof rolling the subgrade. Specifications called for proof rolling both disturbed and undisturbed subgrade materials to a minimum compaction of 98% of maximum density at a depth of 12 inches as measured by the modified proctor ASTM D 1557-70 method C. All subgrade materials which did not meet this compaction requirement were either removed or tilled and allowed to dry, before being recompacted.

Plans called for a 12-inch thick gravel base course under all PCC pavements. The base course was compacted to 98% of maximum density as measured by the above proctor method. Base course and AC pavements were constructed in accordance with a 1984 Standard Specification for "Road Bridge and Municipal Construction", Public Works Association, Washington Chapter.

A minimum concrete compressive strength of 4,000 pounds per square inch at the end of 28 days of curing was required. Following is the approved concrete mix design with volumes shown per cubic yard of concrete produced:

Cement (Type II)	460 Lbs.
Fine Aggregate	1,560 Lbs.
Course Aggregate	1,980 Lbs.
Total Water	25.0 Gal.
Admixtures:	
Water Retention Agent	
Air Entrainment Agent	

PCC pavement was constructed in accordance with "Standard Specifications for Municipal Public Works Construction", 1975 edition, by Washington Public Works Association as amended by "City of Seattle Supplement to Standard Specifications for Municipal Public Works Construction" dated 1976.

Contraction joints were spaced 25 feet on center. Transverse contraction joints within 100 feet of a free edge of the pavement were doweled with smooth steel dowels 1-3/4 inches in diameter by 22 inches long spaced 18 inches on center. All other contraction joints were saw cut 1/4-inches wide while the concrete was still green and later routed to 3/4-inch widths. These joints were filled with a backer rod and cold applied joint sealant. An AASHO premolded joint filler type M213 was placed between the pavement and adjacent structures such as light tower foundations and drainage structures. All construction joints were keyed using a tapered 4-inch by 2-inch nominal key way.

During construction a great deal of emphasis was placed on quality control. A total of 670 compaction tests were taken on the subgrade and gravel base. During paving operations, 586 concrete cylinders were tested. The testing required the full time services of a man from a testing laboratory.

Figures 4-6 show the on-site batch plant, the smoothing of the pavement at the SIG yard and the operational truck entrance.

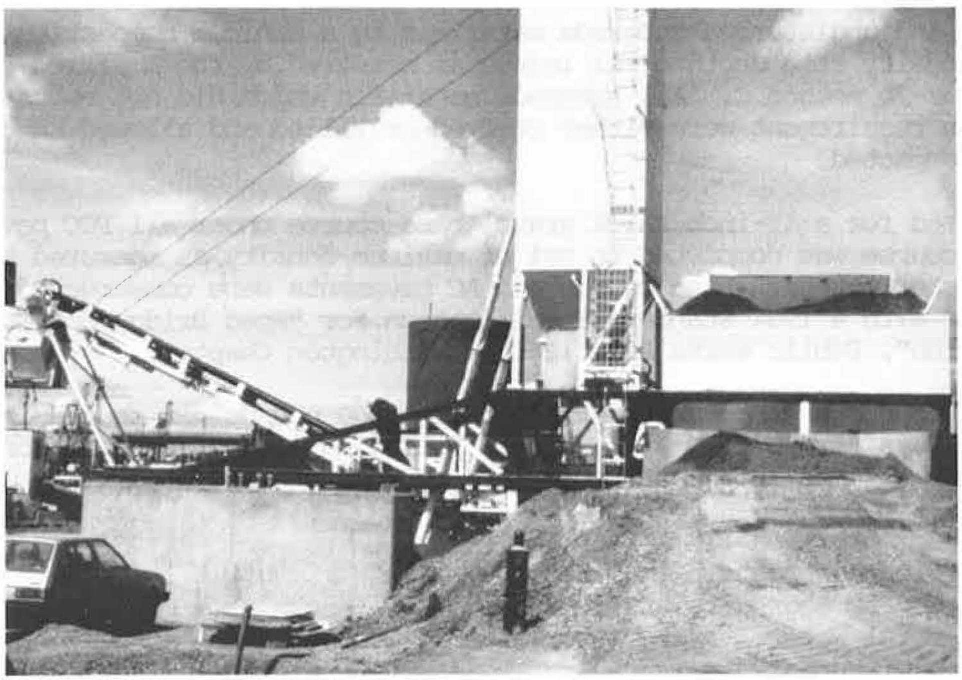

FIGURE 4. On-site batch plant

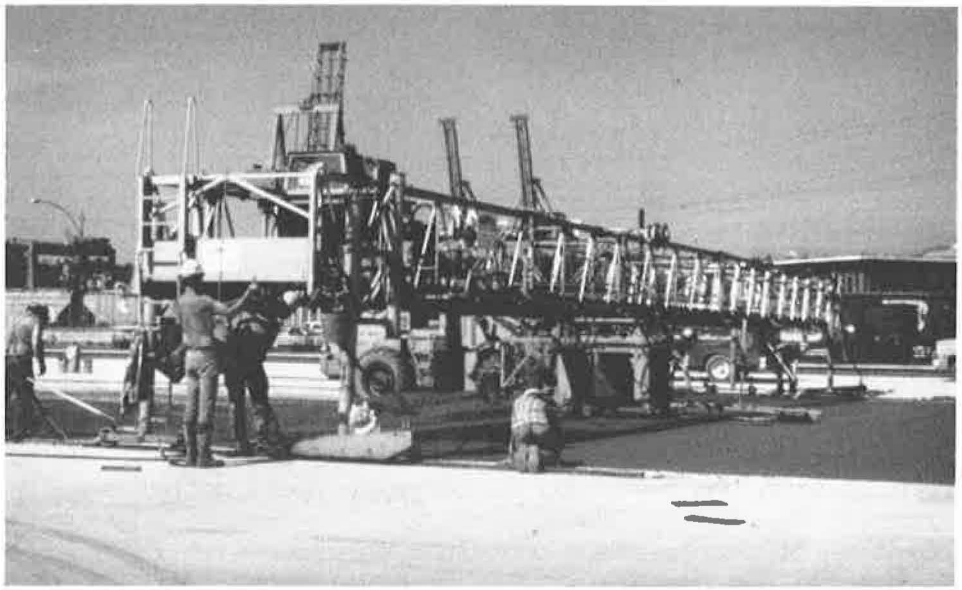

FIGURE 5. Smoothing pavement in SIG Yard

FIGURE 6. Operational truck entrance

Pavement Performance

An inspection of the SIG facility was made in June 1988. At the time of this inspection it is estimated the total number of containers handled since its opening was 540,000. This inspection found no apparent problems with the pavement. There is no undesired cracking, surface spalls, joint degradation or other signs of deterioration.

DOUBLE-STACK CONTAINER TRAINS POTENTIAL FOR AGRICULTURAL EXPORTS

BY
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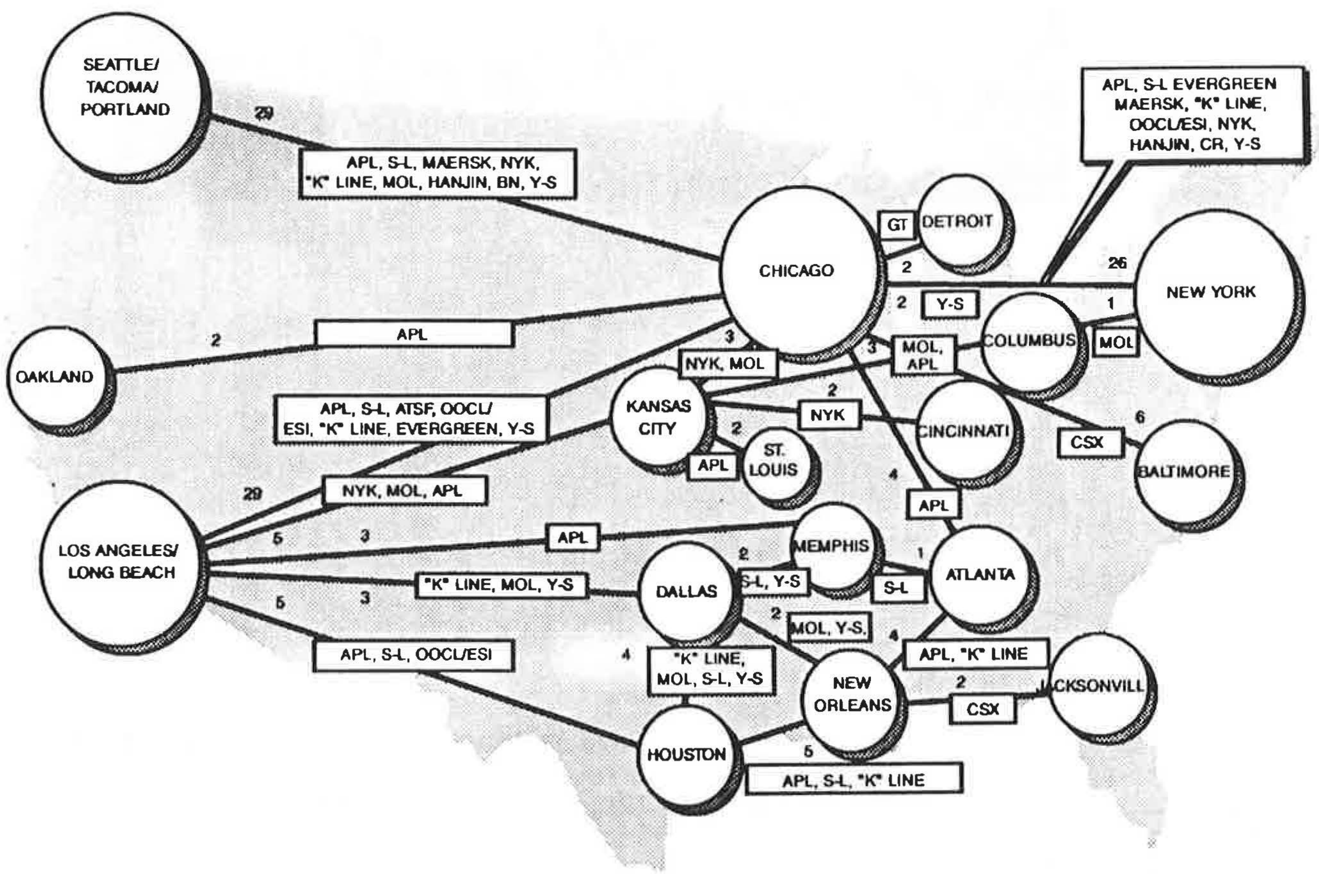
U.S. Department of Agriculture

Double-stacking containers on specially designed flatcars has produced great changes to intermodalism in this country. This development is comparable to the introduction of containers by McLean Trucking in 1956. Increased use of intermodal transportation and domestic containerization for the U.S. shipper may become more pronounced with double-stack service. The rapid emergence of double-stack service and the opportunity for more efficient domestic moves provides the shipper with unique rate opportunities and expedited service that is more competitive with motor carrier service. This is not to say that double-stack service is more advantageous in all instances. However, it is a new technology with the potential to serve shippers better.

The integration of double-stack container services with railroad line-haul hub centers and port load centers is a major development in the evolution of U.S. intermodalism. Since April 1984, when the first dedicated rail service was inaugurated between Los Angeles and Chicago and featured the first non-railroad owned double-stack container trains, this service has flourished. Today, there are 104 double-stack trains in operation leaving the West Coast each week. In



NOTE: REFLECTS UNIT TRAINS AND LARGE BLOCKS RANGING IN SIZE FROM 50 TO OVER 300 UNITS (FEU).
SOURCE: TEMPLE, BARKER & SLOANE, INC.
FIGURE 1. Major double-stack services, January 1988 (departures per week, eastbound).

July 1987, there were 54 trains in operation. Two more trains will begin weekly service August 1st. Figure 1 shows the routes of stack trains as of January 1988.

The challenge of the double-stack railcar can be divided into two broad categories: operational and economic. In the operational area, the articulated double-stack flatcar is designed with five platforms, each capable of handling two 40-foot containers. A typical train consists of 20 cars with total capacity of 200 containers. The biggest operational problem with stacking containers two high is that tunnels and bridges, under which the trains must pass, are often too low. For this reason, drop-frame or deep-well flatcars, similar in design to those used by trucks in hauling heavy equipment, are employed.

Also, double-stack service has mandated greatly expanded terminals with bigger, faster, and stronger port cranes. These cranes can lift 20 to 30 forty-ton containers each hour and have outreaches of 145 feet to accommodate the larger Panamax-sized ships. This intermodal interface is requiring efficient terminal configuration with the means to maximize intermodal transfers with minimal cost and disruption.

In the area of economics, the challenge of double-stack service lies primarily in the cost field. Experience has shown that double-stack carriage operations can offer savings in the 20-40 percent range when compared with TOFC/COFC. A study prepared for the AAR and Trailer Train estimates that double-stacking containers reduces crew costs by 50 percent, fuel costs by 35 percent, maintenance by 35 percent, and miscellaneous cost by 28 percent.

In addition to cost savings, double-stack trains offer faster transit times which can be translated into inventory-in-transit finance savings for shippers. Also, improved equipment utilization rates reduce operating costs for carriers. For instance, double-stack trains regularly travel from Seattle to Chicago in 60 hours.

An incidental cost savings, especially for the agricultural shipper, is the improved cargo damage protection inherent in double-stack trains. The minimal vertical vibration and the lateral stability, which is a unique feature of the articulated double-stack flatcar, reduces in-transit damage.

The potential benefits for the agricultural shipper is the service's capacity to efficiently move containers. Double-stack service provides better use of railcar space, improved cargo damage protection, and expedited movements.

The promise that double-stack service offers agriculture is the increased number of containers moved per train which permit a significant lowering of unit costs. The economies of scale provide the agricultural shipper with increased speed and efficiency in handling containers at ports and hub centers, and expedited movements to inland destinations.

Although the prospects for agriculture are many, double-stack service still has problems in moving perishables. The first of these obstacles is weight. The weight of a refrigerated marine container with a self-contained motor generator is between 12-15,000 pounds versus 6,000 pounds for a dry freight container.

This poses a problem for the shipper because it severely limits the size of a payload which can be loaded into a refrigerated container. With a 100,000 pound weight limitation per flatcar, two fully-loaded containers often exceed these limits.

Another problem which agriculture has with double-stack refrigerated service pertains to the power for the reefer units during transit. Originally, the system was designed to provide power for refrigerated containers on the five-platform double-stack railcar from a centralized source. However, this aggravated the already existing weight problem for the double-stack carrier.

Recently, a self-contained refrigeration unit, equipped with its own generator, was developed and currently is being tested with the hope of solving this problem. These refrigerated containers can be loaded in any position on a stack train and can be readily transferred to a truck or a conventional flatcar as required. These self-contained units have 70-gallon tanks to carry sufficient fuel for the Seattle-to-Chicago run. (Fuel is expended at the rate of 1 gallon per hour, travel time is about 60 hours for this run). Containers are refueled at Chicago and proceed to New York.

Finally, double-stack service is directly dependent on a sufficient volume of cargo moving. The question is whether the volume exists for agricultural products to move domestically on their own double-stack trains. Double-stack service is best suited for handling time-sensitive cargo on very high volume corridors. There are many intermodal flows that cannot support volumes large enough for double-stack unit trains. It has been cited often that a shipping corridor must have at least 50,000 loads per year in the head-haul direction to support a regular or continuous double-stack operation. Three thousand container-equivalent loads of fresh fruit and vegetables moved from California to New York City in 1987.

In summary, inland transportation of international marine containers on double-stack unit trains has been a successful concept and has produced a significant impact on rail freight transportation in the United States. Stack trains are, in many instances, more cost efficient in comparison to conventional TOFC/COFC intermodal trains.

The stack trains advantages are many and include the damage free ride and the excellent condition of commodities transported. Additional advantages include a dedicated unit train operation, articulated flatcars and their cost efficiencies. Finally, the scheduling and speed with which stack train service is operated increases significantly the utilization rate of both equipment and rolling stock.

Although there have been problems in the transport of agriculture perishables on double-stack trains, both carriers and manufacturers have been working to develop equipment which will overcome these problems. As the need and demand for the service increases among agricultural shippers, solutions to these problems will hopefully be found.

PRELIMINARY ASSESSMENT OF THE SHIPPING ACT OF 1984: A CASE STUDY OF PACIFIC NORTHWEST AGRICULTURE

BY
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The paper will identify some agricultural exporters in the Pacific Northwests perceptions of the Shipping Act of 1984. A review of the specific provisions in the Act, an examination of the perceptions of shippers towards the Act, and identification of some impacts of the Act on agricultural shippers will be discussed.

Shipping Act of 1984 Provisions

1. Conference Structure

- The Act made little basic change in the conference structure.
- The Federal Maritime Commission, (FMC) lost the authority to approve or disapprove carrier agreements, which, from the carrier viewpoint, made things happen faster and with more certainty. Agreements still had to be filed with the FMC.
- The court system became the arena for the evaluation or contesting of agreements.
- Rate agreements were streamlined to 45 days, which was important in terms of efficiency and market conditions.
- Conferences were to remain open.

2. Mandatory Right to Independent Action

- Individual carriers could depart from rates collusively set by conferences. This introduced both rate uncertainty and rate flexibility.

  From a shipper point of view, the Act allowed for better response to market conditions for shipments of perishable agricultural products.
- Full market information was no longer available to all the participants in the market.

3. Service Contracts

- Service contracts are quantity and rate agreements. For a given rate, the shipper gets a specific service. Or, the shipper gives a specific quantity and then gets a lower rate.

- There has to be public disclosure of the essential terms.

- The option to offer contracts can be eliminated by a conference.

- Most favored shipper clauses ensured that no shipper has a better rate from a carrier. Also, service contracts have "Crazy Eddie" clauses which says that if a shipper can find anyone to offer a lower rate, then the carrier has to match it.

- Contracts specify a legal minimum volume.

4. Shipper Associations

- These strengthen the bargaining position of small shippers.

- Associations are nonprofit organizations, but are not exempt from antitrust laws. But, they can apply for a Business Review letter from the Department of Justice.

Finding of 1988 Shipper Survey

The shipper survey was partially funded by the Office of Transportation of the U.S. Department of Agriculture. A mail questionnaire was sent to 174 agricultural firms in the Pacific Northwest, and 50 responses were received from major agricultural exporting firms. The responses include about 90% of the apple volume exported, 70% of the frozen potatoes and over 50% of the onions that are expected. Therefore this response reflects some of the attitudes of the major firms dealing in those commodities.

The respondents also included shippers of hay, lumber, onions, apples and frozen products. These commodities range from the extremely bulky to very high value. The average length of time in business by the responding firms was 36 years, and the average time in exporting was 21.5 years. Of the products shipped by these firms, 53% was into the export market. It is evident, then, the respondents include people who are knowledgeable in the exporting area and whose businesses depend on exporting.

Following is a discussion of the survey questions and responses:

1. Impact on Rates

- Did the Act result in increased rates?

Yes-26 firms	No-14 firms
65%	35%

- Did these increased rates cause a loss of sales?

Yes-24 firms	No-12 firms
67%	33%

- Did the increased rates cause a loss of international markets?

  Yes-11 firms   No-14 firms
  44%   56%

- Did the Act increase the volatility of shipping rates?

  Yes-32 firms   No-9 firms
  78%   22%

  This response would be expected due to the availability of independent action.

- Did the increased volatility in rates cause a loss of sales?

  Yes-23 firms   No-11 firms
  68%   32%

- Did the increased volatility in rates cause a loss of markets?

  Yes-10 firms   No-13 firms
  43%   57%

2. Shipper Desires

a. Conferences

Do you desire open conferences?

Yes-38 firms   No-1 firm
97%   3%

- Should the conference system be eliminated?

  Yes-22 firms   No-16 firms
  58%   42%

- Would the elimination of conferences lower rates?

  Yes-25 firms   No-2 firms
  93%   7%

b. Mandatory Right to Independent Action

- Have you utilized independent action rates?

  Yes-27 firms   No-12 firms
  70%   30%

  This response was a surprise in that many of the respondents are small agricultural shippers.

- Do you want to retain mandatory independent action?

  Yes-37 firms No-9 firms
  80% 20%

- Do you want a shorter notice period, 10 days or less?

  Yes-29 firms No-13 firms
  69% 31%

  The idea from the shippers point of view is that if they can immediately introduce independent action, then they have a better negotiating position with the carrier as the sailing date draws closer.

c. <u>Service Contracts</u>

- Do you want mandatory independent action on service contracts?

  Yes-40 firms No-6 firms
  87% 13%

- Should essential terms of service contracts be published?

  Yes-26 firms No-18 firms
  59% 41%

  We found that some of the companies that had been successful in negotiating service contracts did not want the essential terms published, as they were afraid that the competition might learn from their activities.

<u>Preliminary Conclusions About the Act</u>

- The Act may be working well in balancing the concerns of carriers as they compete in international markets, but there are concerns from the viewpoint of the agricultural shipper.

- The power of the Federal Maritime Commission has been decreased, which probably is better for the carriers. Shipper interests have increased due to provisions for service contracts, independent action and shippers associations.

- Significant impacts on agricultural shipments have occurred due to higher rates.

- Shippers maintain that rate levels and volatility and container availability problems have increased, causing some loss of sales and markets.

- Shippers want open conferences, if conferences are to be retained.

- Shippers desire mandatory independent action with a short notice period.

- The new provisions of the Shipping Act have made the conference structure fairly workable. No urgent request exists on the part of agriculture to abandon the Act, but shippers desire to modify some provisions pertaining to service contracts and independent action.

COMPETITIVE ROUTINGS VIA MINIBRIDGE AND THE PANAMA CANAL

BY
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Introduction

Imports of foreign goods into the United States experienced tremendous growth during the 1980's as rapidly increasing domestic consumption, coupled with the soaring value of the U.S. dollar abroad, drove import demand to record highs. The growth in containerized imports from the Pacific Rim nations of East and Southeast Asia was particularly dramatic with the volume more than doubling from 1.3 million TEUs (Twenty-Foot Equivalent Unit containers) in 1982 to nearly 2.8 million TEUs by the end of 1987.

Traditionally, such imports moved by all-water routes to a port nearest to the final U.S destination, since maximizing the water leg generally provided the lowest cost transportation option. In recent years this pattern has changed dramatically. Today, imports from the Far East to destinations on or near the U.S. East or Gulf coasts can continue to use the all-water route, transiting the Panama Canal, or alternatively these imports can be unloaded at West Coast ports and shipped by rail "minibridge" across the country to points of destination. Conversely, imports from Europe to the West Coast of the United States can transit the Canal westbound, or these imports can be unloaded at a U.S. Atlantic port and be shipped overland by rail.

West Coast Port Container Traffic

The growth in containerized import traffic has been distributed unequally among U.S. ports. The rapid growth in traffic from the Asian Pacific Rim nations to the United States has been felt most at West Coast ports, which have benefitted from both a growing hinterland market and the use of rail minibridge to reach interior and East Coast markets. U.S. Pacific ports increased their share of the nation's container trade from 31 to 44 percent between 1981 and 1986. This increase has been almost entirely at the expense of ports on the Atlantic and Gulf coasts. However, among the West Coast ports themselves, growth has also been unequal. The ports of Los Angeles and Long Beach have experienced the greatest increase in total container throughput (import and export, foreign and domestic), growing at an annual rate of nearly 20 percent from just over 1 million TEUs in 1981 to over 3 million TEUs in 1987. Figure 1 indicates the growth in West Coast container traffic.

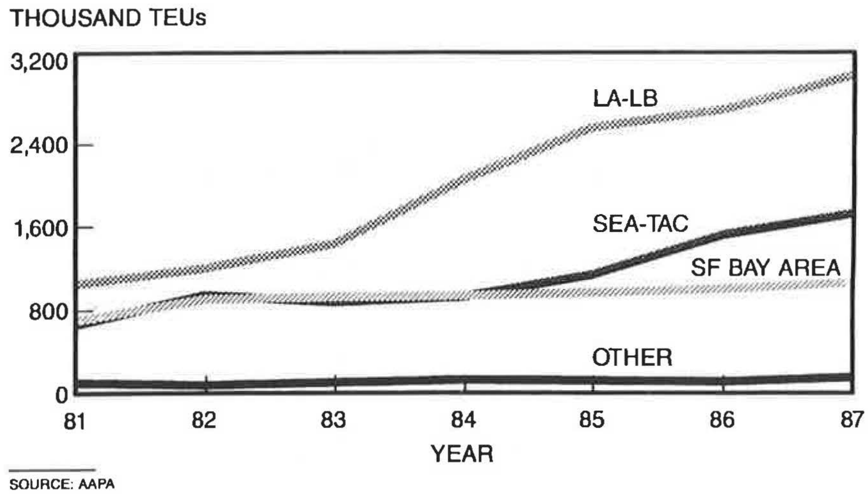

FIGURE 1. Growth in container traffic at West Coast ports, 1981-1987

The ports of Seattle and Tacoma experienced modest growth to 1984, but then containerized traffic began to increase significantly. Volume nearly doubled between 1984 and 1987, increasing from 926 thousand TEUs to over 1.7 million. This rapid growth in container throughput at Pacific Northwest ports coincides with the introduction of dedicated double-stack rail service from the West Coast to Chicago and the location of added terminal facilities at these ports. Container throughput at Bay Area ports (Oakland, San Francisco) has grown also, but much more slowly than the other West Coast port regions for a variety of reasons. Volume increased from around 700 thousand TEUs in 1981 to a little less than 1.1 million TEUs in 1987, corresponding to an annual growth rate of 7 percent. Growth in container traffic in the Bay Area has been constrained by low tunnel clearances in the region which limited the height of double-stack trains and by ocean carrier decisions to "load center," concentrating their port operations at fewer locations and thus limiting their number of port calls.

Growth of Minibridge Traffic

An analysis of Census Bureau foreign trade data by the Port of Oakland estimated containerized imports to the U.S. East Coast based on liner traffic statistics. Assumptions were made that liner traffic is generally containerized and that liner imports to the U.S. East Coast that were unloaded at a West Coast port moved across the country by rail "minibridge". The study found that minibridge rail traffic in Far East containerized imports bound for the U.S. East and Gulf coast areas has been growing nearly every year since 1978. Minibridge volume is estimated to have grown from less than 1.1 million tons in 1978 to 1.7 million tons by 1983 (an annual rate of 9 percent). The rate of growth then increased to over 15 percent annually, and the volume of traffic reached 3.0 million tons in 1987. Total West Coast liner imports from the Far East have grown at an even faster rate since 1983, increasing from 7.3 to 13.7 million tons in 1987.

Meanwhile, Asian Pacific Rim liner traffic destined for the East and Gulf coasts of the United States by the all-water route via the Panama Canal fluctuated over the early part of the period from 1978 to 1983, but increased thereafter from 4.1 to 5.6 million tons in 1987.

Therefore, the data indicates that while the minibridge rail traffic in Far East imports bound for the U.S. East and Gulf coasts has been increasing, so generally has traffic through the Panama Canal, albeit at a slower rate. Minibridge has nonetheless captured a slowly increasing share of the East Coast market, growing from 29.7 percent in 1983 to 34.8 percent in 1987 (for an annual growth rate of 4.0 percent).

Panana Canal Traffic

Total traffic moving through the Panama Canal has begun to rebound after dropping significantly in 1983 with the opening of a $300 million oil pipeline across the isthmus. Canal traffic fell to 11,707 vessel transits in 1983 from 14,009 a year earlier. Traffic recovered to 12,230 ships in 1987, and data for the first five months of 1988 indicate continued growth. Traffic using the Canal is increasingly bulk commodities, especially grain and coal from the U.S. East and Gulf coasts to the Far East, some crude petroleum eastbound, and automobiles being shipped to the U.S. East and West coasts. Containership tonnage, however, has continued to grow throughout the 1980's, and container movements to or from the U.S. dominate container tonnage through the Canal, accounting for over 70 percent.

Attraction of Minibridge

The economics driving this increase in minibridge rail traffic are based on the savings associated with the use of double-stack container unit trains in dedicated scheduled service between West Coast ports and points in the Midwest and the East. A double-stack container train can carry more than twice the cargo volume of a conventional piggyback service and do so with only a marginal increase in locomotive power and virtually no increase in labor.

The potential efficiencies of double-stacks for both railroads and ocean carriers has led to a rapid increase in the number and routes of double-stack unit or mixed trains departing West Coast ports every week for interior and East Coast destinations. The number and destinations of stack trains has proliferated dramatically over the last two years, growing from 22 per week in February 1986 to at least 76 by January 1988.

The services are operated by both the railroads on their own lines (such as Burlington Northern, Sante Fe, CSX), and by ocean carriers or intermodal subsidiaries using their own or leased equipment and railroad supplied headend power (such as APL, Sea-Land, and many others). Los Angeles and Long Beach have claimed the lion's share of these double-stack departures with over 45 per week, compared to 29 in the Pacific Northwest and only 2 per week from the Bay Area.

West Coast Port Competition

The rapid growth in double-stacks has opened up virtually the entire U.S. market east of the Rockies to West Coast ports. Each of the major port areas has a natural hinterland generally served by truck, and imported containers to these areas will usually move via one of the local ports. The size of this local market is one reason many trans-Pacific carriers make Los Angeles/Long Beach their first port of call. The use of double-stack trains, however, has opened a secondary market in the interior and eastern United States which can be considered discretionary since it can be served nearly equally efficiently from any of the West Coast port areas. Consequently, fierce competition has developed among West Coast ports to capture as large a percentage of this discretionary traffic as possible.

The port region of Los Angeles/Long Beach has done well in this contest because of the size of its "local" market, which consumes about 55 percent of incoming container traffic. The remaining 45 percent generally moves by rail to markets in the interior and eastern parts of the country. By contrast, the Pacific Northwest has a much smaller local market and about 70-75 percent of the containerized imports in this area move eastward into the discretionary market area. One advantage of the Pacific Northwest ports is the shorter steaming time across the Pacific to Japan and Korea, making this region attractive for picking up containers for the return trip to the Orient.

Beyond Panamax

Further evidence of the importance that minibridge rail traffic has gained is the development of the "Beyond Panamax" containership. Early containerships were modified general cargo ships with a beam of about 76-90 feet. "Panamax" size vessels followed with a beam of about 105 feet, which was the largest practical vessel beam which would still permit transit of the Canal. This year American President Line is taking the delivery of five new "C-10" ships with a beam of 129 feet, making them the first containerships too wide to transit the Panama Canal. APL has committed to a strategy of relying on rail minibridge to move Far East imports from West Coast ports to markets in the East.

Conclusions

The use of rail minibridge offers certain advantages which have attracted significant amounts of cargo that would have otherwise moved entirely by water between the Far East and the U.S. East Coast via the Panama Canal. Minibridge offers considerable savings in time of 10 to 15 days between Far East ports and New York, and these savings in time can also translate into savings in cost, depending on the type of cargo and its destination.

A number of factors will affect the future of container traffic moving both by minibridge rail and via the Panama Canal. The weakened U.S. dollar has begun to dampen import demand and strengthen exports. East Coast ports are improving container handling facilities and reducing costs to carriers and shippers in an effort to retain traffic. These ports are also looking at ways to encourage more westbound double-stacks for cargo arriving via the Atlantic. Success of such marketing efforts could make further inroads into container traffic that would have moved through the Canal. Shifting production areas in Asia may also have an impact in the future as manufacturers look for cheaper labor in southeastern and southern Asia. Changes in production areas could lead to a shift in favor of U.S. East Coast ports (a container from Singapore to New York takes 23 days all-water via Suez and 30 days via a West Coast port and rail minibridge). Currently, however, the volume of containerized traffic passing through the Canal has continued to grow. It is apparent that competition among ports for containerized cargo will be increasingly fierce in the future, and the ultimate role of the Panama Canal in this trade remains dynamic.

Future Research

Further analysis of transportation costs could provide an indication of the sensitivity of alternative routings for containers, including the Asia to U.S. East Coast routing via the Panama Canal and via minibridge through West Coast ports. A series of cost curves can be developed based on a variety of assumptions regarding the degree of utilization of container ships, the provision of backhaul for the double-stack rail movement, various port costs and inventory costs for different valued commodities. These curves should help ascertain the level of sensitivity of routings for various commodities and foreign areas.

A recent paper by John L. Eyre, published in International Trade and Transport, April 1988, indicated a cost of 0.3 cents per ton-mile to operate a new 4,200 twenty-foot equivalent ECON container vessel, which compares to the cost of 0.5 cents for the 3,000 TEU containership, 1.0 cents for the 1,800 TEU containership and 4.0 cents for the conventional freighter. For rail, the double-stack express train costs 2.0 to 4.0 cents per ton-mile to operate compared to 4.0 to 15.0 cents or an average of 8.0 cents per ton-mile for conventional rail. For trucks, the jumbo super twin costs 3.0 to 6.0 cents per ton-mile to operate which is about 1/2 of that of a conventional long-haul truck movement.

NAVIGATION ON THE COLUMBIA-SNAKE RIVER SYSTEM

BY
PEGGY BIRD
Pacific Northwest Waterways Association

The Pacific Northwest Waterways Association (PNWA) is a 54-year old non-profit organization. The Association represents the interests of a broad base of members who are committed to the economic development of the region through the appropriate use of the region's natural resources. The association was formed by a group of farm interests and ports on the Columbia River. They wanted the plans for the Bonneville Dam that was about to be built to include a lock that would allow passage of grain barges.

PNWA's members include firms, organizations and public bodies in the states of Oregon, Idaho and Washington. Members range from ports to engineering firms, public and private utilities to grain growers, financial institutions to river pilots. They come from the Puget Sound, the coasts of Oregon and Washington, the dryland areas east of the Cascade Mountains, the major metropolitan areas of Boise, Portland, and Seattle, and the Columbia River corridor.

The Columbia begins in the Canadian Rockies, 1,200 miles from the Pacific. It drains 219,000 square miles of the U.S. The navigation system consists of 365 miles of shallow draft waterway from Portland, Oregon/Vancouver, Washington upstream to Lewiston, Idaho (making Idaho a seaport state). The shallow draft system includes 139 miles of the Snake River. The deep draft portion, from the sea to Portland/Vancouver, is 100 miles.

The Columbia drops 2,650 feet from its headwaters to the Pacific. The river generates one-third of the entire hydro capacity of the United States. The river's volume is second only to the Missouri/Mississippi system.

The river was developed by the Federal government as a multiple use system--navigation, energy generation, flood control, irrigation, recreation, fish. At the height of development in the late 1950's and early 1960's, 10% of the national public works budget was being spent on the Columbia.

Throughout the entire drainage basin of the Columbia-Snake in the U.S., there are 102 dams built and maintained by the Bureau of Reclamation, the Corps of Engineers, private and public utilities and irrigation districts. On the navigation system, the dams are all owned and operated by the Corps of Engineers.

During the 1850's the gold rush spurred a steamboat boom. Steamboats brought grain to ocean going ships that sailed into the lower Columbia. A major bottleneck was the Cascade Falls rapids where all freight was portaged by rail around the falls. The first major navigation project on the Columbia was the Cascade Lock and Canal, built by the Corps of Engineers. It was completed in 1888 and cost $3.8 million.

As the Cascade Lock and Canal was completed, plans began for eliminating the last barrier to navigation to the interior of Oregon and Washington--Celilo Falls. With support from the region and the Corps, Congress approved the Dalles-Celilo Canal in 1905 and the canal was completed in 1915.

In 1913, new work at the mouth of the Columbia brought a depth of 36 feet over the entrance. In 1918, a navigation channel 30 feet deep and 300 feet wide from Portland to the sea was completed. By 1926, oceangoing cargo using the system had more than tripled. But larger vessels calling the lower Columbia meant that further improvements were needed. In 1933, the channel was deepened by five feet and widened by 200 feet. The bar was deepened in 1957 to allow ships to fully use the deeper channel.

In the 1930's, the Federal government began a program of dam building. The need for navigation, substantial hydro potential, the need for flood control and the national program to create work to offset the Great Depression all coincided to produce the drive to construct the series of dams that now control the river.

Bonneville, the first major Federal dam on the river, was constructed to create power as well as a slackwater pool that would reach 48 miles upriver to the

Dalles. But it was clear that the Snake River could not be navigated with larger loads and deeper draft craft.

Again, the ports, the Corps and business worked together through the Inland Waterways Association (PNWA's predecessor organization) to extend navigation. Those efforts resulted in passage of the "River and Harbor Act of 1945" authorizing McNary Dam on the Columbia and four dams on the Snake: Ice Harbor, Lower Monumental, Little Goose and Lower Granite.

The "River, Harbor and Flood Control act of 1950" authorized The Dalles and John Day dams. Finally, in 1975 slackwater navigation reached Lewiston, Idaho 465 miles from the sea. In the first two years, more cargo moved through the locks at the last dam than had been projected for the year 2000.

A 40-foot channel in the lower Columbia was dedicated in 1976 and a 50-foot bar was dedicated in 1984, completing the current system. These navigational improvements have helped make the Columbia/Snake River System one of the fastest growing waterways in the U.S.

Cargo is loaded on ships for Korea, Japan, China and our other Pacific Rim markets. To give you some idea of how important this trade is, over two-thirds of Washington state's grain is grown for export. And one of every five jobs in Portland depends directly on port activities. Soft white wheat, which is what we grow best, has been marketed to various potential customers in innovative ways. The Oregon and Washington growers, for example, took ovens and bakers and recipes to Japan to teach them to use our wheat. They, in fact, changed the diet of the Japanese.

In addition to grain, the area exports lumber, fruit, beef, wool and other bulks such as soda ash. It imports containers, petroleum, motorcycles, bauxite and cars. The Port of Portland is one of the largest car import ports in the country. One hundred autos a day cross the docks bound for 32 states. What makes it all possible are dams like Bonneville, The Dalles, Little Goose, Lower Granite. And what they make possible is barge traffic. The Columbia is the West Coast's only major navigable river. With 34 allied ports, it is the fastest growing inland system in the country. Total cargo on the system last year was 28 million tons. Most of that moves in international trade. But nearly 10 million tons move on the inland barge system.

Log rafts and lumber move on the system. In movements upriver, the Columbia/Snake is unique. It is the only system in the United States to successfully barge containers. Over 40,000 containers are barged to and from upriver ports each year. In fact, 30% of all container traffic on the river moves on barges.

No overview of the Columbia would be complete without mentioning Mt. St. Helens. Mt. St. Helens erupted in May 1980 sending mud and ash down the Cowlitz and Toutle Rivers and into the lower Columbia. Within a few hours of the eruption,dredges were scooping the mud and ash out of the channel. It only happened once. And we want to keep it that way.

The Corps is at work constructing a sediment retention structure on the mountain. It will keep the remaining sediment on the mountain and out of the river, avoiding the extra $10 million per year it has been costing the Corps to dredge the sediment out of the navigation channel. The sediment retention structure is yet another Japanese import. The concept has long been used there. They call them "sabo dams" and there are 23 on one river alone.

The Bonneville Lock, the oldest on the river, was originally built to accommodate ocean going ships. It was assumed that those ships would go as far as The Dalles. But it was not to be. The Lock is primarily used by barge tows, usually in a 4-5 barge configuration. The narrow lock at Bonneville forces the tow boat to break up the barge tow and lock through in two or three passes. This increases time and expense.

The Corps of Engineers is now replacing that bottleneck on the river with a new lock. It will be completed in 1993 and will cost about $200 million dollars.

At Ice Harbor there is a different problem. The gate on the lock is a lift gate, not the miter gates found on most of the other locks. The gate is not wearing well. The Corps has slowed down the speed with which the gate is raised and lowered and has limited recreational use of the locks to twice a day each way. In this way, they hope to reduce the strain on the gears and other pieces of machinery which is causing problems. The Corps is also trying to find out why the wear has occurred, and they are looking at how to deal with replacing worn machinery without totally disrupting commerce on the Snake.
We also have some interesting navigation hazards on the river. The mid-Columbia has become the sailboard capital of the U.S., some say the world. In the summer with strong currents running west and winds blowing to the east, there are hundreds of "board heads" on the river everyday.

Now, technically, the board sailors are correct when they say that sail has precedence over powered tow boats. However, it has been pointed out to them that a barge tow takes about a quarter of a mile to stop. And the operator has a large blind spot which can be dangerous for the board sailor.

The Pacific Northwest has always been dependent on its natural resources and agricultural commodities. That has brought boom and bust cycles that have played havoc with the economy. The climate of deregulation in the railroad industry, airline industry and the trucking industry has resulted in the rail abandonments, shipping lines moving from port to port, and independent trucking companies springing up everywhere.

There has been some predatory pricing by the railroads on segments on the Columbia in order to drive barges off the river. Integrated transportation companies have been created that own truck, rail and barge and have the potential of eliminating the leverage many Pacific Northwest businesses have enjoyed with a competitive, multimodal transportation system. Planning is difficult, to say the least.

On the other hand, the region is now beginning to enjoy the fruits from completion of the Columbia/Snake River system. The Port of Lewiston, Idaho shipped more cargo in its second year of operation after slackwater was achieved than had been projected for the end of the century.

At Kalama there is a computerized grain elevator where feed corn is loaded at breathtaking speed. The largest load of grain ever shipped on the river was shipped out of this facility. A ship drawing 42 feet moved out in a 40-foot channel. What made that possible is the new river level forecasting system now in place. It has been the plan for some time to eventually deepen the channel. However, because of the cost and the climate of fiscal constraint, better use of the existing resources have been achieved. The river level forecasting system gives ship captains accurate, to the hour, information on the river level.

PNWA is also working with the Corps and Coast Guard to establish new safe anchorages for ships waiting to take advantage of the system. We continue to pursue the concept of extending navigation to Northcentral Washington, on the Hanford reach of the Columbia, through an innovative barge lift system. Explorers once hoped that the Columbia would turn out to be the Northwest Passage. Now we know that it's the Northwest network to the world--and it works.

VESSEL OPERATIONS ON THE COLUMBIA RIVER

BY

PETER J. BRIX
Knappton Corporation

From an operation standpoint, the significant thing about the locks on the Columbia River is that most are 86 feet wide and 675 feet long. Bonneville Lock is 76 feet wide and 500 feet long. This requires breaking up tows at Bonneville, and doubles the number of lockages.

The tows on the shallow-draft portion of the Columbia River are very small compared to those on the Mississippi River. Tows of 10,000-12,000 tons of cargo in 4-5 barges are the most common. The standard locking configuration is two barges side by side and two barges long, and sometimes there is a fifth barge alongside the towboat.

The grain barges have capacities of 3,000-3,500 tons. There are also a number of other barges that are not standard. This causes inefficiencies, and the odd sized barges are being phased out.

The towboats on the Columbia range in size from 2,000 to 4,000 horsepower. These are more comparable to the types of towboats operating on the Upper Mississippi than the larger boats operating on the Lower Mississippi.

The boats have crews of four or five people. This is the result of the short river system and the relatively small number of barges in a tow. Since our barges are twice the size of those operating on the Mississippi, there is less breaking up and making up of barge tows.

The main commodities moving on the Columbia River are grain, oil, logs, other forest products such as pulp, paper and woodchips, and containers. As manufacturing plants are being developed, the movement of chemicals is increasing, including dry and liquid fertilizer and caustic soda.

The lower section of the Columbia between Portland/Vancouver and the mouth at the Pacific Ocean is a deep-draft river. There is a large volume of log rafts moving on this section. A raft is usually 800 feet long by 60 feet wide, the equivalent of about 80 truckloads. The logs are stored in rafts like floating warehouses until they are ready to be cut or shipped overseas.

One development occurring on the lower Columbia River is more coastwise barging in barges measuring up to 400 feet long by 100 feet wide with drafts of 22-23 feet. Woodchips are moving from coastal locations on the ocean and then up the river to pulp and paper plants. Containers are also moving on these barges.

While the ideas presented for barge-lift systems on the middle section of the Columbia are interesting, there is a question of whether they are economically competitive. We do not think there is the volume of traffic, and, from a rate standpoint, they would not be competitive.

CURRENT DELIBERATIONS AND RECOMMENDATIONS OF THE INLAND WATERWAYS USERS BOARD

BY

PETER J. BRIX
Inland Waterways Users Board

The Water Resources Development Act of 1986 (PL 99-662) was a historic event for the inland waterways in several ways:

1) The log jam of ten years duration which had stopped construction of major inland waterway projects was broken when seven major projects were approved.

2) The Inland Waterways Users Board (IWUB) was established to be composed of eleven members selected by the Secretary of the Army.

3) The fuel tax on vessels operating on the inland waterways was increased from ten to twenty cents per gallon.

The creation of the IWUB is an extension of the user pay/user say philosophy. PL 99-662 leaves great latitude in the extent and geographical scope of recommendations which the Board may make. The Board can limit itself to reviewing Corps of Engineers investment decisions or it may review investment decisions and the implementation process. The Board looks at the national interest without being parochial. Our role is to look at problems of the inland waterways and to make recommendations for future policies that are best in our independent judgement. The Board is not involved in lobbying for or against projects.

The membership of the Board, seven carriers and four shippers, reflects commodity and geographic diversity and a balance between carriers and shippers. Such diversity will help reflect national priorities and needs throughout the system.

The Board was established in late spring of 1987 and first met on July 15, 1987. The Board has (1) encouraged the Corp to expedite the study, design, and construction cycle; (2) requested an inventory of all inland waterway projects in addition to the 27 waterways that come under the current fuel tax; (3) requested a detailed Trust Fund cash flow projection; (4) requested User Tax payment verifications; and (5) requested an evaluation of the waterborne commerce statistics collection and analysis system.

Due to the Board's formation at the tail end of the budgeting process, it was difficult to provide detailed input on the Corps FY 1989 budget. Therefore the Board made general priority recommendations based on information which it had.

At the September 28th meeting, the Board chose to assign various projects to three separate categories, representing different levels of priority. Included in the categorization were construction projects, major rehabilitation projects, projects in various stages of preconstruction engineering and design, and navigation planning studies. The Board established the three categories as follows: Category 1 was for those projects and studies which the Board felt should be accelerated to the extent possible within existing Corps capabilities, or where possible, for which Corps capabilities could be increased consistent with overall Corps responsibilities. Category 2 was for projects and studies whose current schedule of completion seemed consistent with scheduled Corps capabilities, and which the Board felt should proceed as planned. Category 3 was for projects and studies for which the board felt either: (1) that there was not sufficient information regarding project or study justification to enable it to make a priority recommendation, and thus Board action on such projects or studies should be deferred until additional information was provided, or (2) that the information available to the Board justified a recommendation that the project or study be terminated or delayed. Such delays may come when limited funding is available.

While project justification is beyond the interests of the Board, the Board is interested in the needs of the waterways that carry commerce now and the priorities for that system. The credibility of the Board requires that we identify low priority projects as well as high priority.

The Board has begun an in depth analysis of the Inland Waterways Trust Fund. Work has been initiated to determine if the trust fund is receiving all of the taxes which are due. We do not believe that the reporting is complete and we are seeking ways in which to assist the IRS.

The Trust Fund has a current balance of approximately $300 million and is receiving approximately $50 million per year from user taxes. This figure is projected to escalate to over $100 million per year in the 1990's. In spite of the increased funding, our projections show a declining balance in the trust fund. In the year 2000, the fund balance is projected to be (1) $265 million with only scheduled construction, (2) breakeven with rehabilitation projects and (3) negative with additional construction. Lock and dam construction expenditures by the Corps were $224 million in FY 1987, $297 million in FY 1988 and $343 million in FY 1989, of which $77 million was from the Inland Waterways Trust Fund.

In addition, projections show that 5% inflation on projects will outrun the 1.5% increase in fuel consumption. While some elements of the government wish to use the Trust Fund for rehabilition, the Board will oppose such use in order to maintain solvency of the fund for new projects.

Today, the waterways are basically sound and efficient, although parts of the system are not operating at maximum efficiency because of downtime. The Board believes that the advent of the new cost sharing relationship with the government, users, and shippers will be able to help the Corps evaluate components of the system in order to maximize the best use of our limited financial resources, by directing those resources where they are needed the most. Our goal is that the Board will play an important role in establishing an order of procedure to ensure that projects are studied, rehabilitated, or replaced in a timely manner and with a good return for the investment in the system. The Board has already made progress toward that goal. I believe that the Board and the Corps have learned a great deal from each other. As the IWUB matures and learns, it will achieve the results that were intended by the Congress.

UPPER MISSISSIPPI RIVER TRANSPORTATION ECONOMICS STUDY

BY
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The upper Mississippi River Transportation Economic Study is a cooperative effort between five states and two federal agencies--the U.S. Maritime Administration, U.S. Department of Agriculture and the Departments of Transportation of the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The study is investigating the short-term alternatives to the costly infrastructure investments on the Upper Mississippi River. "Upper Mississippi" is defined as the area from Cairo to just north of the Twin Cities. The objective of the study is to identify, test, and analyze relatively low-cost, practical measures that will improve the cost structure of transportation on the river. A product of the study will be a micro-computer based model which can be applied in analyzing other waterway systems as well.

The Impetus Behind the Study

The Upper Mississippi River is an important link in the transportation of bulk commodities which are vital to the Midwest economy. Low transportation costs are essential in maintaining the competitiveness of Midwest grain exports, as well as controlling the cost of regional energy. The current system of 26 locks imposes high capital and operating costs on barge operators due to lock and navigation constraints. The recent increases in user fees, together with deteriorating infrastructure conditions further detract from the cost efficiency of the system.

Federal funding is unlikely to provide relief in the near future. There are currently no major infrastructure improvements budgeted for the Upper Mississippi River other than the current construction at Lock and Dam 26.

Similarly, the depressed state of the inland barge industry makes it impossible for operators to subsidize capital projects. Therefore, near-term cost savings will have to result from improvements in the utilization of the current system. To respond to these concerns, the five states formed a Study Committee, retained a consultant to assist in developing a study plan and funding requirements, and then went to MARAD and USDA for funding assistance. The project began in August 1986 and is scheduled for completion by October 1988.

Study Phases

The study has five phases:

Phase 1: Metodologies, forecasts and data

a. Identification and evaluation of various methodologies, forecasts, data and information sources which might have application to the study. The product of this phase is an extensive bibliography.

b. Formation of an Industry Advisory Group, comprised of representatives of major carriers and shippers in the region. This group assisted the study team by providing data relating to their operations, and by generating feedback on various interim study findings.

Phase 2: Identification and preliminary screening of potential efficiency measures. These measures fall into four general categories:

a. Tow Efficiency Measures: Those which affect the productivity of individual tows and include advancements in towboat, barge, barge transfer or fleeting technology, which improve productivity and efficiency on the system--examples include fuel monitoring systems and new barge/hull designs.

b. Waterway Efficiency Measures: These measures include low-cost changes to the physical waterway system which would relax constraints or improve efficiency. These include non-structural and minor structural measures such as real-time channel depth monitoring.

c. Vessel/Barge Management Measures: These are improved management techniques aimed at achieving more rationalized service or improved pricing and marketing, such as improved communications and scheduling and cooperative barge fleeting.

d. Public Management Measures: These include examination of alternative dredging practices and/or water management policies which could influence transportation costs and channel reliability. The 1988 drought resulted in requests that water be diverted from the Great Lakes to the Mississippi to maintain a navigable waterway.

Phase 3: Interactive computer model

The model is based on relational databases which represent the waterway's operating and cost characteristics under base and forecast scenarios. The model links these databases through individual software modules used to estimate and summarize waterway activity, system costs, and system impacts for the current database values. The efficiency measures are evaluated by comparing the model's output for the base and test sets of data values.

a. The primary databases used to represent the current and projected status of the waterway system include:

- Waterway Characteristic Database--the physical and tow operating characteristics for individual river segments, as defined within the database using river-mile points;

- Lock Characteristic Database--physical, tow operating and processing time/delay elements for locks described by mile locations;

- Equipment Characteristic Database--operating capacity and cost characteristics for various categories of barge types and towboat sizes;

- Commodity Characteristic Database--average load and forecast growth factors for defined commodity groupings;

- Commodity Flow Database--base segment-to-segment flows for defined commodity and barge groups.

b. The system modules which link and process the data include:

- Database Manager to enter and edit primary databases.

- Waterway Activity Generator to convert commodity flows for selected time periods into seasonal segment and lock throughputs by equipment type and direction.

- Lock Unit Resource Calculator to generate seasonal lock processing and delay functions for projected throughput under "active" lock conditions and traffic patterns.

- Segment Unit Resource Calculator to estimate weighted cost and time factors by season, tow type and river segment based on traffic distributions and described channel operating conditions.

- Resource Allocation Module to allocate and assign unit transportation time and cost factors by equipment type for individual traffic flows.

- Tow Power Calculator to estimate required horsepower hours and fuel consumption for active speed, segment and towboat/barge characteristics.

- Efficiency Measure Tester to alter appropriate database values for a selected measure or set of measures and compare the estimated system costs and impacts to base cost estimates at a system or micro level.

The open-ended database structure will allow the model to be applied to other waterways by customizing the databases (with local data) without altering the model structure. The level of detail required for each application can be determined by the user, not the model structure. The modular software structure allows individual sections of the model to be replaced or refined without re-designing the entire model. Additional modules can also be added in the future.

Phase 4: The actual application of the model and the analysis of the results, which leads to

Phase 5: The final assessment and evaluation of the measures and preparation of the final report.

The impact of the efficiency measures can be measured at two levels:

- The micro impact of the measure evaluated by comparing transportation cost and time estimates for individual tow movements.
- The system impact measured by differences in total system demand and impact, as well as system costs.

Study Problems

Some of the problems that have been encountered in this study include:

Data Availability and Collection Problems:

- Lock-oriented PMS system concentrates on capacity of locks, not efficiency of channel operations.
- Lack of representative physical river characteristics made it difficult to "model" relationships with tow operations.
- Operator cost and operating data are on a system basis and not closely related to conditions to be improved with efficiency measures.

Modeling Methodology Problems:

- Attempting to represent a highly dynamic system under static conditions--we used detailed distributions and relationships to isolate "measure-related" conditions.
- A vast array of highly variable characteristics, many of which are interrelated, made it difficult to reconcile data variations with model calibration.
- "Average" representations of characteristics such as tow size and river conditions were not accurately portraying irregular distributions--We used high, medium and low distribution patterns to resolve this.

- Traffic flows "react" to system characteristics based on both a trip (e.g., maximum draft) and segment/node basis (tow operating speed). The model structure assigns certain characteristics on an origin/destination basis and then estimates individual segment/node factors using weighted values for these characteristics.

- Attempt to incorporate all possible efficiencies from tow operations to system management resulted in too complex a specification.

<u>Model Features</u>

In summary, the interesting features of the model include:

- applications of segment characteristics on both a trip and individual basis.

- individual flows and allocated cost and time factors based on commodity, barge, tow type (unit/mixed), and the specified combination of segments.

- rudimentary distribution functions (high, medium, low) more closely relate to actual distributions and permit different "reactions" to system conditions.

- equipment flows are balanced on an annual basis, but loaded and empty flows are allocated separately by season using weighting factors.

- lock delay calculator incorporates detailed representations of lock processing functions and operating procedures directly related to efficiency measure definitions. Estimated "non-scheduled" delay can be related directly to reduced tow speeds in lower and upper pools.

The consultant and others on the study team (as well as the Study Committee) will admit that the entire effort has been far more complex and challenging than anyone had envisioned at the outset. However, the final product will serve as a valuable tool in future inland waterway planning efforts.

The final report will be available through the Iowa Department of Transportation in late 1988. The software and documentation will be available through the Maritime Administration.

<u>MIDDLE COLUMBIA RIVER STUDY</u>
<u>SHIP LIFT ALTERNATIVES</u>

BY
NOEL GILBROUGH
U.S. Army Corps of Engineers

This paper summarizes the options for opening up the Middle Columbia River from Richland to Wenatchee, Washington, for navigation and commerce (See Figure 1).

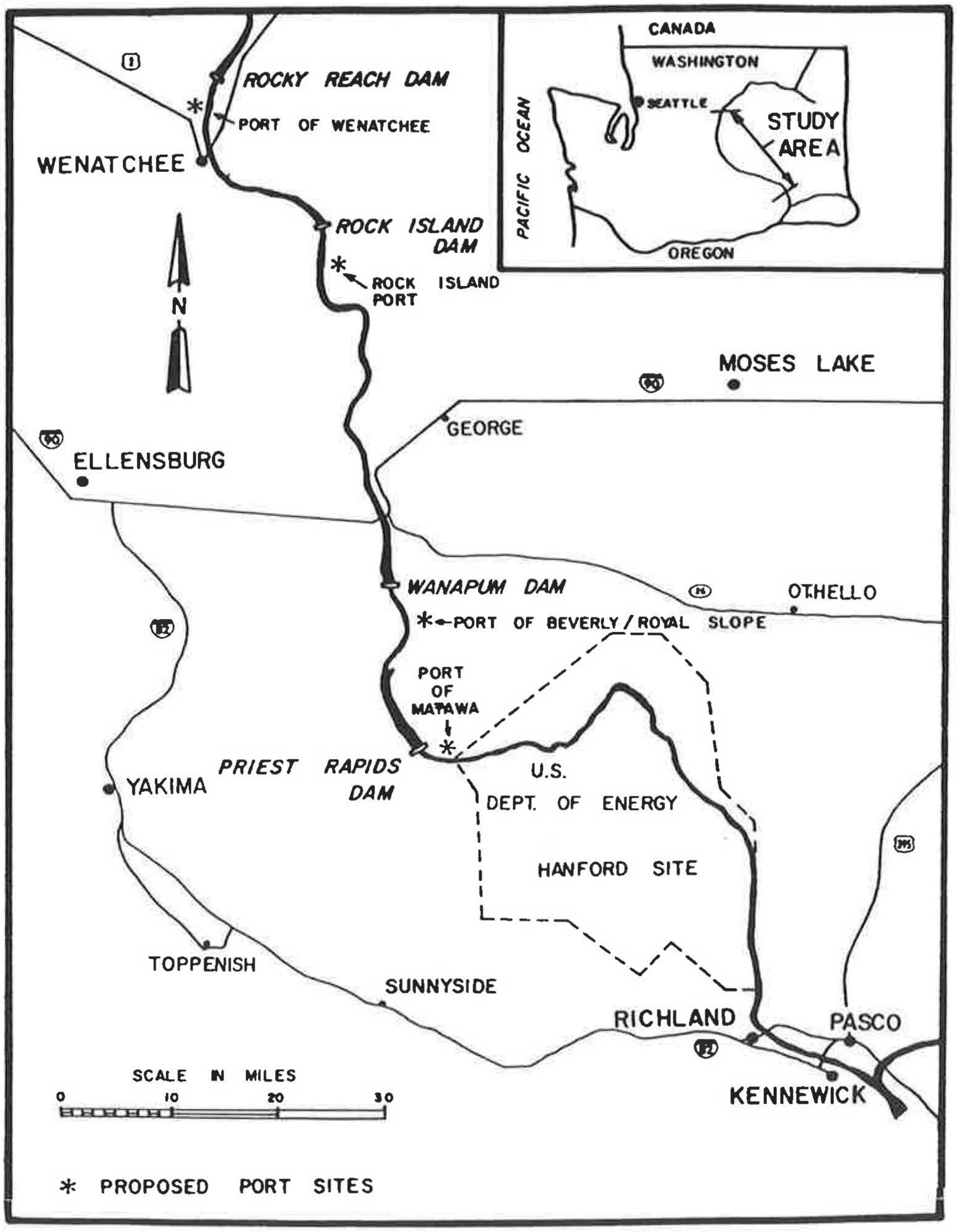

FIGURE 1. Middle Columbia River navigation study (Washington state)

Several alternatives have been proposed and investigated since 1967.

BACKGROUND

In the 1800's and early 1900's, much of the Columbia River system was open to navigation by stern and side wheel boats. The development of a major railroad system made this system non-cost effective.

Incremental expansion of the Columbia-Snake River Navigation system for modern barge traffic started with the construction of the Bonneville Dam in 1936. Through the years until the early 1970's, expansion for navigation and commerce purposes continued. However, the stretch of the Columbia River between Wenatchee and Richland remained nonnavigable. Over the course of the past twenty years, several projects have been proposed to further develop this portion of the Middle Columbia River.

In the late 1960's, the Corps of Engineers studied and proposed several conventional alternatives. They consisted of either a lock and dam on the

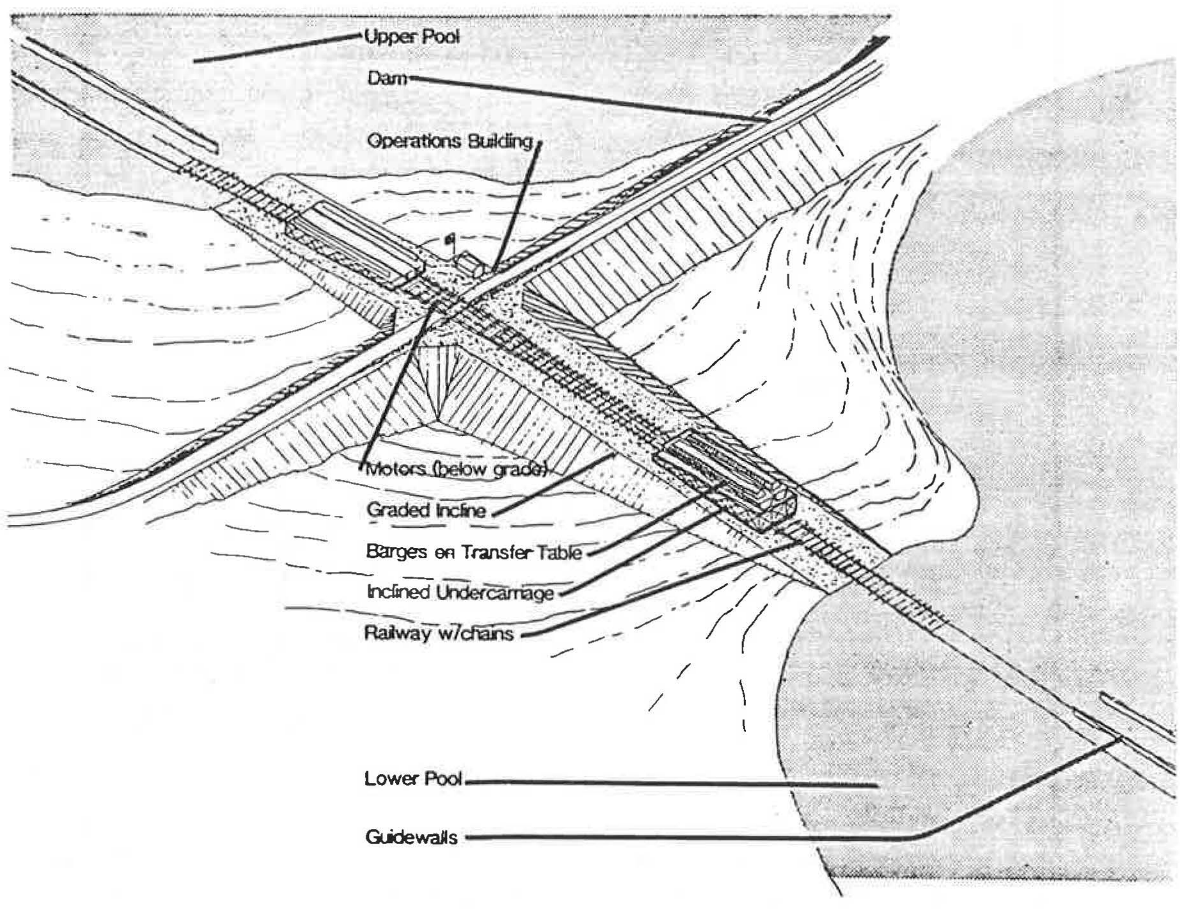

FIGURE 2. Inclined railway barge lift: concept

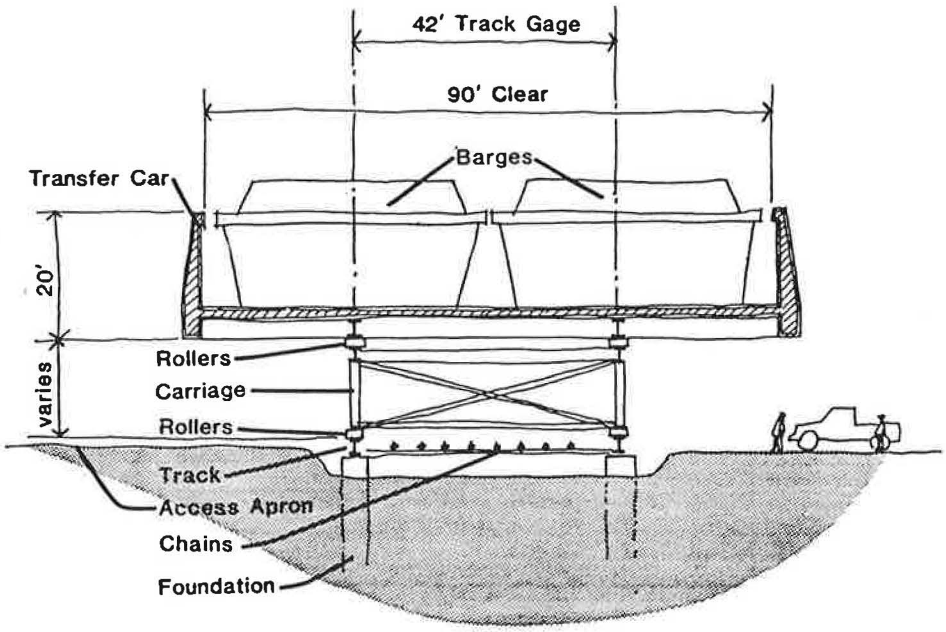

FIGURE 3. Inclined railway barge lift: cross section

Hanford Reach of the Columbia and conventional locks at the upstream dams, Priest Rapids, Wanapum and Rock Island. For many reasons none of these alternatives were found acceptable.

In 1984 the Corps initiated studies of an alternative that included a canal across the Hanford Reservation with a lock and powerhouse on its downstream end. This alternative would have eliminated some of the impacts of a dam or channel through the Hanford Reach. This alternative was not cost effective. In 1985, an alternative was suggested that would include the use of European styled barge lifts to reduce the overall cost of the project. It was also suggested that a peaking wave concept be investigated that would utilize the daily peaking flows out of Priest Rapids Dam to float heavily laden barges downstream and reduce the amount of dredging required in the Hanford Reach. This "peaking wave" and barge lift method led to the investigation of an alternative approach using an inclined railway barge lifting system (See Figures 2 and 3). This concept was deemed feasible and a detailed design study was undertaken.

Further research into this inclined railway lifting system triggered the inception of a vertical barge lifting system (See Figures 4 and 5).

In 1987, a similar design based on the vertical lifting concept using the Syncrolift system was proposed (See Figure 6).

In 1988 a study was conducted using both the Syncrolift and Crandall barge lift alternatives to evaluate the feasibility of using a smaller 2200 ton barge similar in size to a Mississippi River "Jumbo" barge.

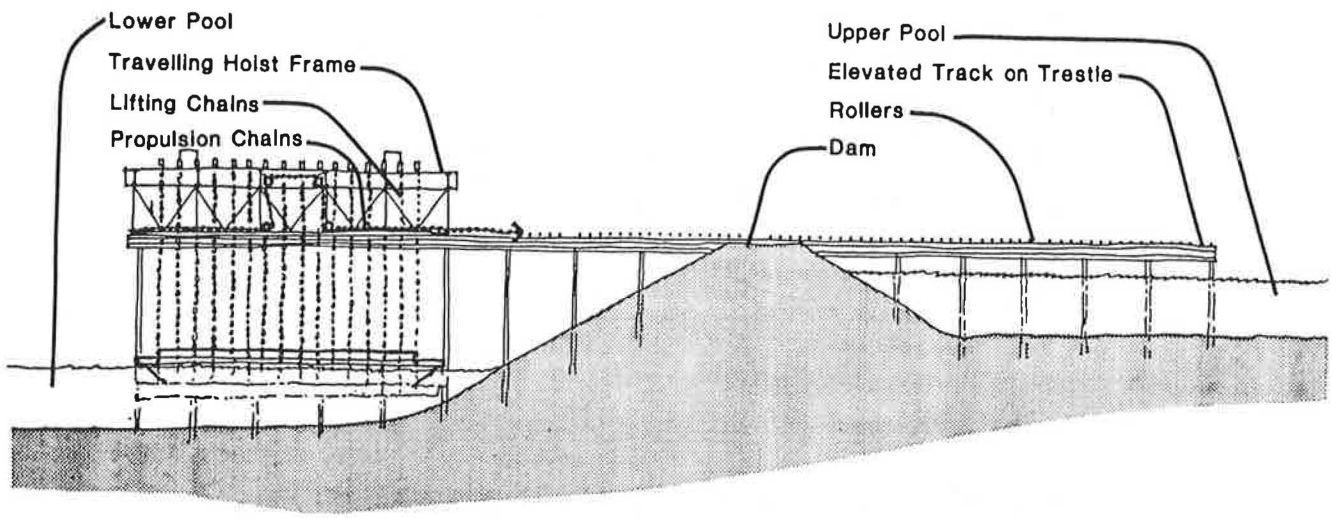

FIGURE 4. Vertical barge lift: Longitudinal section

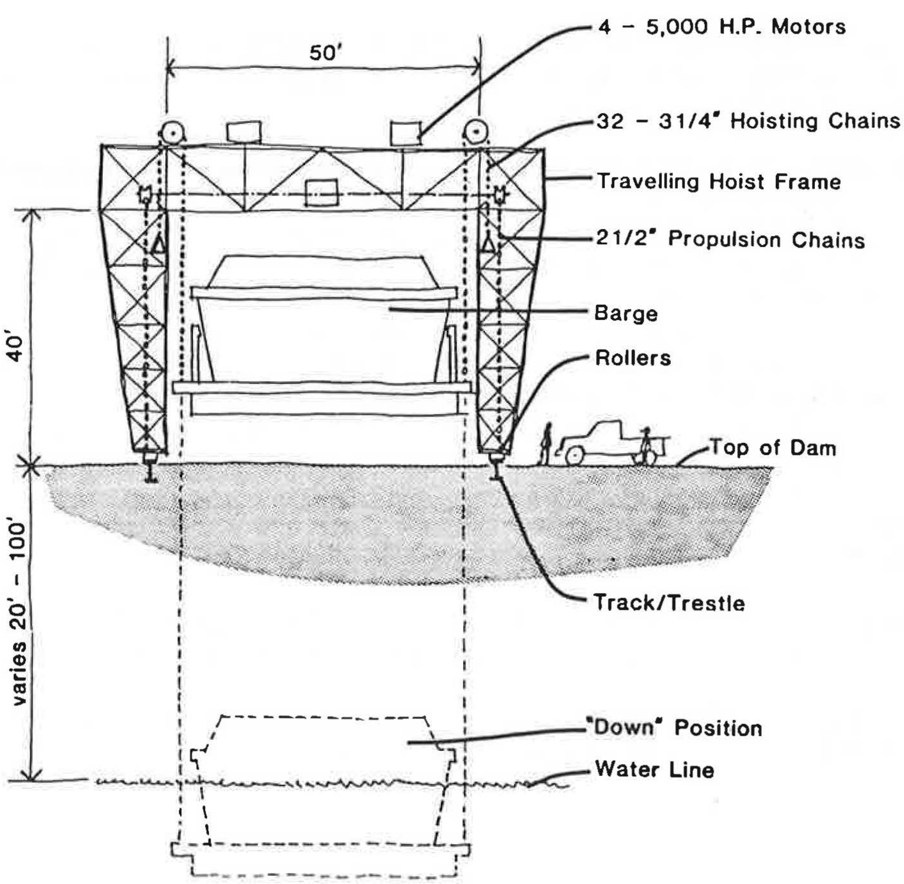

FIGURE 5. Vertical barge lift: cross section

Also in 1988, the Corps conducted a detailed navigation benefit study and found the 4500 ton barge lift to be the most cost effective because its higher capacity offset its higher costs. This study also showed that none of the barge lift alternatives were justified at this time. The following table is a comparison of the costs of a conventional lock and the other barge lift alternatives at Wanapum Dam.

Barge Lift System	Construction Cost
Conventional Locks	$157.0 million
Crandall Bargelift	49.0 million
Marine Railway	48.8 million
Syncrolift Bargelift*	40.0 million

* includes reduced channel size from the Crandall and Marine Railway alternatives.

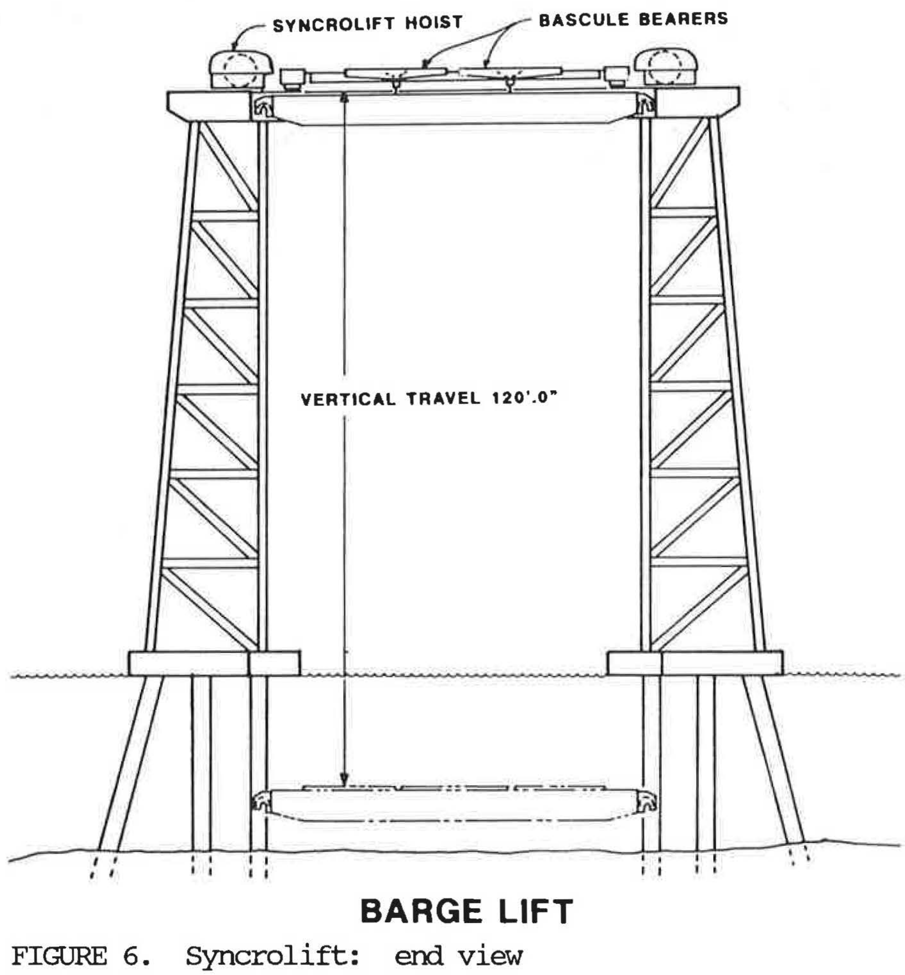

FIGURE 6. Syncrolift: end view

<u>Summary</u>

By 1985, the Corps of Engineers decided that the most feasible approach to opening the Middle Columbia River for navigation was to employ a horizontal or vertical lift system to by-pass the dams. Various and progressively more feasible designs were developed. In 1985/1986 the horizontal lift design using a marine inclined railway system was proposed. A thorough review and analysis of this design led to the development of another concept, the vertical barge lifting design. In June 1987 a report was completed that recommended a design using a chain driven, vertical, dry barge lifting system. Also in 1987, a similar design which uses a cable driven, vertical, dry barge lifting system was presented.

In 1988 an analysis was conducted of a smaller 2200 ton barge instead of the 4500 ton alternative. Presently, for use on the Middle Columbia River, the 4500 ton design appears to be the most feasible.

In this study numerous alternatives were investigated and a vertical barge lift was found to be the most cost effective. Even though a barge lift system was shown to not be cost effective on other similar navigation reaches where conventional locks have proven economically infeasible, if detailed design studies were conducted on the barge lift alternatives in the future, all systems shown in this paper would deserve more extensive research before choosing a construction alternative.