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THE FUTURE OF MARITIME FACILITY DESIGNS AND OPERATIONS

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ABSTRACT

Cargo in ocean-going vessels continues to grow in volume. The typical current growth rate of 6% to 7% per year is expected to continue through the next decade or more, resulting in a doubling of total throughput volume. Facing this incredible growth, port authorities, railroads, and all levels of government agencies (municipal, regional, state, federal) are searching for solutions to an impending traffic nightmare. Proposed solutions range from new infrastructure inventions to improved and technology-assisted operating procedures.

In order to review and validate the potential success of these ideas, computer simulation is increasingly a key tool. Simulation is allowing experimentation in infrastructure, technology and operations without the millions of dollars in actual construction. In addition, with the high level of competition in the industry and the razor thin margins which decide not only mode of transport but the choice of specific carriers, ports, railroads and trucking companies, simulation allows for experimentation without the potential penalty of lost productivity and customer share.

This paper outlines two major concepts in handling the future cargo volumes: big ships and fast ships.

1 INDUSTRY BACKGROUND & TRENDS

There are new dynamics in intermodal shipping today, caused by the elimination of international trade barriers, lower tariffs and shifting centroids of global manufacturing and consumption. Trade worldwide is growing at an unprecedented rate, with the majority of cargo shipped in containers. Worldwide containerized trade is growing at a 9% annual rate and the U.S. rate is 6%. The growth in containerized trade is anticipated to continue as more and more cargoes are transferred from break-bulk to containerized. By 2010, experts predict that 90 percent of all liner freight will be shipped in containers. Every major container port is expected to double and possibly triple its cargo by 2020.

As these cargo volumes continue to grow, planners and engineers through the U.S. and the world are working on solutions to move cargo more efficiently. This push is prompted by:

- The ever-decreasing inventory which manufacturers and retailers keep on hand to supply assembly lines and customers
- Increasing congestion around traditional maritime centers due to truck traffic and train service
- Increasing competition for waterfront property for non-industrial uses, such as tourist and shopping centers, business parks and condominiums.

Two major ideas in ship design and operations are at the forefront of possible industry solutions. They are the Mega-Ship and the FastShip.

2 MEGA-SHIPS

Containers are carried via specialized container ships. The first-generation ships held only 1,000 Twenty-Foot-Equivalent-Units (TEUs) or about 500 trucks worth of cargo. Since these first ships in the 1960s, subsequent generations of larger ships have been designed and put into service. The latest ships put into service by Maersk, a major international shipping line, hold over 6,000 TEUs. These ships are affecting dredge depth for major waterway channels and the waterside service equipment. In addition, as ships get larger, the surge of cargo flowing through a port becomes more intense. Shipping lines task ports with servicing a vessel as quickly as possible to minimize the "down-time" suffered when a vessel is not moving. Current service-window expectations for a mega-ship is 48 hours.

This translates to over 6,000 truck trips or over 20 two-mile long double-stack trains in two days.

2.1 Agile Port Concept

The ability of current port facilities to handle these surge situations is in question. Waterfront property is highly-valued and is often ecologically sensitive. Ports today commit large parcels of property to the storage of containers. A typical 1,200 to 1,600 container discharge operation uses between 70 and 80 acres of storage area. As the ships grow in capacity, the number of containers requiring storage will increase. This storage requirement, combined with the increased truck and rail congestion in the surrounding community, is prompting the exploration of a new port concept: the agile port.

The agile port removes the bulk of the storage from the waterfront to an inland storage and sorting location, the Intermodal Interface Center (IIC). Containers arriving via vessel to the port can be transferred onto railcars immediately upon discharge and moved inland. Conversely, containers destined for export on the vessel can be collected, sorted and stored at the IIC until vessel arrival and shuttled to the port via these same dedicated shuttle trains. By moving the storage and sorting functions inland, the port can save property and reduce congestion in the surrounding port community.

2.2 Agile Port Simulation

TranSystems has performed multiple simulation experiments of this agile port concept, including one for the Kowloon Canton Railway Company (KCRC) in Hong Kong. KCRC wished to develop a system for moving port cargo out of the Hong Kong area more efficiently and with the potential for reducing the excessive truck traffic at the port and through the city. Using the agile port concept, containers from vessels would be drayed a short distance to the Port Rail Terminal (PRT) where they would be loaded onto short, double-stack trains which shuttle the cargo to an inland facility (IIC). At the IIC, trains would be sorted and sent to inland China for cargo distribution and pickup for return to Hong Kong. The trains headed into China will be single-stack due to bridge and tunnel clearance restrictions.

For KCRC, TranSystems investigated a five-phase implementation of the system. The phases were:

- **Phase 1:** Only 25% of the port facility, the PRT, constructed, and no IIC constructed. Trains are loaded at the port and sent directly to China. Trains are only single-stack. Target of eight trains each way per day.

- **Phase 2:** Full build-out of PRT, or eight tracks. No IIC constructed. Trains are only single-stack. Target of 32 trains each way per day.

- **Phase 3:** Full build-out of PRT. Partial IIC construction (50%). Target of 39 trains each way per day. Only 22% of the day's trains will use the IIC. The other 78% will function as in Phase 2.

- **Phase 4:** Full build-out of PRT. Further IIC construction (67%). Target of 47 trains each way per day.

- **Phase 5:** Full build-out of PRT (eight tracks) and IIC (18 tracks). Target of 54 trains each way per day.

Each of these phases was simulated and key statistics reported, including:

- Number of trains completed
- PRT track utilization
- PRT crane utilization
- IIC track utilization
- IIC crane utilization
- IIC hostler (internal drayage) utilization
- PRT lorry (external drayage) utilization

These statistics, along with queue waiting times and customized trace reports, were used to determine the adequacy of the infrastructure to meet the daily train schedule and to recommend equipment levels, including lorries, hostlers, railcars and locomotives. Equipment levels determined by the simulation analysis are shown in Figure 1 and Figure 2.

These simulated results can be extrapolated to forecast achievable annual throughput at each stage. These results are presented in Table 1.

This table illustrates that KCRC can design the intermodal system to handle close to 3.8 million TEUs, or 1.9 million trailers worth of cargo with this system. The largest intermodal facilities in operation today can handle less than half this amount. In addition, the amount of land which this system uses per cargo unit moved is much less than that of a conventional terminal, as illustrated in Table 2.

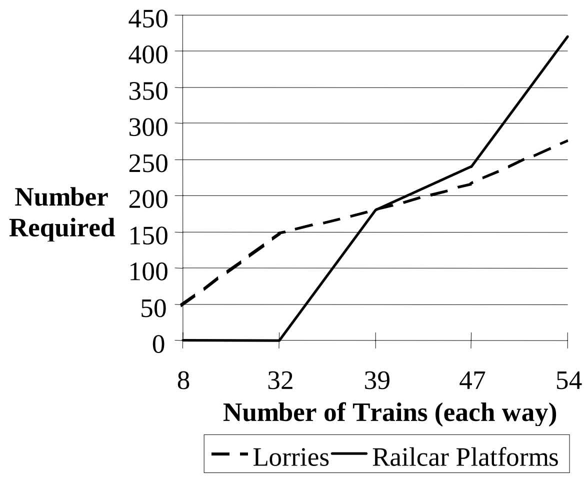

Figure 1: Required External Equipment

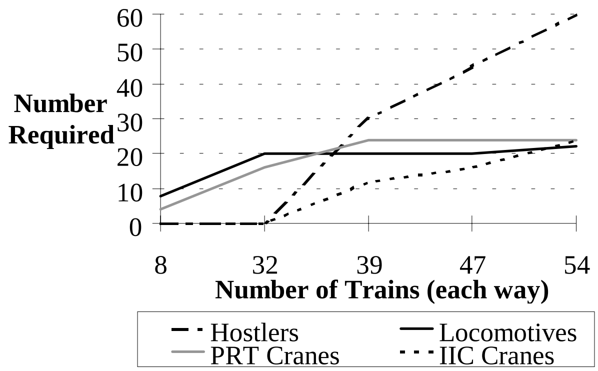

Figure 2: Required Internal Terminal Equipment

Table 1: Extrapolated Annual Throughput for KCRC

Phase	Trains per Day (each way)	Throughput per Day	Throughput per Year
1	8	1,600	560,000
2	32	6,400	2,240,000
3	39	7,800	2,730,000
4	47	9,400	3,290,000
5	54	10,800	3,780,000

3 FAST SHIPS

Fast container ships represent an alternative line of development for advanced technology vessels. These vessels offer higher speeds than current vessels in exchange for higher construction and operating costs per TEU. This means that the longer the distance to be traversed, the more profitable and valuable the service, especially for high-value, time sensitive cargoes.

Table 2: Intermodal Rail Throughput Comparison

Facility	Annual Throughput (TEUS)	Facility Total Acres	Through put per Acre
LA Intermodal Container Transfer Facility (ICTF)	1,400,000	190	7,300
Tacoma North Intermodal (NIM)	268,000	35	7,600
KCRC Agile Port System	3,780,000	220	17,100

3.1 FastShip Atlantic

FastShip Atlantic (FSA) is a highly publicized fast container ship venture. FSA has designed a vessel which can travel at 37 to 42 knots, versus 25 knots for the fastest conventional ships. FSA is planning to initiate transatlantic service in 2001, providing door-to-door service times of five to seven days, compared with fifteen to thirty days conventional service.

While the speed of the ship will be a crucial element in the FSA service goal, the servicing of the ship at harbor is also critical. Since the ship is so expensive to operate ($100 million per year), it is of paramount importance that the ship make as many transatlantic crossings as possible. The less time the ship must wait for loading and unloading service to be completed, the more sailing time available. To that end, FSA has designed a revolutionary discharge and load operation which differs from conventional service entirely.

While conventional ships use wharf-side cranes to lift one container at a time from ship to shore or vice versa, the FSA ship and terminals will be designed to load strings of containers via a ramp and a series of container carriers. These lightweight platforms will be shipped with the containers and used to unload the containers off the vessel at destination. Yard tractors will be used to pull these container strings, which look like small trains, off of the ship into the terminal. Once the discharge strings have been removed, already loaded export strings will be pushed onto the vessel and the ship will be ready for departure. FSA has estimated the entire ship may be unloaded and reloaded in only four to six hours. An FSA vessel can hold 1,448 TEUs, so the load/unload rate is 480 to 720 TEUs per hour. A conventional wharf crane handles 70 TEUs per hour, so a comparable conventional facility would require six to ten cranes working simultaneously. Typical crane assignments per shift range between two and five.

3.2 FastShip Simulation

With the rapid rate of discharge and loading, and the goal to service the ship in only six hours (compared with 24 to 48 hours for a conventional ship), the facility must be carefully designed to minimize congestion and be adequately staffed to process all of the trucks and trains servicing the facility. TranSystems has simulated the FSA design, at the request of the Delaware River Port Authority (DRPA), the U.S. East Coast port for FSA. The purpose of the simulation was to verify equipment requirements and examine the peaking of truck arrivals to the facility and their service performance. In addition, the percentage of containers which will arrive and depart via rail is predicted to be very high - around 75%. Cranes in the facility may lift containers directly from the vessel strings to railcars and vice versa, *given that the railcar and vessel string are adjacent*. Rail tracks and vessel strings are paired such that one crane spans one vessel string and one rail track. If the vessel strings are well planned, using a real-time terminal operating system, then a high percentage of containers may be lifted directly from vessel string to rail (or vice versa) with the crane. If the vessel strings are not well planned, only a small percentage of containers can benefit from a direct lift. All other containers will need to be lifted via the crane to a hostler (in-yard tractor). The hostler will move the container to the appropriate destination where another crane will lift it to either vessel string or railcar. The simulation examined several different levels of string planning efficiency in order to observe the effect, if any, on the system. This split was known as the Rail Pre-Planning Percentage (RPPP).

The simulation looked at several key statistics, including:

- **Ship Service Time:** The time from ship arrival at the facility until the ship is ready for departure. Target is between four and six hours.
- **Truck Service Time:** The time a trucker spends at the facility, including any waiting time to enter the facility gate. Usual service targets are under 30 minutes.
- **Required Rail Export Arrival Time:** In order to have all of the export containers ready for the vessel, trains with containers need to arrive a certain minimum time prior to vessel arrival. If the trains arrive too late, they may not be finished when the vessel arrives, delaying vessel service or resulting in containers being left behind until the next ship call.
- **Hostlers Required:** The simulation tracked the average and maximum number of in-yard hostlers required to shuffle containers from one yard location to another.
- **Cranes Required:** The simulation also tracked the average and maximum number of cranes in use throughout the simulation duration.

The results of these statistics are presented in Figure 3. The results are shown for two extremes in the RPPP. If the RPPP is high, then 95% of the containers can be directly lifted between railcar and vessel string. If, on the other hand, the RPPP is low, then only 25% of the containers can be handled in this manner. All others must have a hostler move.

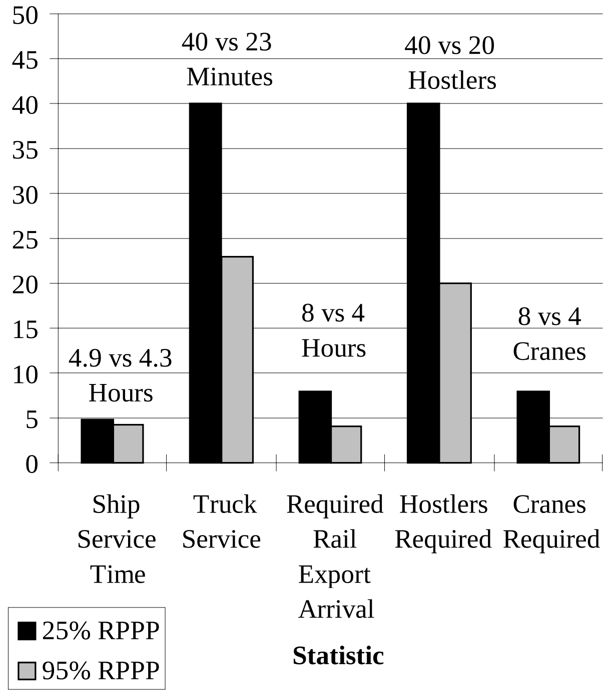

Figure 3: FastShip Terminal Performance Statistics

Figure 3 illustrates how the RPPP affects the efficiency of the proposed system. While the ship time is not dramatically affected, all other statistics show a marked decrease in performance as the RPPP drops. Trucks which arrive to the facility to either drop off or pick up containers have a 74% increase in terminal time and fail to achieve the 30 minute service target. The rail service for trains is slowed to the point where trains may arrive to the facility no later than eight hours prior to vessel arrival, rather than four hours. Both of these decreases in performance are directly related to the increased equipment requirements shown. The number of hostlers in the yard must double due to all of the shuffling from track pair to track pair which must take place. In addition, the number of required trains must also double since the vast majority of containers now require two lifts per transfer (onto hostler, off of hostler) rather than just one. This extra equipment leads to yard congestion which slows down the truck service time. The average cycle time per container is increased due to the required hostler move, resulting in a longer overall time period needed to handle the export trains.

The simulation illustrates two main points. First, the FSA terminal system can work and can service a ship in the four to six hour window. However, second, the terminal performance will be highly sensitive to the accuracy of the terminal operating system and the vessel planning and loading rules. While the facility will still operate with a poor planning system, the equipment requirements will cause an enormous increase in operating and capital expenses, the local trucking community may avoid the terminal due to excessive terminal time and more containers may miss the scheduled ship due to late train arrival.

CONCLUSIONS

The face of the transportation industry continues to change. Propelled by the dynamic growth of international trade, shipping lines and other transportation providers will formulate potential advances in infrastructure, information technology and operations. The expense of these systems and the repercussions of disturbing today's operating trade gateways precludes the implementation of any proposed systems without extensive study. Computer simulation has been and will continue to be a prime tool in this study process.

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