COMPARISON OF ATTRIBUTES AND CHARACTERISTICS OF STRATEGIC PORTS TO AGILE PORT MODELS

FOR
CENTER FOR COMMERCIAL DEPLOYMENT OF TRANSPORTATION TECHNOLOGIES
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UNIVERSITY OF SOUTHERN CALIFORNIA
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EXECUTIVE SUMMARY

The Center for Commercial Deployment of Transportation Technologies (CCDoTT) is responsible for assessing the agile port concept for the United States Transportation Command (USTRANSCOM) and the Maritime Administration (MARAD). In support of this effort, the University of Southern California has been asked to compare the attributes and characteristics of strategic ports to agile port models. This document is the University of Southern California portion of the interim report for subtask 1.2.4 under the CCDOTT 1997 statement of work.

The agile port concept is based on the use of advanced technology to enhance the operation of marine terminals in support of both military deployments and commercial shipments. Deployment of forces during Desert Shield/Desert Storm demonstrated the ability of the military to use commercial terminals. However, a post-war discussion indicated that efficiency could be increased and the costs decreased. Furthermore, future crises may require deployments to be completed faster than in the past.

Commercial marine terminals in the United States do not consistently use the most advanced technology for handling and processing cargo and containers. Labor intensive methods and procedures are often used, even though technologies exist to improve efficiency. The practices and technologies result from many factors, including company objectives, financial state, and prior experience. Nevertheless, through the course of our study, we have identified examples of effective use of technology to improve terminal productivity. Widespread adoption of best practices and technologies, however, would require institutional changes in the maritime industry.

Although the requirements of military and commercial customers are different, terminals can be configured to support both needs. Military requirements emphasize moving cargo through terminals within short surge periods. Some commercial customers, on the other hand, use the terminal as a warehouse for storing containers until needed. Because virtually all terminals suffer from a shortage of land, and commercial cargo containers consistently consume a large amount of land, providing sufficient space for the military to marshal its cargo is a major challenge. This challenge can be met, in part, with a two-priority system. Holguin-Veras and Walton used a computer model to show that as long as the percentage of priority cargo is relatively low, the two-priority system can substantially reduce the dwell time of priority cargoes. As the percentage of priority cargoes increases, this advantage is lost.

As proposed, Task 1.2.4 was intended to incorporate an extensive amount of data on practices, operations and plans of actual maritime terminals. The data collection component of Task 1.2.4 was to be completed by a separate sub-contractor under CSULB. As the data collection task was never executed, the University of Southern California portion of Task 1.2.4 was completed to the best of our abilities, based on already available information.

1. INTRODUCTION

In the past the military operated a number of dedicated transportation facilities that could be used to meet its needs. The closing of bases, both in the Continental United States (CONUS) and overseas, has increased the military need for transportation facilities and decreased the number of dedicated facilities available to them. The reduction of forward deployed forces and the closure of bases creates an increased dependence on commercial transportation facilities in reaction to crises requiring military intervention.

At the same time, the demand for rapid and effective transportation of cargo is increasing in the commercial sector. This increased demand for transportation capacity could be met either by expanding the existing facilities or by making the existing facilities more effective and efficient in the movement of cargo. The brute force expansion approach is not in the best interests of commercial firms and counteracts the desired cost reduction from base closures. Furthermore, constraints on the availability and development of coastal land preclude adopting a pure expansion approach. Therefore, the enhancement of transportation capacity needs to focus on the effective and efficient operation of facilities.

One way to increase efficiency of maritime terminals could be to deploy new technologies. As part of CCDoTT, Ioannou et al (1999) identify a number of potential technologies, which can be classified as follows:

Storing and Retrieving Cargo and Containers

- Storage and retrieval systems
- Automated storage and retrieval multi-story systems for yard operations
- Automated container terminals
- Automated container yard using multi-story structures

Information Systems

- Equipment tracking technologies

Physical Handling Systems

- High-speed-sealift specific shiploading technologies
- Multiple trailer systems
- Automated guided vehicles for port applications
- Linear motor-conveyance systems
- Automated container yard using automated-guided-vehicles
- Automated container yard using linear motor-conveyance systems

Deployment of advanced technologies, such as these, cannot take place until they are fully developed, to the point where their economic benefits exceed their full costs of installation, maintenance and operation. An additional challenge, in the maritime industry, is that benefits can only be captured with the full cooperation of unionized labor. Management has often been unsuccessful in negotiating agreements with labor that facilitate productivity improvements, posing a significant deterrent to technological innovation.

Maier (1998) modeled the attrition of new products from invention through diffusion, as shown in Figure 1. He found that approximately 60% fail technically, and of the remainder less than one in four survive economically. Just 8.8% of new inventions eventually become both technically and economically acceptable. Overcoming both technical and economic obstacles is clearly a challenge in the maritime industry, explaining why many good ideas never reach full deployment.

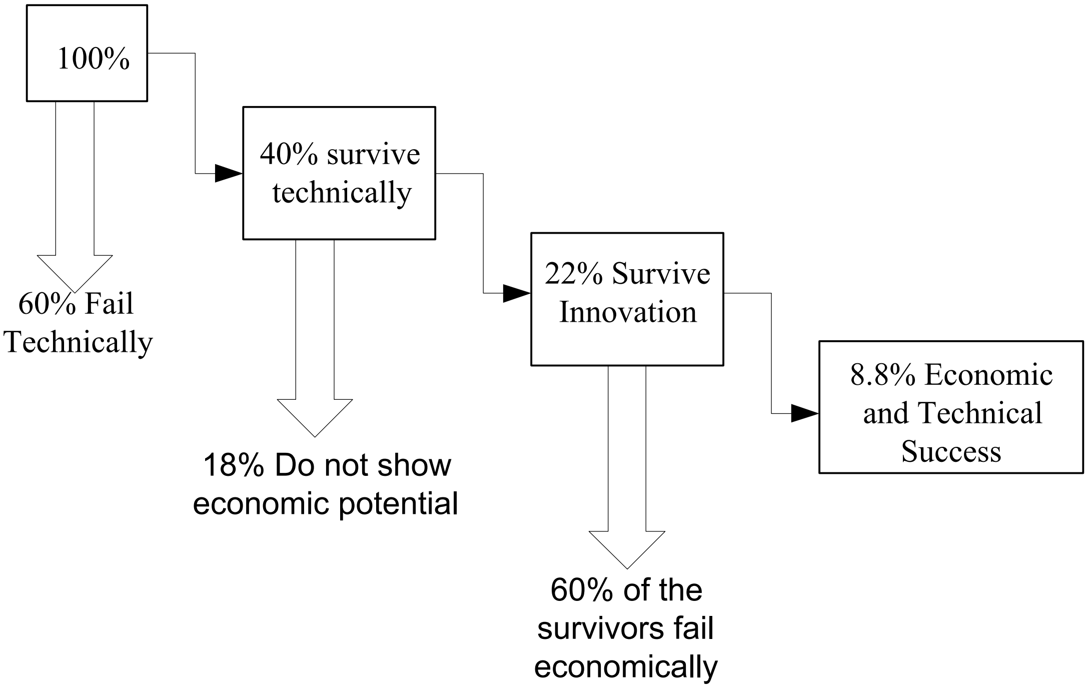

Figure 1. Project Attrition

The remainder of this report is organized as follows. A description of the methodology used in this study is provided in Section 2. Technology applications are discussed in Section 3. The section covers three types of technology: information systems, physical handling systems, and storage/retrieval systems. Throughput differences between Asian ports and Western ports are presented in Section 4. Also included in this section are the results of a computer simulation by Holguin-Veras and Walton (1997) of a two-priority cargo scheme. Section 5 addresses the legal and institutional arrangements that influence the adoption of technology in maritime terminals. Finally, our conclusions are presented in Section 6.

2. METHODOLOGY

A wide variety of data gathering techniques was used in this study. The goal was to obtain a general perspective of the policies, procedures, and equipment that influence the operation and performance of maritime terminals and military deployments. The data include both qualitative and quantitative information from managers, workers, design engineers, port authorities, researchers, and Department of Defense personnel. We visited three ports (Long Beach, Los Angeles, and Oakland) and had several telephone discussions in the data gathering effort.

While there is a considerable amount of published literature concerning transportation and logistics, there is a relative scarcity of information concerning the actual operation of maritime terminals. A substantial portion of the information concerning maritime terminals deals with proposed designs for new equipment and terminal layouts. Nevertheless, we were able to locate several informative papers. The results of the literature search were especially useful in describing the generation and flow of information in maritime terminals.

Interviews with individuals and tours of terminals provided a wealth of information. We observed operations in a variety of terminals including Hanjin, Sea-Land, Evergreen, American President Lines, and Toyota. Observations were made in all the major operating areas of the terminal (gate, yard, and dock). We discussed the procedural aspects of the operation with individuals ranging from truck drivers to senior managers and many of the intermediate levels as well. We were afforded the opportunity in one of the terminals to travel through the yard and onto the dock area with a longshoreman and to observe all aspects of the operation.

We also conducted interviews with freight forwarders, port managers, and a terminal designer. Other sources of data include discussions with consultants, equipment designers, and government representatives. Internet searches also provided considerable information, especially in the area of military logistical concepts and procedures. The web sites maintained by USTRANSCOM, MARAD, MSC, and MTMC were particularly useful in providing information about the military aspects of the problem. The web sites maintained by some of the ports (Long Beach, Los Angeles, Seattle, Hong Kong, Oakland, and others) provided some of the quantitative data.

As proposed, Task 1.2.4 was intended to incorporate much more data on practices, operations and plans of actual maritime terminals. The data collection component of Task 1.2.4 was to be completed by a separate sub-contractor under CSULB. Because this data collection task was never executed, the University of Southern California portion of Task 1.2.4 was completed to the best of our abilities, based on information that was already available.

3. TECHNOLOGY APPLICATION GAPS

Ioannou et al (1999) divided cargo handling technologies into 11 categories, which we organize into three groups: information systems, stacker/retrieval systems, and physical handling systems. Information systems are used to collect, process and apply information, through such means as radio-frequency (RF) tags, global-positioning-system (GPS) units, container tracking software, and load-planning software. Automated stacker/retrieval systems (AS/RS) are used to efficiently store cargo awaiting shipment or awaiting pickup by a customer. AS/RS are used to increase the packing density of cargo and containers, and for storage and retrieval with minimal human effort. Physical handling systems are used to move cargo or containers within a terminal, to or from a ship, or to or from a storage location. Example technologies include anti-sway systems, dual-hoist cranes, and automated guided vehicles.

3.1 Information Systems

Kang and Kwon (1997) observed that "to achieve the maximum strategic benefits of logistics, the full range of functional work must be performed on an integrated basis." Information systems are the means by which the elements of the logistics system are integrated. They can improve productivity in the following ways, to name a few:

- Assignment of containers to storage locations in a manner that minimizes excess movements, total travel distance in the yard, and effort locating containers.

- Repositioning equipment and containers in a manner that minimizes empty mileage and deadheading.

- Sequencing cargo movements and loadings to ensure that highest priority cargo arrives first and on time, and to ensure that minimal effort is needed in loading and unloading ships.

- Synchronizing the dispatch of vehicles from terminals with the arrival of cargo and containers.

These benefits apply almost equally to commercial and military transportation.

There are apparently large differences in the use of information technology among the various providers of logistics services. Independent truckers, who often transport cargo to terminals in urban areas, have a reputation for being on the low end of using technology. The logistics providers in the rail and marine modes tend to use technology to a greater degree than independent truckers. However, within the maritime industry, terminals vary in their sophistication.

Holguin-Veras and Walton (1996) surveyed 12 maritime terminals to determine how they use electronic data interchange (EDI) in their operations. These information interchanges provide bills of lading, clearances, and other information that enable the physical flow of containers. As shown in Figure 2, EDI was used most often by shipping companies, followed by government agencies and railroads. Brokers and motor carriers trailed in their EDI usage.

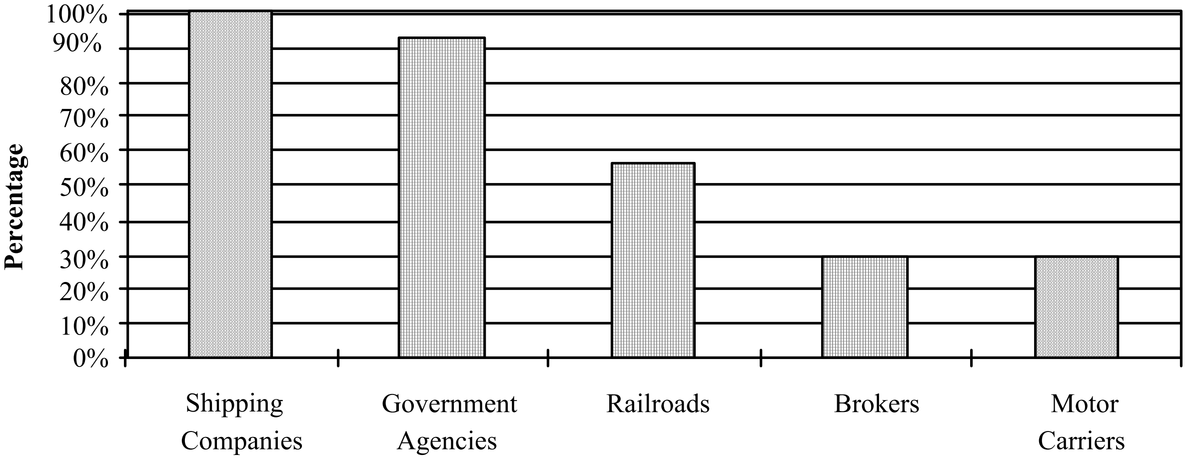

Figure 2. Electronic Data Interchange Usage

The military is vitally interested in data flows associated with monitoring and control shipments during deployments. During Desert Shield, there were instances of wrong equipment being sent to the theater, lost shipments, and inappropriate use of resources. To avoid recurrence of these events, the United States Transportation Command (USTRANSCOM) has reengineered their command and control procedures.

“Use of the high speed sealift and agile port to speed unit material and sustainment supplies to the operational theater requires a host of supporting factors. In-place Maritime Administration (MARAD) port orders, available MTMC representatives, use of TTUs, arrangements with stevedores, coordination of railroad and port authorities, and computer support from a number of systems are all important to getting the job done quickly and efficiently. Knowledge of unit lift requirements and support for port marshalling and ship loading programs will be necessary for minimizing idle time and confusion at the POE.” (Law, 1996)

The military requires in-transit visibility so that action officers and decision makers have adequate detail to make timely decisions. Without this information the execution of the operations plan can be interrupted (Joint Transportation Corporate Information Management Center, 1996). Only a small number of maritime operations provide this type of integrated visibility. Sea Land and American President Lines (APL) have tracking systems that are compatible with military requirements (Seiberlich, VZM Transystems), but others have not.

Ioannou et al identify three components to a total asset visibility system (TAV): (1) system to determine location of the assets, (2) system to identify the assets and (3) communication technologies to access and deliver the information. The system as a whole provides a capability both to track the location of assets, and to optimally route or position assets based on their current location or status. The benefit comes in higher utilization of available capacity, reduced in-transit time, and an enhanced ability to accommodate cargo once it arrives (because arrival times can be predicted with greater certainty).

TAV systems can be enhanced with automated data entry or identification. Instead of using a human operator to identify a container, for instance, the container can be identified through short-range radio-frequency communication between a stationary reader and a tag mounted on the container. Most American railroads have adopted RF tags. However, the rate of adoption has been much slower in the maritime industry. A survey of twelve terminals by Holguin-Veras and Walton (1996) indicated that automated data entry is not widely used. For example, they found that 92% of the terminals in their survey used only clerks to identify containers (Figure 3), and 2/3 of the terminals used labor intensive methods to identify trucks entering the terminal (Figure 4).

One explanation for the failure to adopt RF tag technology is that the entire industry (crossing national boundaries) will have to adopt it to achieve full efficiency. If some of the shipping lines do not adopt the data tags, then terminals will have to maintain both the manual system and the automatic system to accommodate the containers coming from the lines that do not adopt the technology. Maintaining both an automatic and a manual system does not allow terminal operators to realize the cost savings inherent in the technology. There are also issues surrounding the standards to be used in the devices. Moreover, unlike the rail industry, the container shipping industry is much less closed, as containers can reside in numerous locations outside the control of the carrier.

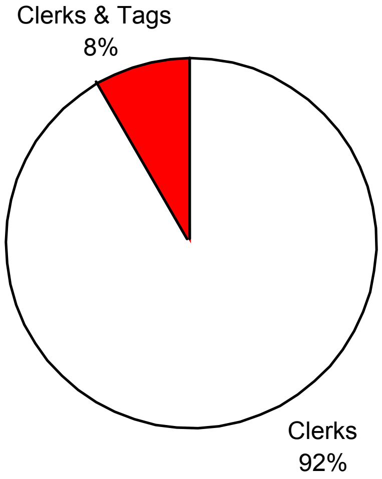

Figure 3. Container Identification Methods

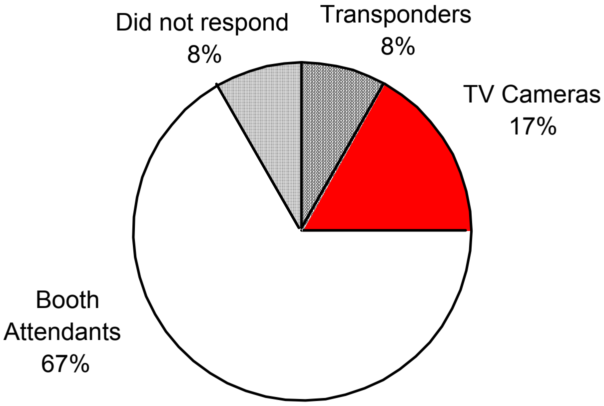

Figure 4. Truck Identification Methods

3.2 Technologies for Physical Movement

Physical movement technologies can be characterized by the dimensions in which they operate. Automated guided vehicles, multiple-trailer systems, cassette loading systems and linear motor conveyance systems operate in the surface plane of the terminal, moving cargo and containers from one location to another. Lift technologies, such as cranes, operate in the vertical dimension, usually in addition to a horizontal dimension. Some yard vehicles, such as fork-lifts and straddle carriers provide movement in all three dimensions. Speed, cycle time and capacity are other defining characteristics.

3.2.1 Cranes

Crane technology is the single most important determinant of the time required to process a ship at a terminal. The productivity of a crane system depends on many factors, including:

- The time for each crane to complete a load or unload cycle
- The number of cranes that can simultaneously work on a ship
- The time required to move a crane from row to row along the length of a ship
- Efficiency of the interface with a ground movement systems
- Ability to simultaneously load and unload a ship
- Time required to take ships in and out of the dock
- Number of excess moves required to access containers that are underneath containers destined for other ports
- Effective hours of operation per day

The cycle time is an especially important factor. It consists of several steps, beginning with latching onto the container, a vertical lift, a horizontal movement, a vertical drop and a release step. Reducing the time for any of these steps reduces the total cycle time and increases the capacity of the crane. Another approach is to convert these sequential steps into parallel processes, allowing a crane to serve multiple containers simultaneously. This is the idea behind new technologies, such as the dual hoist crane.

The cranes used to lift cargo onto and off from ships can either be located on the shore or on the ship. Carriers have a definite preference for ship cranes since the ship mounted cranes reduce the volume and weight that can be allocated to cargo, increase the cost of the ship, and decrease the stability of the ship. The shore-based cranes also typically achieve higher productivity. Shipboard cranes, however, have the advantage of not being dependent upon the shore facilities for loading and unloading at more primitive ports.

PRC, INC., in a report for the Maritime Administration (MA-RD-840-93003), discussed several designs for future loading and unloading facilities, many of which involve the reconfiguration of the docks and the use of future ship designs. Some designs incorporate float-on/float-off concepts, which will require the construction of new ships and dock facilities. Since these concepts involve the redesign of the ships, they will not be further discussed.

Two proposed enhancements to current crane operations are the anti-sway system and the intelligent spreader bar. The anti-sway system envisions the use of feedback control mechanisms to reduce or eliminate the pendulum like motion of containers. Currently, operators must reduce the speed of the crane trolley movement to avoid the undesirable swinging of the container. Elimination or reduction of this tendency would improve the throughput of the ship-to-shore transfer. The intelligent spreader bar enables the crane operator to control the spreader bar orientation in six degrees of freedom. This capability would improve the operator's performance in latching and placing containers. Both of these proposed enhancements have been demonstrated in engineering models, but their development cost to a terminal operator is likely an impediment to adoption.

Other proposed improvements for the ship-to-shore transfer include a cell elevator, which has been studied by August Design. The speed and ease of crane operation varies over a cycle. Maneuvering the spreader bar in the hatch cell is difficult and slows the overall cycle time. August Design has proposed an elevator that would lift a container to the top of the hatch, thus eliminating this slower portion of the crane cycle. The enhancement also has the advantage of decreasing the vertical motion of the spreader bar, which is usually a detriment to the cycle time. As with the intelligent spreader bar and anti-sway system, the cell elevator requires further development, and the cost is most likely a deterrent to immediate adoption.

On the positive side, improvements to dock crane operation are possible with relatively small changes in the design. The rope-towed trolley (RTT) has been the traditional design of dock cranes. However, in Europe, the machinery-on-trolley (MOT) design has been well received. This design was recently introduced in the United States. In 1996, American President Lines (APL) purchased twelve cranes of the MOT design for use in the Port of Los Angeles. According to Bhimani and Hoite (1998) the apparent advantages of the MOT design are:

- Reduced maintenance costs.
- Reduced environmental and safety concerns.
- Improved load control.
- Improved operator comfort.

They state that in the first five months of operation the new cranes provided a 30% reduction in maintenance cost and have maintained a productivity of about 25 moves per hour without difficulty. This throughput value is partially due to the MOT's operating speed of 800 feet/minute (compared to the RTT design with a speed of 600 feet/minute speed). The reduction in maintenance cost is equivalent to approximately ten to fifteen percent of the acquisition cost of the cranes when the equivalent present value of the maintenance cost is computed over a twenty-year life at an 8% interest rate.

From the military perspective, improved crane technology has benefits limited to equipment that can be lifted on or off the ship, with the greatest benefit for cargo that is transported in standardized containers. Cranes are not at all applicable to roll-on/roll-off cargo.

3.2.2 Automatic Guided Vehicles

Robots have dramatically improved labor productivity of some manufacturing industries, such as painting and welding processes in automotive assembly. One type of "robot" used in transportation is the automated guided vehicle (AGV). AGVs provide a higher level of route flexibility than automated conveyor or railed systems, though not as much flexibility as human controlled vehicles. AGVs can also operate on smooth surfaces. These factors are important for maritime terminals, as flexible routes are needed in storage and retrieval and smooth surfaces are needed for movement of a great variety of yard vehicles. One of the drawbacks, however, is that it is difficult to attain high system safety when AGVs operate at high speed and are intermixed with pedestrians or, perhaps, non-automated vehicles. The primary advantages of AGV over manually operated vehicles are labor reduction and enhanced ability to route and track cargo.

Currently, the only marine terminal using automated guided vehicles (AGVs) is the Rotterdam Delta Terminal. According to Hopkins (1997), "The Port of Rotterdam's Delta Terminal is the best example to date. This terminal, in partnership with Sea-Land Services, is highly advanced technologically, with more than 50 unmanned automated guided vehicles (AGVs) carrying containers from ships to stacking areas. Currently the Delta Terminal is the only container terminal that uses AGVs extensively. In the 4 years since [automated vehicle control systems] AVCS deployment, wage costs at the terminal have decreased from 61 percent to 51 percent of total costs."

Automatic guided vehicles were also deployed at the Thamesport intermodal port facility in England in 1992, using a different design than Rotterdam's (Hopkins, 1997). Durrant-Whyte (1996) provides an in-depth description of the design of the Thamesport AGVs. Since their deployment they have been removed from service due to a lack of funding. Hopkins points out that there were no reported incidents, but safety of these vehicles is a serious concern. Reportedly the Port of Singapore (PSA) plans to deploy a fleet of AGVs by the year 2000.

In their report to the Maritime Administration (MARAD), PRC, INC. states that "the primary advantage of using automated guided container carriers is increased productivity through more accurate vehicle positioning under the cranes and transtainers. … Also, there is a reduced potential for error in storing the container since there is no potential for the vehicle to take the cargo to the wrong storage location. The main disadvantage of the AGV carriers would be the obviously high initial investment."

Many of the articles discussing AGVs state that one of the barriers to adoption is the work force. The workers and their union apparently perceive the AGV to be a threat to their jobs. On the other hand, they require a significant capital investment, and demand highly skilled labor for their maintenance and operation. Therefore, unless terminal management can achieve a return on their investment through a reduction in direct labor costs, they have no incentive to pursue this technology. Many terminal managers are aware of the high degree of automation used at the Rotterdam terminal, but have not seen a cost effective way to capture the benefits.

From the military perspective, AGVs are less flexible than manually operated vehicles, as they require installation of guide paths, and software development to control their movement within a given yard configuration. For these reasons, under a surge deployment, it could be advantageous to simply disable the AGV and rely entirely on manual equipment.

3.3 Storage/Retrieval Systems

Automated storage and retrieval systems (AS/RS) provide automatic transfer from an input station to storage, and an automated transfer from storage back to an output station. AS/RS can increase the packing density of containers by doing the following:

- By following a randomized storage pattern, all empty positions are available for container storage. Manual systems frequently required fixed assignments, reducing the ability to utilize empty positions.
- Containers can sometimes be stacked higher while still providing access to containers placed in the bottom.
- Internal transfer vehicles can be designed to operate in narrower aisles, sometimes at higher speeds, providing more space for actual storage.

AS/RS can also interface directly with an AGV system, further reducing labor content. These benefits offer more efficient utilization of available space, and often quicker and less labor-intensive storage and retrieval. AS/RS is most often used in distribution centers, which stock large numbers of items, instead of trans-shipment terminals (such as ports). The goal of distribution centers is to rapidly fill orders for standard "stock-keeping-units" (SKU), whereas terminals do not, by design, inventory items over long periods.

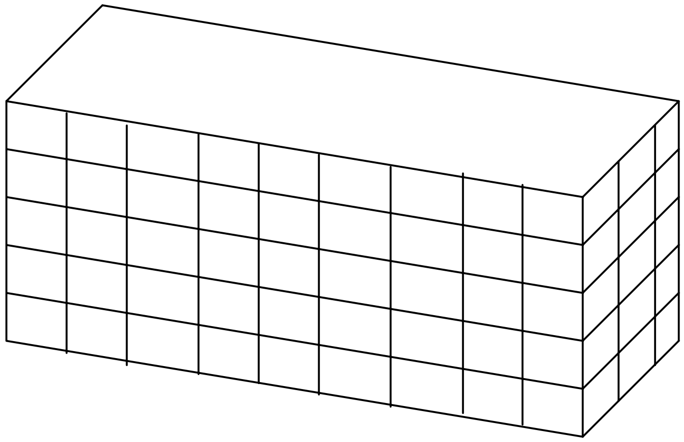

Figure 5. Automated Container Storage Facility

Like AGV systems, AS/RS require significant capital investment and skilled labor for operation and maintenance. Naturally, the benefits of an AS/RS would be greatest in ports where land and labor costs are especially high or space is especially constrained.

PRC, INC. examined an automated container storage structure as sketched in Figure 5. This structure would replace the current yard storage with containers stored in cells in the structure. The developer proposed tracking the location of containers in the cells with a computer system. During off hours, the system would automatically re-arrange the containers for ship loading at a future time. While the concept seems intriguing, the PRC, INC report found that it was not cost effective. Ioannou et al (1999) describe several additional AS/RS concepts for container storage.

To date, AS/RS has been used almost exclusively in warehousing operations, where storage items are no bigger than a pallet load. Because of the small size of the units being stored, the labor advantage from automation can be significant. It is less clear that it would be cost effective to automate container storage, as a single driver can already transfer a large quantity of goods in a single move. Technically, it is also more challenging to automate movement of large containers than smaller sized pallets.

Given these factors, a better option in space constrained ports is likely a two-tiered storage system. Land immediately adjacent to the wharf is devoted to containers that reside for very short periods, awaiting immediate pickup or delivery. Containers that must wait longer are stored away from the wharf, where land is more plentiful and cheaper.

Besides the investment cost, AS/RS are unlikely to benefit the military for two reasons. First, they are not designed to accommodate wheeled containers or containers that fall outside standard dimensions. Second, they would not be flexible in serving surge deployments, as a fixed AS/RS structure precludes a simple reassignment of space.

3.4 Summary

Many advanced technologies are not used in maritime terminals for the simple reason that they require large investments, and do not provide sufficient benefits. In some cases benefits are limited because management is unsuccessful in negotiating labor agreements that enable productivity gains to be realized. Nevertheless, as ports become more constrained in available land, the incentives to increase productivity will grow, and more ports will invest in technology. Unfortunately, if terminals invest in specialized technologies solely designed to handle and store standardized containers for set shipping patterns, military needs may not be served.

4. THROUGHPUT DIFFERENCES

The throughput represents the rate at which cargo is processed through a terminal. Throughput is a function of both the demand for shipping cargo through the terminal, and the capacity for processing cargo at the terminal. The capacity depends on the technology, the terminal configuration and area, management practices and labor productivity.

Vandeveer (1998) found that terminal throughput is highly correlated with the area of the terminal, and that distinct differences exist between Western and Asian ports. The differences can be appreciated by separately fitting a regression line for each region (Figure 6). The figure clearly indicates that Asian ports and Western ports have very different performance for the same land area. Vandeveer (1998) attributed the superior performance of Asian container terminals to "… highly-intensive labor practices, high-density storage, and high percentages of transshipment cargo." Wiley, however, attributes the difference in performance of the Port of Hong Kong to a considerably more active control over the yard and the activity of the yard equipment.

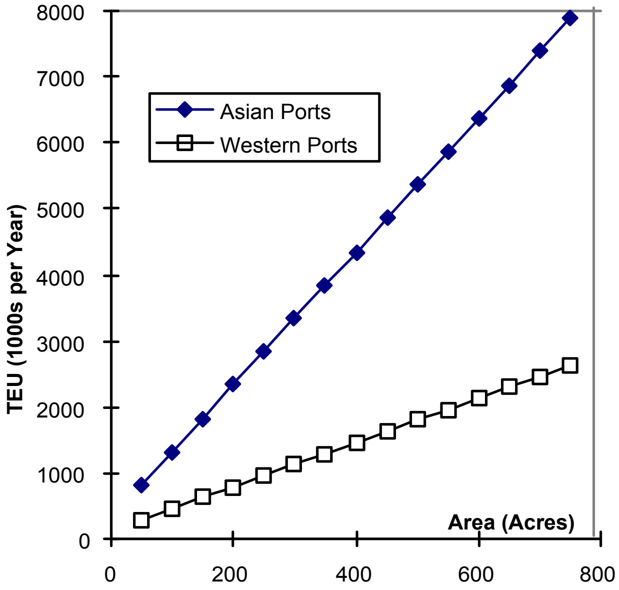

Figure 6. Asian and Western Port Comparison

Other factors that could influence the observed difference in performance of Asian ports include the considerable amount of export business that is conducted relative to other parts of the world, a difference in the method of counting containers or land area, and the number of ships being serviced. Also, their may be greater incentives to increase productivity per unit land area due to scarcity of land and higher land costs.

On the subject of benchmarking, Deming, a highly regarded advocate of quality control, observed that, "The question is not whether a business is successful, but why?" From this perspective Walker and Helmick (1998) are correct in stating that we need to look at

the terminal performance from a systems point of view and need to consider more than a single measure of productivity in identifying the best application of technologies.
Data on throughput differences between terminals using more advanced technology and other terminals are difficult to obtain due to the general lack of use of advanced technology.

4.1 Effects of Technology on Throughput

At the conclusion of the Desert Storm operation there was discussion of how the deployment process could be improved. One of the potential solutions was for the military to contract with commercial carriers to deliver the cargo in the manner of a commercial shipper. This suggestion is especially relevant during the sustainment phase of a deployment.

Such an arrangement would have several advantages. One advantage would be fewer partial shiploads and another would be utilization of the commercial carrier's infrastructure. Partial shiploads would be avoided by mixing military and commercial cargo in shiploads. The ship rotation schedule would then be adjusted so that the commercial cargo are delivered to their destinations and the military cargo are handled by transshipment to a military port. This would keep the commercial shipping out of harms way, reduce the cost, and still meet delivery schedules.

Many of the commercial shipping companies have extensive infrastructure in the ports of call, including equipment, labor, and agreements with local transportation companies. By using the existing infrastructure of commercial companies, the military could avoid the costs and effort needed to establish a transshipment capability at these ports. This approach to shipping, however, would have to use a priority system to ensure that the military cargo receive precedence over commercial cargo.

4.1.1 Priority Model

Holguin-Veras and Walton (1997) simulated a two-priority terminal system under different technological scenarios. Specifically, they evaluated the technological and economic implications resulting from dividing container cargo into high priority and low priority categories. By contrast, in a conventional terminal, cargo is not differentiated by time sensitivity, which reduces the terminal's capability to serve customers that demand quicker and more reliable service. (Some terminals attempt to segregate cargo that is known to be time sensitive by loading it in specific hatches (i.e., hot hatches) that will be unloaded first.) The model was applied to the Port of Houston.

Holguin-Veras and Walton created a micro-simulation that explicitly captures the geometry of the system and its interactions with operational policy. It also models the time required for the movement and operation of yard cranes, gantry cranes, and other equipment. Table 1 summarizes the terminal policies investigated. In the base case, all containers are treated the same. The base case was then compared to prioritization. The condition of wheeled storage was also addressed in isolation of the other policies. Taking a cue from APL and Matson, who use automatic data reading equipment, they examined RF-tags in isolation of other technologies. Then combinations of various technologies were examined.

	Location of High Priority Containers	Yard Crane Operations	Yard Gate Operations
Base Case	Random	No priority	No priority
Hot hatches	Containers on hatches	No priority	No priority
Wheeled	Random	High priority containers wheeled	No priority
Gate	Random	No priority	Priority to high priority containers
All but gate	Containers on hatches	High priority containers wheeled	No priority
All	Containers on hatches	High priority containers wheeled	Priority to high priority containers

Table 1. Terminal Policies

Each of these scenarios was examined under conditions representing the number of containers processed per week and the proportion of containers that are high priority. The test conditions are summarized in Table 2.

	Throughput Rate	
Priority Percentage	1000 containers per week	2000 containers per week
25% priority containers	• Basic • Gate • Hot hatch • All but gate • Wheeled • All	• Basic • Gate • Hot hatch • All but gate • Wheeled • All

Table 2. Computer Test Conditions

The performance outputs of the model included: the total unloading time, total retrieval time, the probability of noncompliance, and operating costs. These were defined as follows:

- "Total time at unloading is the summation of the average service and waiting times of the stages composing the unloading process (i.e., unloading the ship, movement to the storage yard, and unloading at the yard).
- Total time at retrieval is the summation of the average service and waiting times of the stages composing the retrieval process (i.e., service at the gate, movement to the yard, loading at the yard, movement to the gate, and service at the gate).
- Probability of noncompliance is the probability that a given container will not be ready when the owner's representative arrives to retrieve it.
- Operating costs are an estimate of the amount of resources used."

We use the symbols in Figure 7 to compare simulation scenarios:

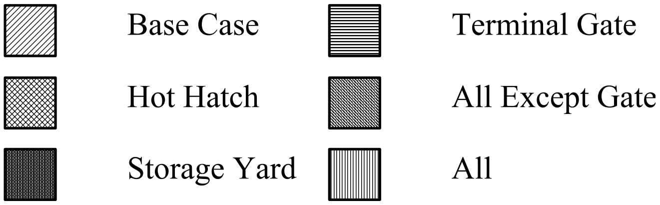

Figure 7. Identification Scheme

Results of Holguin-Veras and Walton (1997) simulations are shown in Figures 8 – 11. They provide results for all four performance measures, with 1000 containers per week, and Figure 12 shows unloading time results for 2000 containers per week. With one exception, unloading time for low priority containers was better under the base case than all other terminal policies (see Figure 8). The exception was wheeled storage for high-priority containers. The unloading time for the low priority containers improved by about 5.7% relative to the base case, likely because of increased availability of yard cranes for low priority containers. If the high-priority cargo does not require yard cranes (since it is stored on the chassis), then the low priority containers have better access to yard cranes (assuming a fixed number of cranes).

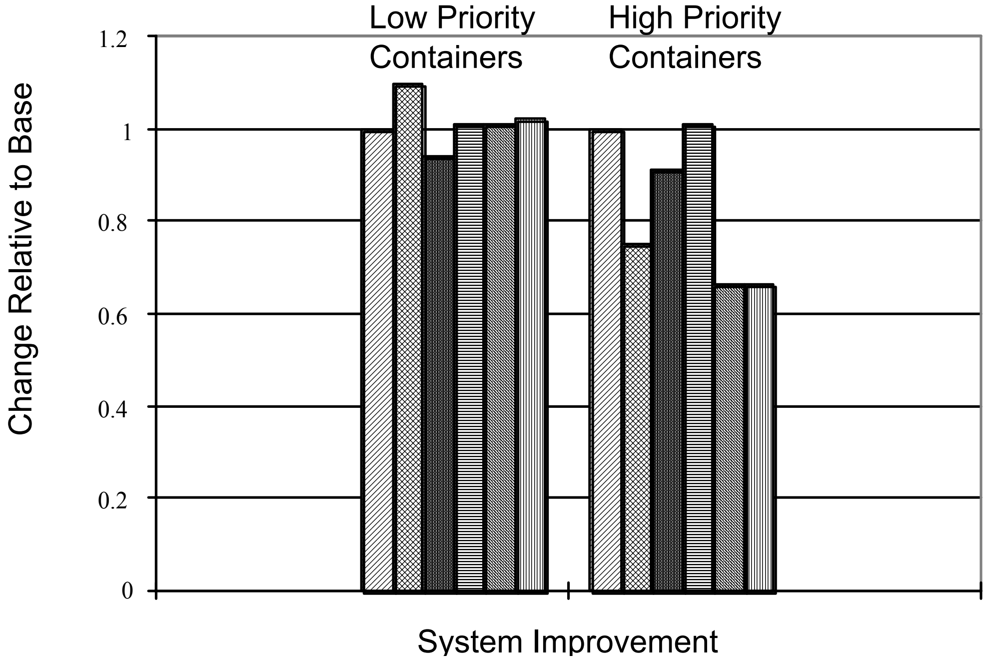

Figure 8. Unloading Time for 1000 Containers per Week and 25% High Priority

All system improvements, except gate processing, caused a decrease in the unloading time for the high-priority containers (Figure 8). Gate improvements actually increased unloading time by 1.2% relative to the base case. This is likely because trucks are allowed into the yard at a faster rate, effectively moving queues from outside the yard to inside the yard. The best interpretation is that capacity increases in one step of the process may require concomitant capacity increases in other stages. Taking all of the improvements together, for instance, provides a 33.5% improvement in the unloading time relative to the base case.

The retrieval time includes the service times and the waiting times for a truck to receive gate processing, move through the yard, load the container onto the truck, move to the exit gate, and receive service at the exit gate. Changes in terminals policies increased the retrieval time for low-priority containers (Figure 9). On the other hand, wheeled storage of high-priority containers dramatically reduced (83.3%) the retrieval time for high-priority containers. Taking all improvements together, retrieval time declines by 99.1% relative to the base case for high-priority containers, with a slight increase for low-priority containers. It should be noted that improvements in the yard alone have a substantial effect on the retrieval time, but the improvements to the gate and the hot hatch concept have virtually no positive effect on retrieval times. Only by combining the improvements in all areas is there a dramatic effect on retrieval times.

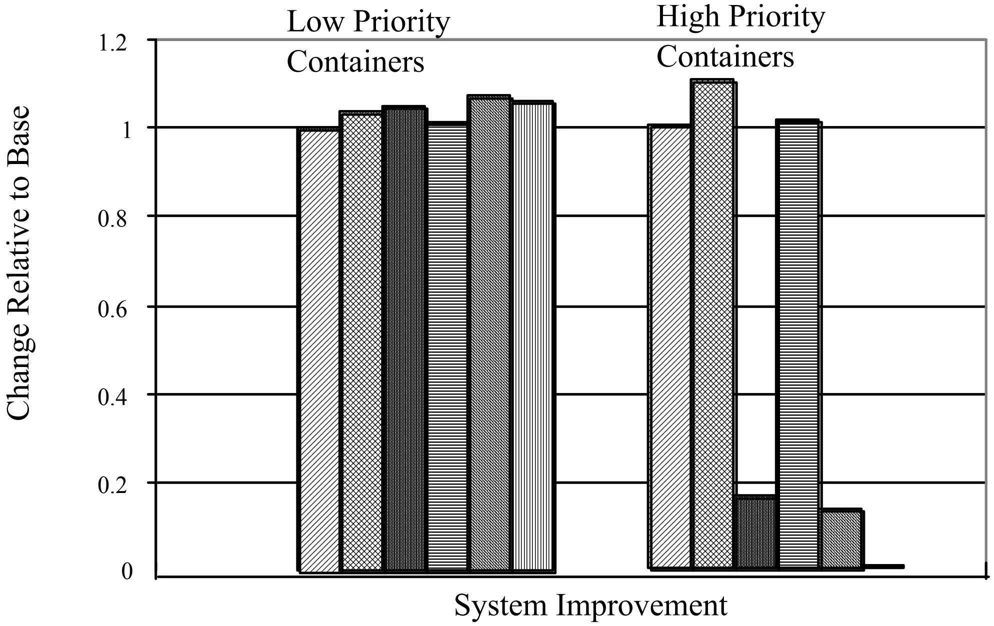

Figure 9. Retrieval Time for 1000 Containers per Week and 25% High Priority

Noncompliance (Figure 10) can be reduced to approximately 10% of the base case for high priority containers through combining all improvements. The gate improvements have relatively little effect in this case and the hot hatch concept is a dominant contributor to improved performance.

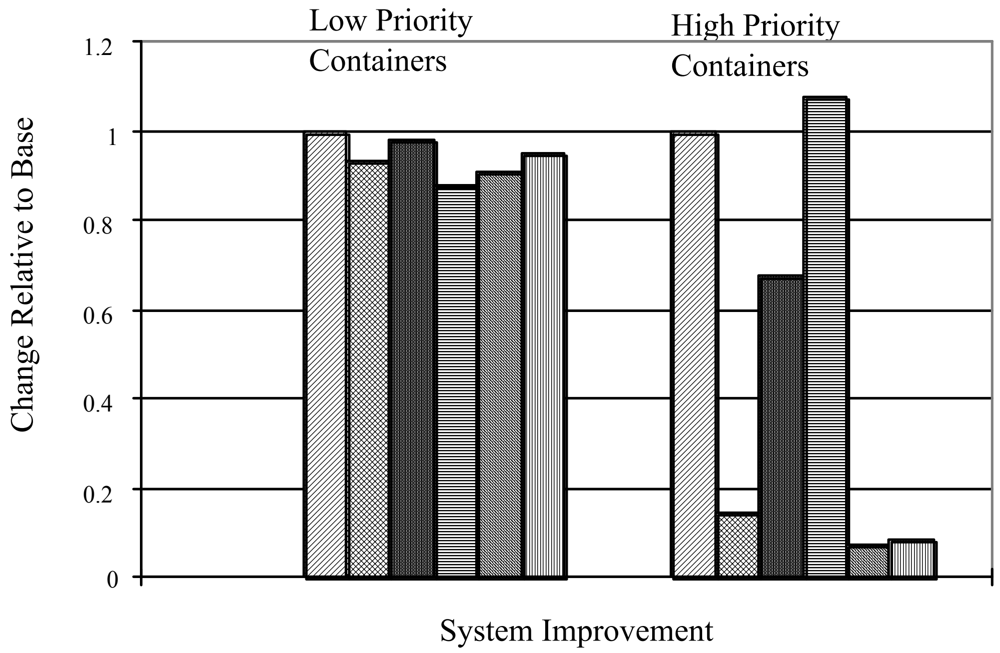

Figure 10. Noncompliance for 1000 Containers per Week and 25% High Priority

Total costs (Figure 11) only improve moderately with the various improvements. The hot hatch concept provides only a small reduction in the total costs, but the yard improvements and the gate improvements provide somewhat larger reductions in the total cost for high priority cargo. When all the improvements are implemented together, the total cost for high priority cargo is reduced to about 40% of the base condition. The total cost for the non-priority cargo remains essentially unchanged.

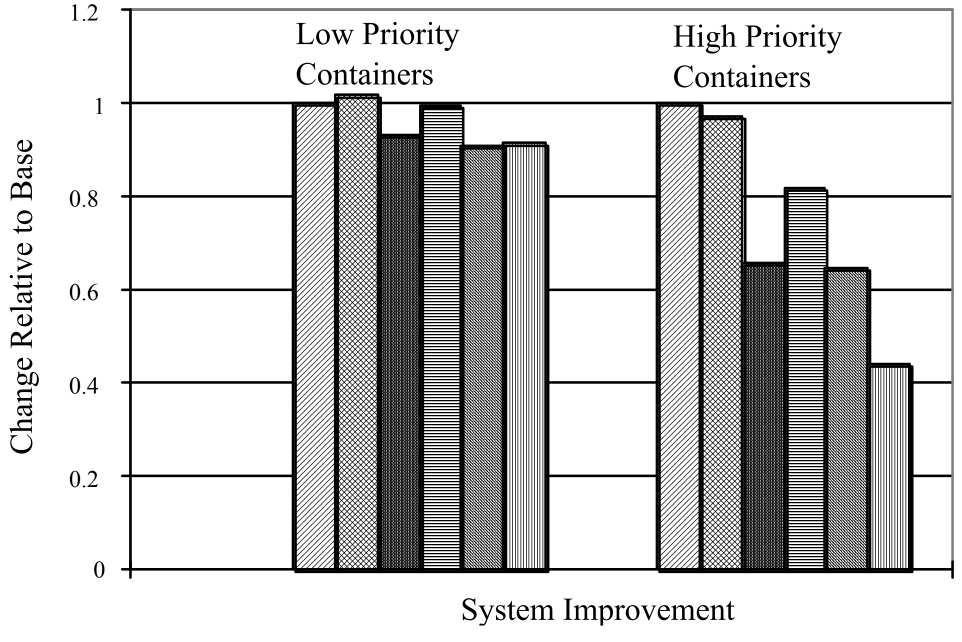

Figure 11. Total Cost for 1000 Container per Week and 25% High Priority

The system performance depends on the volume of containers per week. When the volume is doubled to 2000 containers per week, the unloading time (Figure 12) for high-priority is improved by 33.5% relative to the base case when all the improvements are implemented. In contrast, unloading time is 1.1% worse for low-priority relative to the base case.

As the percentage of high-priority containers increases, the advantages offered by the technology improvements deteriorate due to the increased workload at the servers handling the high-priority containers. However, there is a residual improvement relative to the base case.

Holguin-Veras and Walton (1997) point out that: "a modification should be made in the way the information is processed to prepare the ship loading plan, the yard plan, and the yard equipment assignment so that they take the priority level of the containers into consideration." Both in the paper and in private conversations, Holguin-Veras warns that without considering the effects of a network of ports, these results should be considered tentative. Apparently he suspects that other important influences are not captured in the model discussed here. Even superficially it is obvious that the actions and policies of the originating terminal could influence the performance of a destination terminal.

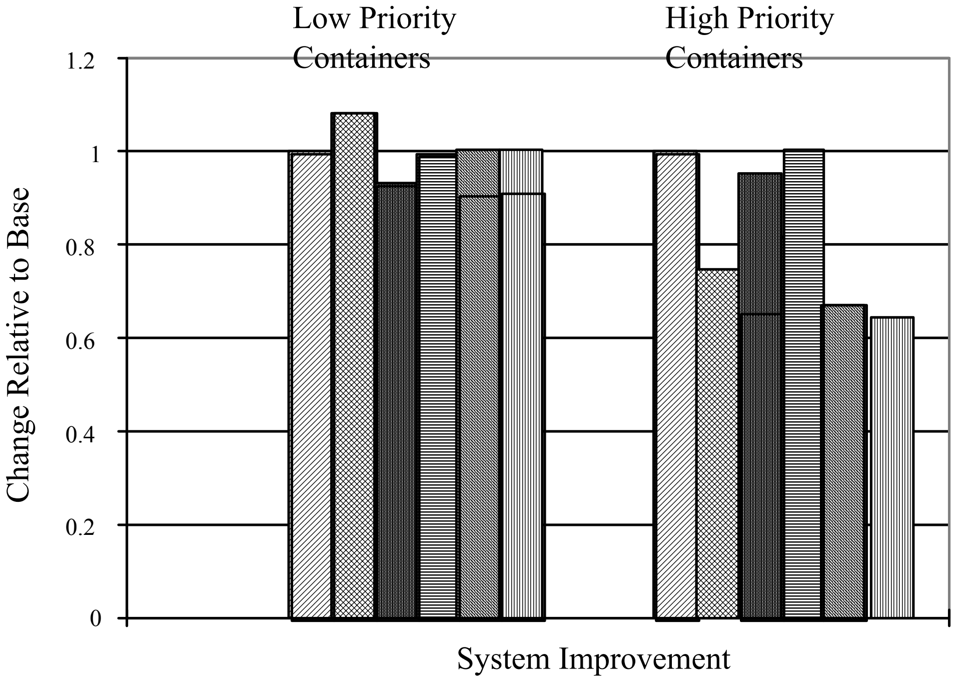

Figure 12. Unloading Time for 2000 Containers per Week and 25% High Priority

5. LEGAL AND INSTITUTIONAL ARRANGEMENTS

Virtually all business problems have economic, technical, social, political, and legal aspects. Often it is the interactions of these various aspects that are at the heart of difficult decisions. Quantitative models of the maritime activities will not address many of these interactions, but they are nonetheless important.

5.1 Maritime Development

Currently, the maritime industry appears to suffer from a slower rate of innovation than other industries. Like other modes of transportation, shipping lines and terminals operators do not invest significantly in research, relying on vendors to invest in development of new technologies. Compared to manufacturing industries, transportation has been slower to adopt information and automation technology, and has not adopted the culture of continuous technological improvement. One feature of efforts in the development area is the considerable risk and economic impact of such an undertaking. In the aerospace industry, the risk and economic impact of research and development is attenuated by government agencies such as the National Aeronautics and Space Administration (NASA). Under the NASA efforts both military and commercial companies have benefited from scientific and engineering findings. Government agencies have not similarly invested in research on transportation technologies for goods movement (they have, however, invested in infrastructure related research).

5.2 Labor Relations

The relationship between the maritime companies and the labor union is frequently cited as a constraint to improvement. There appears to be rather substantial differences between the East Coast and West Coast labor unions in terms of willingness to negotiate. We could not determine a reason for the difference; we could only obtain anecdotal evidence of the difference. One specific item may be a clause in the ILWU contract dealing with automation and mechanization. While this clause apparently does not prohibit the acquisition and use of high technology equipment, it does appear to be a negotiable item with each terminal. We could not determine the degree to which this clause is an impediment to adoption of technology, but this should be investigated in the future.

5.3 Equipment Standards

Standardization of software and hardware would assist in the flow of information and containers across terminals. Although efforts have been initiated to develop standards, industry participation has been weak. Without software and communications compatibility the flow of information among the stakeholders (terminals, brokers, freight forwarders, etc.) will remain fragmented.

The fragmented flow of information slows the movement of containers since clearances, shipment schedules, and other information must come from multiple sources. Without information, the containers will not move to their correct destinations. As part of creating a smoother flow of information it is important that the trucking industry, including independent trucking companies, not be neglected.

The use of electronic (computer-based) communications among the ports, steamship association and trucking industry would allow terminal operators to notify truckers when their containers are ready without needing expensive and specialized equipment. Such a system would allow all parties in the transaction to share their documentation electronically. It would also improve the customer knowledge cargo status.

5.4 Acquisition Regulations

Consideration should be given to the revision of the laws concerning acquisition of services during a period of crisis. Currently, movements of military equipment are delayed while contracts are negotiated. Use of prearranged contracts to cover contingencies would enable the rapid initiation of flow to a forward area. After the initiation of the flow, the wording and terms of a specific contract could be negotiated.

The use of commercial carriers, especially for the sustainment phase, without an active military participation in the day-to-day operations should be considered. Commercial steamship lines have representatives worldwide with a better knowledge of the local conditions and the ability to deal with vendors and truckers more rapidly than the military representatives.

6. CONCLUSIONS

The following is a list of actions and future studies that may help to improve the development and acceptance of technologies in the maritime industry:

- Investigate the creation of a logistics research and development facility. The aerospace industry benefits from the research and development provided by NASA and the FAA research facility. The Merchant Marine Academy may be useful since the students are the future managers in the maritime industry.

- Generate and distribute descriptive information and data concerning the operation of terminals. This could provide a basis for the realistic development of technologies that would be acceptable to the managers of terminals. Currently, quantitative information about the maritime industry is difficult to obtain and firms are very protective of their data.

- Development of standards for the integration of new technologies into the industry (e.g., software portability across tracking systems and common communications methods across stakeholders).

- Incorporate sensitivity analysis into the economic studies on new technologies. The studies should include a range of discount rates rather than a single rate. Furthermore, the economic studies should investigate a broader range of variables. That is, they should provide a complete consideration of the costs and benefits over time.

- Investigate the use of priority systems within the industry to differentiate between time sensitive cargo and routine cargo. This investigation should also address the effect of various technologies on a network of terminals rather than the effect within a single terminal.

- Investigate the differences between the unions and the effect that these differences have on the management of terminals. This investigation should also address the organizational behavior aspects of the unions and maritime organizations to find leverage points to resolve differences in the perspectives.

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