

AUTOMATED TECHNOLOGIES IN MARITIME CONTAINER TERMINALS

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Abstract

The purpose of this article is to investigate the potentials of implementing an integrated Automated Storage and Retrieval System (ASRS) and Automated Guided Vehicle System (AGVS) in maritime container terminals. We first define the main components of the proposed configuration and justify the potential impacts of each and that of the integrated system. A 3D simulation (and animation) model is developed for quantitative comparison of the proposed system and current practices. The key ideas are examined using a set of measures of effectiveness including space utilization and throughput. A single criteria measure of effectiveness is also defined as the number of moves per acre per hour. Based on this criteria, the performance of the proposed configuration is 3-4 times the current block stacking practice.

Keywords: Maritime Terminals, Container Terminals, Automation, AS/RS, AGV, Simulation

1. Introduction

Tens of billions of dollars are spent annually in the U.S. intermodal freight system. Improvements in cost efficiencies of only a few percent can save hundreds of millions of dollars per year. Container traffic through U.S. ports is approximately 28 million TEU per year or 138 million tons of cargo. Although this is only 13% of the total U.S. waterborne foreign tonnage, it represents over a trillion dollars in annual trade or 53% of the total value of waterborne cargo. U.S. international container movements are second

only to those of China. However, the top U.S. port, Long Beach is ranked sixth in the world after Singapore, Hong Kong, Kaohsiung, Rotterdam and Busan. Recently, the term Automated Guided Vehicle Systems (AGVS) has become a keyword in publications and conferences addressing horizontal handling of containers in maritime terminals. The European Combined Terminal (ECT) in Rotterdam, the Netherlands, is the most automated container terminal in the world, where a fleet of AGVs integrates yard-cranes and ship-cranes. Several other ports both in Far East and Europe plan to implement AGVS. The term ASRS does not have the popularity of AGVS in container terminals. However, several firms carefully seek potential implementation.

2. Current Practices

Maritime container terminals are the interfaces between ocean and ground transportation. The function of a maritime terminal is to receive, store, and retrieve intermodal containers. Intermodal containers are commonly either 20 or 40 feet in length, and can weigh up to 100,000 pounds. Container movement and storage is now measured in FEU's (Forty-foot Equivalent Units). Containers arriving by sea are removed from ships by massive quay cranes that typically place the containers on yard-trucks. Yard-trucks travel on bi-directional networks connecting road-truck sites, stacking storage area, and ship load/unload site. On average, an inventory of about two weeks of activities is stored on a yard. Forty foot containers are commonly stored in blocks of length of 10, width of 6, and height of 3 containers. The gross area assigned to each block is around 40,000 square feet. Each block is commonly equipped with a gantry crane or a bridge crane. An individual container can be stored in any location of any block in the yard. The cranes have to dig-out the containers in the lower levels.

Material handling moves could be Single Command (SC) or Double Command (DC) moves. A DC move of a gantry crane is to pick-up a container from a yard-truck, store it in a location in the block, pick-up another container from another location in the block, and deliver it to the yard truck. A single command move accomplishes either a store or a retrieve between successive visits to yard-truck. Yard truck moves could be also SC or DC moves. A double command move of a yard-truck is a loaded round trip from ship

site (or truck site) to storage site, and back to ship site (or truck site). In a single command move, one way of the round trip is empty.

Space utilization of a stacking storage is represented by FEUs stored per acre. As an example, if the gross area assigned per block of containers is 40000 ft² and each block is 10 containers long, 6 containers wide, and, containers high, then

$$\text{Number of FEUs stored per block} = (10)(6)(3) = 180$$

$$\text{Number of FEUs stored per acre} = (180/40000)(43560) = 194$$

However, the actual space utilization indices is lower than the above figures. In practice, as soon as an outgoing container of a specific ship is located in a block, at least the whole column on that location is reserved for the containers of the same ship. This is to reduce the digging portion of the gantry crane activities. Furthermore, space utilization substantially decreases when a fraction of a block is assigned to a shipment. As the remaining containers arrive over a period of one to two weeks, they are placed in the available space within the allocated fraction of the block. This is mainly to avoid long movement of gantry cranes needed for retrieving containers to be loaded on the ship. The block fraction is then assigned to a new ship [Ratliff, 1999]. Under such circumstances, a gantry crane can achieve an average of 22 double command moves per hour.

The throughput of the system can be determined by the following relationships:

$$\text{Gantry crane moves per hour per FEUs stored} = (22/180) = 0.12$$

$$\text{Gantry crane moves per hour per acre} = 0.12(194) = 24$$

On the average a yard truck can achieve 5 double command moves per hour.

3. Automated Technology

ASRS offers flexibility, expandability, quality, and reliability. Accuracy and reliability of ASRS are higher than human-operated equipment. ASRS is easily expanded through

construction of additional modules. An ASRS has three major hardware components: *storage racks, storage and retrieval machine (SRM), and a shuttle.*

Rack Structure: An ASRS rack structure is composed of a set of columns referred to as bays and a set of rows referred to as tiers. Commonly, all bays have the same width. Bays in the same tier have the same height. The intersection of bays and tiers are referred to as cells. A typical ASRS structure module consists of single-deep stored unit loads in two parallel long narrow racks and an aisle between them. Storage racks interface with the storage and retrieval machine and require very tight tolerances. The guide rails installed in the aisle must allow the Storage and Retrieval Machine (SRM) to freely move in and out and stop exactly at the desired cell or pick-up and delivery (P/D) stand(s). Typically a P/D station is located at one end on the lowest level of each rack. Such a configuration is referred to as end of aisle order picking.

There are at least two well-known variations in the above mentioned configuration. One is to store loads in more than single-deep racks. This variation is beneficial if the throughput requirement is moderate, and many containers are identical with respect to some attributes. For example, outbound containers going into a specific hatch of a specific ship are all identical with respect to the precedence of loading into the ship. Outbound containers could satisfy this condition; however, in-bound containers do not fully fit into such a requirement.

A second variation in a prototype ASRS is to have multiple P/D stations located at both ends as well as at some middle points of the racks. This is beneficial to separate the inbound and outbound loads, increase the throughput, and increase the efficiency of the horizontal material handling system [Sule, 1994].

Storage and Retrieval Machine (SRM): The SRM moves simultaneously in both horizontal and vertical directions. It moves along floor-mounted rails parallel to the storage racks for horizontal trips, and along a mast for the vertical part of the trip. The SRM picks up a load from the P/D station (or from a storage cell), delivers the load to an empty cell (or to P/D station), sets the load down, and returns empty to the P/D station (or a non-empty cell). Such a trip is referred to as Single Command (SC). It accomplishes either a store or a retrieve between successive visits to the P/D station. In a Double

Command (DC) trip; the SRM picks up a load at the P/D stand, travels loaded to an empty location, sets down the load in the empty location, travels empty to a loaded cell in the rack, picks up the load, travels loaded to the P/D station, and then sets down the load on the P/D station, [Sule, 1994].

The Shuttle: The SRM moves in X and Y directions. A shuttle is mounted on the SRM for pick-up and delivery in storage cells and P/D stands. When the SRM is positioned with the cell or the P/D stand, the shuttle starts to move in the Z direction to pick up or drop down the container.

A horizontal material handling system is the interface between the ASRS and ship cranes on one hand, and truck and train docks on the other hand. In current practice different types of trucks, hostlers, and straddle trucks are used as the mode of horizontal material handling. Recently the term “AGVS” has become a keyword in publications and conferences addressing horizontal handling of containers in marine port terminals. Benefits of AGVS include low operating costs, reduced maintenance, excellent vehicle availability, safety, and environmentally clean operations. Automated Guided Vehicles (AGVs) are driverless, automatically controlled, capable of loading, transporting, and unloading without human intervention. They perform all kinds of tasks from mail deliveries to transportation of 300,000 lbs. loads. AGVs move along guide-paths that can be easily modified. The first AGV was built in 1953. It was a modified towing tractor used to pull trailers and followed an overhead wire in a grocery warehouse. In 1973, Volvo in Kalmar, Sweden, implemented 280 AGVs in its assembly line. The unit load AGV was introduced in the mid- 70’s and gained widespread acceptance in the material handling industry. As electronics and microprocessors advanced, so did AGVS. Today, there are more than 15 types of vehicles and 40 worldwide manufacturers. Unit Load AGV represents the single biggest segment of this market. Generally, these vehicles are designed to carry one load (totes, pallets, containers, etc.) on the vehicle deck. High Tonnage vehicles are designed to handle 10,000 to 100,000 pound loads. These vehicles have been used to transport heavy rolls of steel or paper and intermodal containers, [Material Handling, 1999].

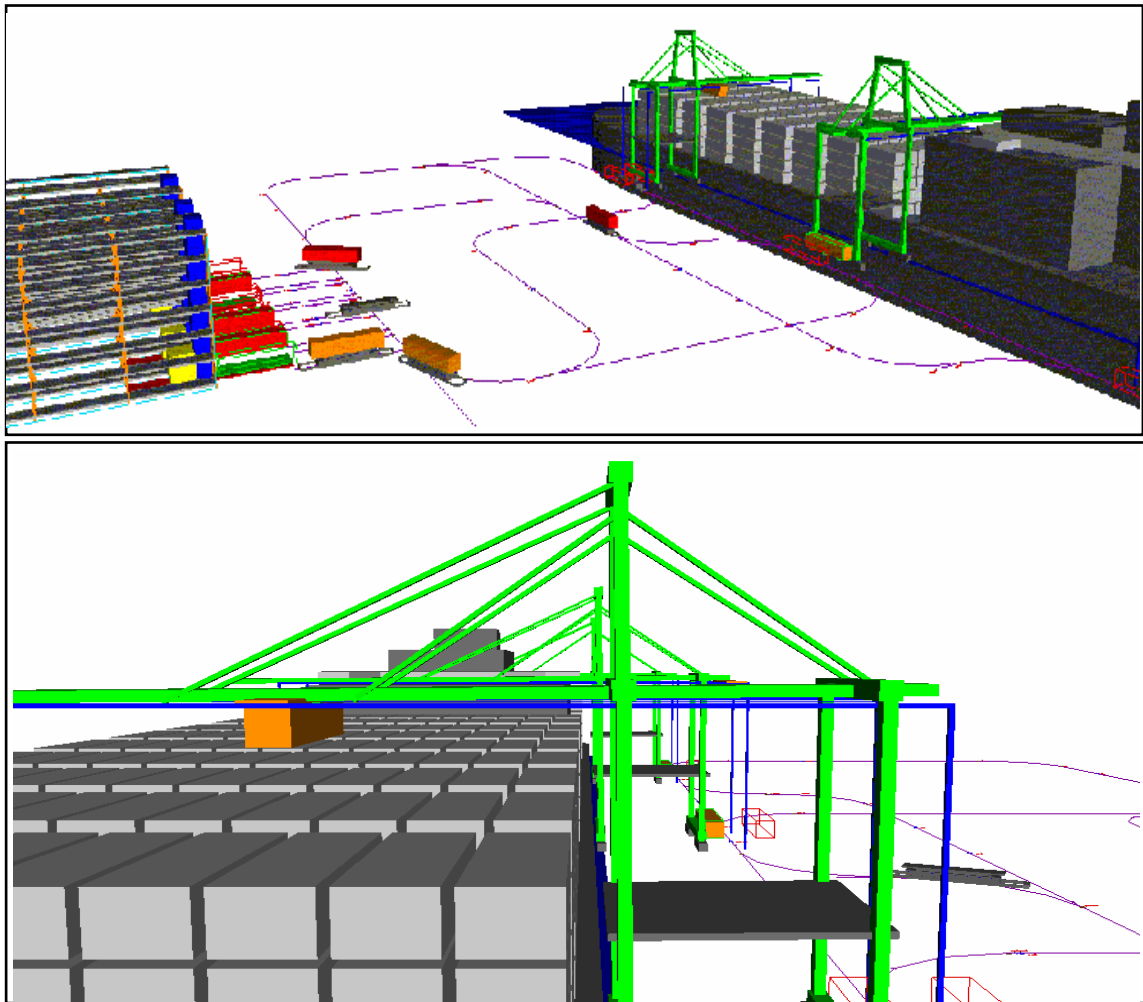


Figure 1. A view of the yard layout and the simulation model

4. The Simulation Model

In this section we present the simulation model of our concept design of a maritime terminal configuration system in which an integrated system of AS/RS and AGVS is implemented for the entire container handling process. We conceive a new AS/RS system which allows for random access of all of its cells.

AutoMod [Automod, 1996] was used to simulate the concept. View of the yard layout and the simulation model are shown in Figure 1 and 2.

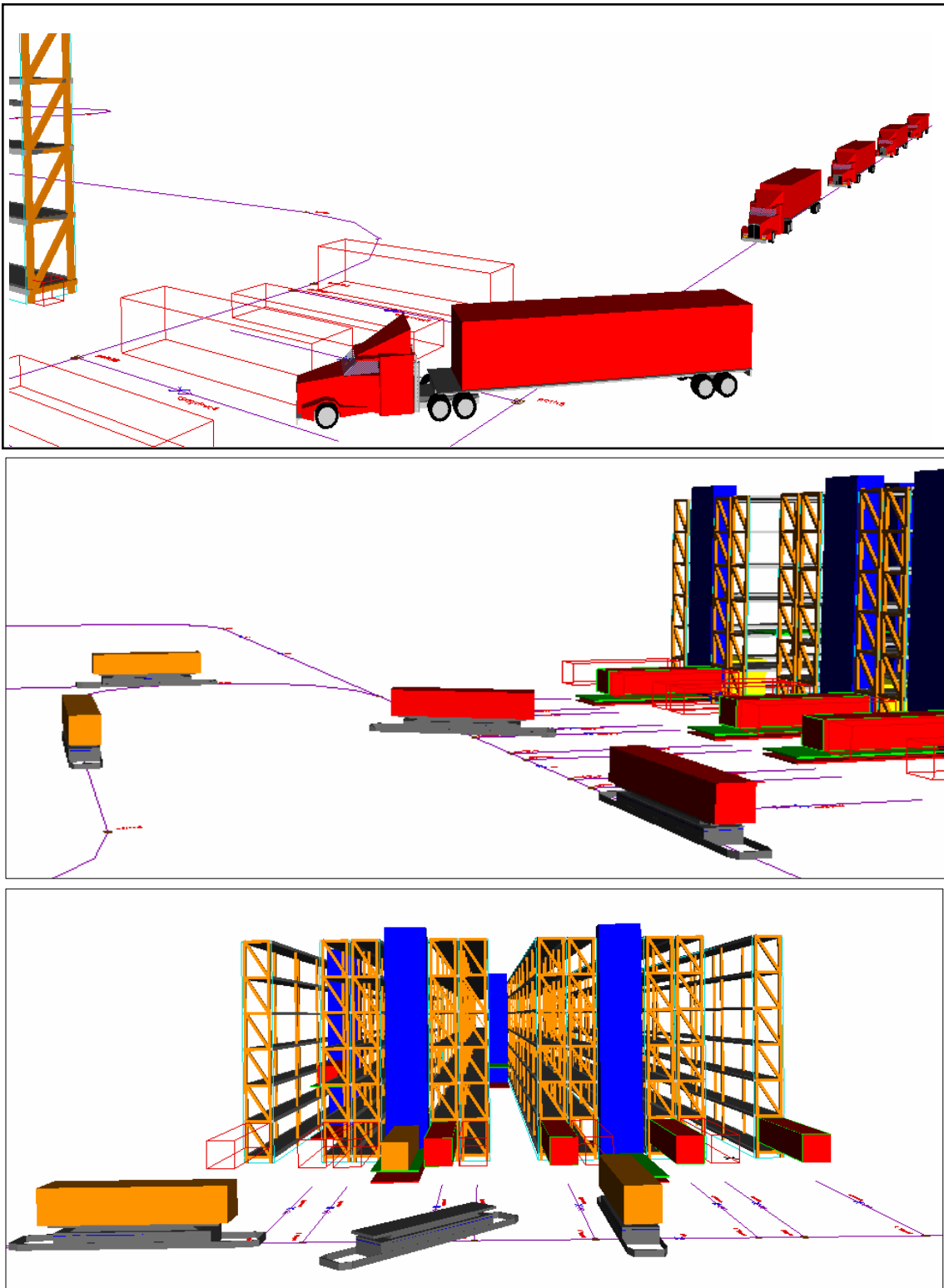


Figure 2. Views of the yard layout and the simulation model

5. Conclusion

We have conceived, designed, and analyzed an automated container handling and storage system for maritime terminals. We have demonstrated the impact of container terminal automation on the operations of container terminals using our computer simulation model. We have shown that the three key-variables of performance assessment, namely throughput, space utilization, and equipment utilization may be drastically improved by appropriately selected automation technologies for container handling and storage operations at maritime terminals. Our computer animation illustrates our proposed scenario with great clarity. Following is a summary of our results:

Space Utilization

Gross area assigned per ASRS module = 11000

FEUs stored per module = 240

FEUs stored per acre = 950

Throughput

SRM moves per hour per FEUs stored $(22.8/240) = .095$

SRM moves per hour per acre = $.083(950) = 90.25$

The measure of effectiveness for comparing the performance of ASRS with that of the current block stacking storage system is the number of moves per acre per hour. This measure, which is 24 for current practice and 90 for the proposed system, shows a ratio of 3.75 in favor of ASRS.

AGV Utilization

Horizontal round trips per hour per AGV $22.8/4 = 5.7$

That is 14% better than the current block layout system.

Ideally, a material handling system should provide the right amount of the right material, in the right condition, at the right place, at the right time, in the right position, in the right sequence, by the right method, and at the right cost. It seems that ASRS

dominates the present conventional block container layouts in all of these attributes except in the initial investment cost. Our future research will be aimed at optimal design of horizontal transportation network and site layout, as well as implementation of a JIT inventory control system.

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