THE USE OF COMPUTER SIMULATION FOR MARINE TERMINAL PLANNING

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ABSTRACT

Marine terminals are an important port activity for shipping lines, require the use of expensive cargo container handling equipment, and occupy limited and valuable property. Existing marine terminal operations are often remodeled to meet increased customer demands as well as to adapt to new technology. The high cost of marine terminal development justifies the use of computer simulation techniques to assist in planning.

A flexible over-model that represents the overall operations of a marine terminal and that also includes the effect of traffic interactions has been developed. This model has been tested and implemented for the proposed remodeling of several marine terminals for a major shipping company.

1. INTRODUCTION

A marine terminal is a port activity which contains one or more berths, a dock with container handling cranes, acreage devoted to storing cargo containers on chassis (wheels) or in stacks, and a set of gates for street access. A marine terminal supports both import and export shipping as well as the movement of empty cargo containers.

In general, containers arrive to a terminal by container vessel and by street trucks carrying containers from rail yards and distribution centers. The terminal yard is responsible for tracking and storing containers until they are loaded into a container vessel or retrieved by a street truck.

Modern marine terminals handle containerized freight almost exclusively; and methods for storing, movement, and retrieval are continually being developed. Terminals require costly container handling equipment, are expensive to operate, and occupy limited and valuable port property. They are typically operated by major shipping companies which may have many terminals in their overall network.

Most of the time, construction of a new marine terminal is not possible and expansion is limited, placing emphasis on operating a terminal as efficiently as possible. Modification of existing terminals may result in lengthy interruptions of service. These interruptions can result in intangible costs such as decreased productivity and customer dissatisfaction.

Marine terminal planners attempt to devise new operating scenarios to reduce costs and provide more service. In many cases, it is not known whether a particular strategy can produce increased terminal throughput. The use of computer simulation to assist planners in making decisions without interruptions to normal services and to avoid the risk of costly mistakes offers considerable benefit.

A model of the overall operations of a marine terminal, including the effect of traffic interactions, would be the ultimate goal of a simulation project. For almost a decade, simulation models have been used to study detailed terminal operations. This is the first time that an overall model of this magnitude has been attempted. This over-model should also be sufficiently flexible to adapt to a wide variety alternate operating schemes. Finally, the model should be constructed using commercially available general purpose simulation software and fit within a personal computer environment.

2. SIMULATION PROJECT BACKGROUND

The over-model is to be used by terminal planners to support major economic decisions. This requires that the model predict the outcome of proposed scenarios with relative accuracy. Execution of the simulation project in phases contributes to reaching the rather ambitious goals.

Phase I of the project consists of constructing detailed modules that accurately simulate the activities of a limited portion of a marine terminal with high precision. These modules represent the container processing activities in specific areas in order that detailed aspects of overall marine terminal operations can be modified and evaluated. These modules are complex and require large supporting data sets. These modules were kept separate in order to create an over-model that is manageable and informative.

To represent container processing activities, "abstract" models were developed that emulate the detailed modules. This approach made it possible to fit the over-model into the confines of personal computer architectures. It also allows for the data set for the over-model to be of a manageable size. Phase II of the project reduced the detailed modules to abstract versions which reflect the overall process times generated by the detailed modules.

Phase III of the project is the construction of the over-model. The over-model is the largest of all the models created for this project and it incorporates traffic control within the entire marine terminal with the abstract versions of various container processing activities. It tracks the arrival and departure of vehicles through their required transactions. The over-model maintains statistics relating to: (1) the overall utilization of terminal storage, (2) the rate of traffic between different areas of the terminal, and (3) the general productivities of each of the terminal activities.

The software package chosen for this project is the SIMAN discrete-event simulation language. This is a proprietary language developed by Systems Modeling Corporation and was chosen for its applicability to the specific problems of this project. Of particular interest, is the ability to run SIMAN/CINEMA under a variety of computer and operating systems without changing the program coding. Also, the high-resolution animation capabilities provided by CINEMA were of interest due to the large scale nature of a marine terminal.

3. DEFINITION OF THE MODEL SCOPE

The over-model must integrate most of the actual operations of a marine terminal with a traffic routing network. In addition, there can be hundreds of vehicles within the terminal at any time. Because of the potentially large size and complexity, the scope of the over-model had to be defined carefully in order to maintain a manageable modeling project.

In order to assist in the definition of the boundaries of the model, experts from a major shipping company in the area of marine terminal operations were extensively interviewed. Also, field observations at several marine terminals were made. This provided guidelines for the simulation project team as to which aspects of a marine terminal have impact upon the overall performance or how seemingly complex activities can be simplified.

In general, there are two types of container flows: streetside flows and dockside flows. The streetside flows are defined to be modeled as originating at an entrance gate and ending at an exit gate and are moved by street trucks. The dockside flows are defined to be starting and ending at a dockside crane and are executed by yard vehicles referred to as "house trucks".

The model integrates both of the general container flows with several abstract submodels for in-yard container handling. The over-model should be flexible enough to incorporate several or all of a selection of abstract submodels: (1) street access gates, (2) wheeled storage in chassis rows, (3) stacked storage accessed by top-pickers, (4) stacked storage accessed by rubber-tired gantry vehicles, and/or (5) stacked storage accessed by straddle-carriers.

The over-model is designed such that other typical in-yard activities within a terminal are also incorporated: (1) automated stacking cranes, (2) intermodal container transfer, (3) vertical chassis storage racks, (4) maintenance and repair, and (5) container freight station.

The traffic network that links the abstract submodels with vehicle movement must include routing information. The routing information must be provided to the model so a vehicle can move to and from any container processing position in the yard. Due to the large physical size of most marine terminals, the number of potential routes is significant. Also, from field visits it was observed that truck drivers may not necessarily take the same route to move between two points. For example, it was seen that a different route may be taken by a driver if there is some local traffic congestion.

The logic and the data required to implement multiple routes between two points was determined to be beyond the scope of the over-model. The model is flexible enough to handle multiple routing if it is found necessary to implement for more accurately representing critical intersections or for other reasons.

4. MARINE TERMINAL MEASURES OF PERFORMANCE

The over-model is designed to be utilized by the marine terminal planning staff of a major shipping company to evaluate proposed layouts and container handling strategies. To compare proposed alternatives for a given terminal, two primary measures of performance are defined: (1) Time required to complete a stevedoring sequence for a container vessel. This offers an indicator of dock productivity and ship turn-time in relation to the overall yard configuration. (2) The average turn time for street trucks. This provides a measure of streetside productivity and reflects the interaction between the entrance/exit gates and the overall yard layout.

Other measures of performance pertain to yard storage utilization, equipment utilization, and traffic network efficiency.

5. DATA REQUIRED FOR THE MODEL

The amount of data to define the various container yard activities and overall traffic routing is significant. The primary objective of the project is that the over-model be flexible to changes in layout as well as container handling strategies. The over-model can be modified to reflect any of these types of changes. The degree of effort and expertise required to make these changes is delineated by three different levels.

Level 1 items can be changed by engineering staff members without extensive training in simulation. Level 2 items can be modified by someone familiar with simulation. Level 3 items can be changed by someone experienced in simulation and with the over-model. The parameters that can be changed within each of these levels are:

Level 1: Small-scale operating parameters:

Processing times
Equipment productivities

Equipment capacities
Stevedoring sequence for a container vessel
Street truck arrival schedule

Level 2: Large-scale operating parameters:

Yard physical layout
Traffic flow rules

Level 3: Logical changes:

Change of abstract submodel mix within model
Modifications to terminal operating procedures

6. MODEL ARCHITECTURE

A vehicle moves through a container yard to perform a series of tasks. A task may be defined as a vehicle stopping at a container handling process such as a wheeled or stacked storage location, a gate access, or at a dockside crane. A task group is comprised of one or more container processing transactions.

Once a vehicle has completed a transaction, its current status within its task group is updated, and the next destination for the vehicle is discerned through the model logic. Task groups are completed when a street truck leaves the yard through an exit gate or a yard truck returns to a dock-side crane.

The task group provides essential information for moving a vehicle to various locations through a marine terminal. Its function is to provide the container processing sequence rather than specific yard destinations. The over-model contains logic which determines an appropriate yard location to perform a container transaction based on current yard conditions and attributes of the vehicle.

A marine terminal is mapped into a network of SIMAN stations. This network includes all dock, container processing, street access, and traffic routing stations. Each of these stations is linked together with physical distance information to provide accurate relative positioning within the layout. There are several categories of stations:

Creation stations are where task groups originate. Task groups are created at the entrance gate and at dockside cranes. Once a task group is created, it is assigned to either a street truck or a house truck. After assignment to a vehicle, the task group set of instructions is referenced, and a destination station is determined.

Processing stations are where container transactions occur with a vehicle. A transaction may entail paperwork, removal of a container from a vehicle, or others. These stations provide a link from the traffic submodel to the abstract submodels that represent actual yard activities.

Transit stations, which are the most numerous within a station mapping, are used by the traffic control logic within the model to negotiate a vehicle between container processing stations. For a vehicle to reach a destination, it has to pass through many transit stations. In the model, a vehicle is not provided with a complete route as soon as it knows its next processing destination. A route is determined in a series of steps. A vehicle determines its next station through accessing data tables encoded with routing information. The vehicle moves to that station and subsequently establishes its next station to reach its assigned destination.

Because a yard is arranged into a series of rows and stacks of containers, it is possible to move in different directions to reach a destination. To implement this situation, the routing tables contain directional as well as next station information.

In association with every station are traffic "zones". A zone corresponds to either a lane of a street or an intersection. The capacity of each zone is based on its representative physical size and the number of traffic lanes it represents. The number of units of a zone required by a vehicle can vary based on whether the vehicle is loaded, unloaded, or if it is a house truck. Before moving from one transit station to another, a vehicle must obtain possession of the appropriate number of

units of a zone.

7. OVER-MODEL VERIFICATION AND VALIDATION

The over-model coordinates the container processing and traffic routing of many vehicles concurrently, requiring careful testing of the model to be certain that the logic and data is accurate. An animation of the layout was constructed using CINEMA, which provides an efficient mechanism to assist in the verification process. The animation was particularly useful for isolating and analyzing traffic congestion situations that occurred.

After model verification, it was validated by comparing the output of the model with actual field collected measurements. The existing configuration of the marine terminal under study was entered into the model. A particular daytime work shift was chosen, with the stevedoring plan of an actual container vessel and street truck arrival rates were placed into the data set.

The measures of performance provided by the over-model were compared with actual field observations. To establish a valid simulation prediction, the analysis was replicated based on the variability of the results. The comparison indicated that the model accurately represented dockside activities while it was optimistic in predicting streetside activities.

Additional field visits were made by the simulation project team to determine reasons for this discrepancy. Several key observations were made in reference to differences in driver behavior for street trucks as opposed to house trucks. It was discovered that house trucks trucks were more maneuverable than the street trucks, and house truck drivers were more experienced and familiar with the yard. The over-model logic was refined to reflect these differences, and the validation procedure was repeated.

The second validation process produced results that represented the field observations. The project team could now proceed with confidence in the evaluation of alternate physical layouts and operational scenarios.

8. RESULTS OF THE SIMULATION PROJECT

The planning staff of a major shipping company provided alternate layouts of a marine terminal for analysis. The proposed layouts included rearranging wheeled storage rows with new traffic routing schemes, revising the locations of gates, and enhanced crane configurations.

A general finding from the simulation study indicates that rearranging the yard to achieve increased yard productivity and efficient traffic routing does not necessarily reduce ship turn time. This is evident when the enhancement of dockside crane configurations to reduce crane cycle times fails to reduce ship turn time. These results suggest that the productivity of the dock and the yard are linked, and the effect of increasing productivity of any isolated activity must also be examined upon overall terminal operations.

The simulation project aided in resolving a long running debate among the terminal planning staff. Through their experiences, many of the computer operators had developed an opinion that the unsymmetrical layout of a terminal contributes to traffic congestion and efficiency. A change in the layout geometry was studied using the model, and the results indicated that there was a negligible increase in terminal performance. This finding avoided the expense of several million dollars in improvement costs.

A valuable use of the simulation model arose when the terminal under study became damaged due to a major earthquake. Because of this unexpected disaster, the terminal required reconstruction to return it to a normal operating condition. The simulation model was used to evaluate revised layout configurations for the damaged portion of the yard.

Marine terminals serve as links within a global logistical network for shipping companies. There are a great number of external factors which may or may not justify the modification of a marine terminal. The over-model provides relative performance results for proposed changes allowing for predicted increases in performance to be evaluated against the effect on the network.

In conclusion, the over-model design is flexible enough such that it can be adapted to represent a wide range of terminal layouts and operating modes. Through this project, the model was tested by analyzing specific marine terminal planning questions for an existing terminal. An important result of this project is that a discrete-event computer simulation model using commercially available software can provide assistance in the terminal planning process.