Using Simulation to Evaluate and Improve the Operations of a Seaport Container Terminal

Gregory A. Harris, Lauren Jennings and Bernard J. Schroer
University of Alabama in Huntsville; Huntsville, AL 35899
harrisg@uah.edu

Dietmar P.F. Moeller
University of Hamburg; Hamburg, Germany

ABSTRACT

This paper presents the use of simulation in evaluating the operations of the Mobile Container Terminal at Choctaw Point that is under construction at the Alabama State Docks in Mobile, Alabama. The purpose of the project is to establish a working model of the container operations to provide decision information for the management team at the new container facility. Included in this paper are a description of the conceptual framework of the model and an analysis of the simulation results.

INTRODUCTION

The Port of Mobile is a strategic link in the transportation infrastructure of Alabama and the south central region of the United States. The Alabama State Port Authority is currently enhancing container and intermodal operations at the Alabama State Docks in Mobile, Alabama through the construction of a new container terminal. The container facility will encompass 57 acres and will accommodate container ships, trucks ands trains that will deliver and pick-up containers from the terminal and from the warehousing and value-added areas (Moffatt & Nichol, 2002). Containers at the Alabama State Docks are currently managed through the Bulk Shipping operations and do not perform at the desired level of efficiency. In the last fiscal year, the Alabama State Docks processed approximately 60,000 TEU's (Twenty Foot Equivalent Units, a container). The new Mobile Container Terminal (MCT) will be capable of handling 250,000 to 300,000 TEU's annually. The Port of Mobile is in position to become a major player in the container freight business in addition to being a major port for bulk materials, but the port must overcome cost and delivery obstacles to succeed. This success, though, will result in an

Preprint submitted to 2nd Annual National Urban Freight Conference.
Received June 22, 2007.

issue of how to move freight out of the Mobile area in such a way as to not cause traffic congestion that eventually impedes economic growth (Jennings, 2006; UAH, 2005).

Figure 1. Artist Rendering of the MCT

The state docks are very interested in validating the design capacities of the container terminal and evaluating the potential of the MCT. Of special interest are the utilization of the resources and the container throughput. The purpose of this project is to establish a working model of the container operations to provide decision information for the management team at the new container facility.

SIMULATION MODEL

Figure 2 is the conceptual framework of the container terminal model. The model is constructed using five sub-models:

- Ship unloading and loading of containers
- Train unloading and loading of containers
- Truck unloading and loading of containers
- Movement of containers from ship dock to container yard
- Movement of containers from container yard to ship dock.

Preprint submitted to 2nd Annual National Urban Freight Conference.
Received June 22, 2007.

These sub-models run independently of one another, each with a different entity. Data are passed between the submodels by a number of global variables. In addition, a number of attributes are assigned to the entities. These variables and attributes control entity movement, branching and activity operations.

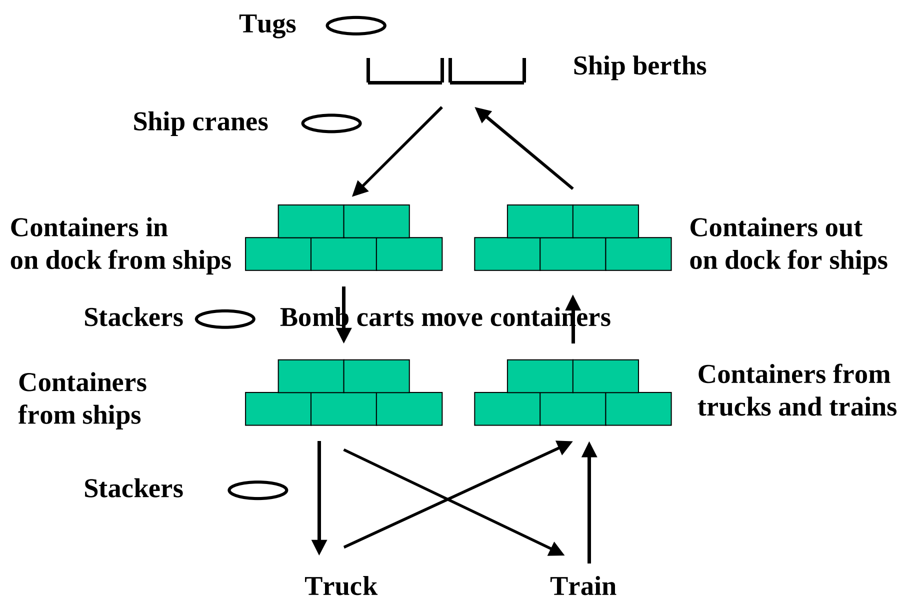

Figure 2. Conceptual framework for container terminal model

The terminal model has two container storage locations. One location is the inventory of containers delivered by ships that are to be loaded onto trains and trucks. The second location is the inventory of containers delivered by trains and trucks that are to be loaded onto ships. Entities in the model are ships, trains arriving full and empty and trucks arriving full and empty. Model resources are tugs, ship berths, ship cranes, bomb carts and stackers.

VERIFICATION AND VALIDATION

Model verification is determining if the model is correctly represented in the simulation code. Model validation is determining if the model is an accurate representation of the real world system. ProcessModel has a “Label” block that displays data generated by the global variables during the simulation (ProcessModel, 1999). By slowing the simulation down it is possible to observe these values as the entities move through the simulation. The model ran for 1,440 hours, or sixty days. As part of the model verification, the containers unloaded from ships (10,000) minus the containers loaded onto trains and trucks (6,000+1,440) minus the containers on dock unloaded from ships (0) equals the containers in yard from ships (2,560). Likewise, the containers unloaded from trains and trucks (3,000+720) minus the containers loaded onto ships (720) minus the containers on the dock waiting to be loaded onto ships (3000) equals the containers in yard from trains and trucks (0). Model validation was not possible since the Mobile Container Terminal is under construction. However, it was possible to use data from the existing container operations for the service times and to visually observe the operations of the terminal during the simulation.

BASELINE RUN

The baseline simulation run consisted of the following inputs:

- Time between arrivals: 3 days for ships, 2 days for trains and 2 hours for trucks
- Time between arrivals: 2 days for empty trains, 2 hours for empty trucks
- Arrival capacity: ship 500 containers, train 100 containers and truck 1 container
- Departing capacity ship 150 containers, train 100 containers and truck 1 container
- 20 minutes for tug to position or remove ship at berth
- 2 minutes for crane or stacker to unload or load a container from ship, train or truck
- 2 minutes for stacker to load or unload container at ship dock or container yard
- 5 minutes for bomb cart to move container from ship dock to container yard or from container yard to ship dock
- 2 ship berths
- 2 tugs
- 2 ship cranes
- 10 slots for trucks to load and unload
- 2 slots for trains to load and unload at a time
- 10 carts for loading and moving containers simultaneously from dock to container yard
- 10 carts for loading and moving containers simultaneously from container yard to dock
- 8 stackers shared for unloading and loading bomb carts, trains and trucks

At initiation, the simulation started empty and idle with no ships, trains or trucks at the terminal, and the container yard was empty. The baseline model ran for 60 days or 1,440 hours. The baseline simulation results are shown in Table 1.

Table 1. – Results of Baseline Model Run

Utilization of Resources	
Tugs (2)	1%
Ship berths (2)	23%
Ship cranes (2)	22%
Bomb carts (20)	8%
Stackers (8)	14%
Ships through terminal	20
Trains through terminal	60
Trucks through terminal	1,440
Average time through the terminal	
Ship	2,088 minutes
Train	482 minutes
Truck	29 minutes
Average time through the terminal (value added time only)	
Ship	1,347 minutes
Train	308 minutes
Truck	13 minutes
Containers in from:	
Ship	10,000
Train	3,000
Truck	720
Containers out on:	
Ship	3,000
Train	6,000
Truck	1,440
Containers in yard:	
From ship	2,560
From train/truck	0
Containers on dock:	
In from ship	0
Out on ship	720

EXPERIMENT DESIGN

The purpose behind the experiment design is to evaluate the interrelationships that the time between arrivals of ships, full trains and empty trains have with the throughput of containers and the time each entity spends in the terminal facility. The experiment design is shown in Table 2.

Preprint submitted to 2nd Annual National Urban Freight Conference.
Received June 22, 2007.

The independent variables for the experiment were the Time Between Arrivals for Ships, Full Trains and Empty trains. The time between arrivals for Full Trucks and Empty Trucks were left unchanged at two hours. All other data remained the same as the baseline.

Table 2. Experimental Design - Time Between Arrivals

	Run1	Run2	Run3	Run4	Run5	Run6	Run7	Run8	Run9	Run10
Ship	3 days	2 days	1 day	2 days	2 days	2 days	1 day	1 day	1 day	12 hrs
Full Train	2 days	2 days	2 days	1 day	1 day	12 hrs	1 day	12 hrs	6 hrs	3 hrs
Empty Train	2 days	2 days	2 days	2 days	1 day	12 hrs	1 day	12 hrs	6 hrs	3 hrs

ANALYSIS

Table 3 presents the container activity for each run. As expected, there is a building of containers in and out as the time between arrivals for ships and trains are decreased in the experiment. Interestingly, Runs 6, 9 and 10 result in similar results for containers in the yard from ships (low) but higher containers in the yard from trucks and trains. These relationships should be the subject of further investigation.

Table 3. Container Activity for Model Runs

	Run1	Run2	Run3	Run4	Run5	Run6	Run7	Run8	Run9	Run10
In from:										
Ship	10,000	13,000	13,000	15,000	15,000	15,000	23,000	29,972	29,973	44,090
Train	3,000	3,000	3,000	6,000	6,000	12,000	6000	12,000	24,000	24,000
Truck	720	720	720	720	720	720	720	720	720	720
Total	13,720	16,720	16,720	21,720	21,720	27,720	29,720	42,692	54,693	68,810
Out on:										
Ship	3000	3600	3600	4500	4500	4500	6600	8850	8850	13,200
Train	6000	6000	6000	9000	12000	13500	12,000	24,000	28,500	42,600
Truck	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440
Total	10440	11040	11040	14,940	17,940	19,440	20,040	34,290	38,790	57,240
In Yard:										
From Ship	2560	5560	5560	4560	1560	60	9560	4529	29	45
From Train/ Truck	0	0	0	0	0	0	0	0	0	0
On Dock:										
From Ship	0	0	0	0	0	0	0	0	0	0
From Train/ Truck	720	120	120	2220	2220	8220	120	3870	15,870	11,520

Preprint submitted to 2nd Annual National Urban Freight Conference.
Received June 22, 2007.

Table 4 gives the entities that move through the terminal along with the average times the entities spent at the terminal. Note the large wait time for Runs 6 and 9. Additional investigation is warranted to determine what aspects of the relationships between the time between arrival settings for those runs and the unusual wait time documented in the model results for those particular runs.

Table 4. Entity Throughput and Average Times at Terminal

Run	Ships Thru	Ship Time (min)	Trains Thru	Train Time (min)
1	20	2088	60	482
2	24	9864	60	482
3	24	26,424	60	482
4	30	2013	90	529
5	30	2013	120	480
6	30	2012	135	18,943
7	44	12,404	120	476
8	59	2012	240	477
9	59	2012	284	18,113
10	87	12,999	424	5496

Table 5 presents the average time for ships and trains in the terminal for model runs 4, 5 and 8. The table also presents the quantity of containers processed for each run and the extrapolated annual container throughput for those three runs. The model settings for run 8 obviously provide better container throughput by almost double the other two runs. Some explanation could be that the quantity of containers per ship are best served by two trains during the same time period. This is another aspect of the port operations that warrants additional investigation.

Table 5. Summary Results for Selected Model Runs and Annual Throughput

Run	Average Time		Containers		Annual Container Throughput	
	Ships	Trains	In	Out	Containers in	Containers out
Run4	2013	529	21,720	14,940	130,320	89,640
Run5	2013	480	21,720	17,940	130,320	107,640
Run8	2012	477	42,692	34,290	256,152	205,740

Table 6 presents the utilizations of the resources associated with ship activities in the model. A utilization rate of 98% and 99%, as seen in Runs 3, 7 and 10 for Ship Berths indicates that there is inefficiency in the system and that ships are sitting at the dock for significant amounts of time without activity. This is an area of significant interest to the port operations management team and deserves additional investigation.

Table 6. Resource Utilizations for Model Runs (%)

	Run1	Run2	Run3	Run4	Run5	Run6	Run7	Run8	Run9	Run10
Ship berths (2)	23	93	99	34	34	33	98	67	67	99
Ship cranes (2)	22	28	28	33	33	33	51	67	67	99
Tugs (2)	1	1	1	1	1	1	1	1	1	2
Carts (20)	8	10	10	13	13	17	18	27	34	44
Stackers (8)	14	15	15	21	22	29	27	42	56	71

Decreasing the time between arrivals for ships from three days (Run1) to one day (Run3) had only a minimal increase on container activity. However, the time in the terminal for ships greatly increased from 2,088 minutes for Run1 to 26,424 minutes for Run3. The utilization of the ship berths increased to 99%. When the time between arrivals for ships is left fixed at two days and the time between arrivals for trains is decreased (Runs4-6) a large increase in the time in the terminal for trains results, from 529 minutes for Run4 to 18,943 minutes for Run6

Leaving the time between arrivals fixed for ships at one day (Runs7-9) and decreasing the time between arrivals for trains lead to a significant increase in the time in the terminal for ships in Run7 to 12,404 minutes and for trains in Run9 to 18,113 minutes. Time in the terminal increased greatly when the time between arrivals in Run10 was reduced to 12 hours for ships and 3 hours for trains, the time in the terminal increased to 12,999 for ships and 5496 for trains. The utilization of the ship berths increased to 99%.

The average times that entities were in the terminal were relatively low for Runs 1, 4, 5 and 8 (See Table 4). The corresponding inventories at the terminal were also relatively low (See Table 3).

Cycle times were similar to the value added times, indicating minimal delays waiting on resources, activities or containers. For example, in Run8:

- Ship time in terminal 2,012 minutes
- Ship value added time 1,347 minutes
- Train time in terminal 477 minutes
- Train value added time 308 minutes
- Truck time in terminal 29 minutes
- Truck value added time 13 minutes

In Run8, the resource utilizations were 67% for ship berths and ship cranes, 27% for carts and 42% for stackers. The utilizations of the carts and stackers were relatively low, indicating that there may be an excess of these resources. Several additional runs should be made with fewer of these resources to understand the true relationships.

CONCLUSIONS

In summary, the model provides the needed insights for relationships that the management of the port desired. The model is very sensitive to the time between arrivals of ships, trains and truck. Due to the assumption that containers arriving on ships leave on trains and trucks and containers arriving on trains and trucks leave on ships, there is considerable dependency between entities. Simply reducing the time between arrivals of entities does not necessarily increase container activity. For example, decreasing the time between arrivals of ships requires an adequate arrival of containers from trains and trucks so ships can be loaded and exit the terminal.

Runs 4, 5 and 8 appear to provide lower times in the terminal for entities and also increased container throughput. There are possible other scenarios that may result in lower times and greater container activity.

Run 8 had an estimated annual unloading of 256,152 containers and an annual loading of 205,740 containers. Over 50,000 containers were in the container yard or on the dock waiting to be loaded. This scenario, along with some others with similar outcomes should be investigated further. The large number of containers in the terminal at the end of the simulation indicates that the system may not have achieved a stable state. This implies that the containers in the terminal will continue to increase over time. Additional research into the interrelationships of model entities and model resources is warranted. Refinements to the model can be made in the application of statistical distributions to the model variables.

ACKNOWLEDGEMENTS

This research was sponsored by the U.S. Department of Transportation, Federal Transit Administration, Project No. AL-26-7262-00.

REFERENCES

MOFFAT & NICHOLS, (2002) Development Master Plan (Choctaw Point Terminal), Moffatt & Nichol Engineers, Mobile, AL.

JENNINGS, L. (2006) The Effects of Globalization on Freight Transportation, *Proceedings of the 2006 Industrial Engineering Research Conference*, Orlando, FL. June 2006.

PROCESSMODEL, (1999) Users Manual, ProcessModel Corp., Provo, UT.

UAH, (2005) Office for Economic Development, Transportation Infrastructure In Alabama - Meeting the Needs for Economic Growth, *Final Report on the Requirements for Infrastructure and Transportation to Support the Transformation of the Alabama Economy*. Prepared for the Office of the Secretary, U.S. Department of Transportation, Grant No. DTTS59-03-G-00008.

AUTHOR BIOGRAPHIES

Gregory A. Harris is Director of the Office for Freight, Logistics & Transportation and the Alabama Technology Network Center and is Deputy Director of the Office for Economic Development at the University of Alabama in Huntsville (UAH). Harris has a Ph.D. in Industrial and Systems Engineering from UAH and is a registered Professional Engineer.

Lauren Jennings is a Research Analyst in the Office for Freight, Logistics & Transportation at UAH. Jennings has a BS in Marketing from Auburn University and a Master of Science in Management of Technology from UAH.

Bernard J. Schroer is a Principal Research Engineer at UAH. He is a Fellow of the IIE, a Fellow of the SME and a member of the SCS. He has a Ph.D. in Industrial Engineering from Oklahoma State University and is a registered Professional Engineer.

Dietmar P.F. Moeller is Professor of Computer Science and Computer Engineering at the Mathematics, Computer Science and Science Faculty of the University of Hamburg, Germany. His is also Chair of Computer Engineering.