Application of Agent-Based Approaches to Enhance Container Terminal Operations

by

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Abstract

The globalization of trade and subsequent growth of containerization for transporting goods in containers have brought many challenges for container terminals. Increasing demand, capacity constraints, lack of adequate decision making tools, congestion and environmental concerns are some of the major issues faced by the container terminals today. Such terminals involve various processes in their operations and effective decision making is imperative in each process to manage scarce resources and improve the terminals’ competitiveness. This dissertation proposal consists of research works addressing three critical operational decision problems in marine terminal involving application of agent-based modeling. The studies address 1) truck queuing problem at terminal gates, 2) inter-block yard crane scheduling problem and 3) the storage allocation problem. These problems share common objectives such as minimizing turn time of drayage trucks, reducing congestion and emission, and enhancing productivity of the terminals.

Queuing at marine terminal gates has long been identified as a source of emissions and high drayage costs due to the large number of trucks idling. The first study in this dissertation addresses queuing of trucks at marine terminal gates and presents a novel agent-based framework where the drayage companies can minimize congestion by using the provided real-time gate queuing information. The
problem was tackled based on the approach of El Farol Bar problem from game theory. Our proposed model can be used as a means of managing demand for the marine terminals, assuming that drayage firms will adjust their plans based on the real-time feedback of congestion. Results from our extensive experiments suggest that the proposed multi-agent framework can produce more steady truck arrivals at terminal gates and therefore significantly less average waiting time.

To facilitate vessel operations, an efficient work schedule for the yard cranes is necessary given varying work volumes among yard blocks with different planning periods. This second study investigated an agent-based approach to assign and relocate yard cranes among yard blocks based on the forecasted work volumes. The objective of this study is to reduce the work volume that remains incomplete at the end of a planning period. Several preference functions are offered for yard cranes and blocks which are modeled as agents. These preference functions are designed to find effective schedules for yard cranes. In addition, various rules for the initial assignment of yard cranes to blocks are examined. The analysis demonstrated that the model can effectively and efficiently reduce the percentage of incomplete work volume for any real-world sized problem.

The storage space allocation problem (SSAP) is the assignment of arriving containers to yard blocks in a container terminal. The third study presents a novel approach for solving SSAP. The container terminal is modeled as a network of gates, yard blocks and berths on which export and import containers are considered as bi-directional traffic. Utilizing an ant-based control method the model determines the route for each individual container based on two competing objectives: 1) balance the workload among yard blocks, and 2) minimize the distance traveled by internal trucks between yard blocks and berths. The model exploits the trail laying behavior of ant colonies where ants deposit pheromones as a function of traveled distance and congestion at the blocks. The route of a container (i.e. selection of a yard block) is based on the pheromone distribution on the network. The results from experiments show that the proposed approach is effective in balancing the workload among yard blocks and reducing the distance traveled by internal transport vehicles during vessel loading and unloading operations.