Improved Inter Terminal Transportation using Agent Technology

Lawrence Henesey[1]

[1]Blekinge Tekniska Högskola, Blekinge Institute of Technology, Karlshamn, Sweden lhe@bth.se

Abstract

Many maritime logistics centres worldwide are experiencing large number of inter-terminal transportation volumes, which raises the complexity of transportation processes between the terminals. Different vehicle systems exist for transporting containers between different terminals, however they often are inefficient due to poor planning or scheduling. We present a solution for dynamic planning of resources by using an agent based simulation tool. The results showed improved resource planning and utilization of different resources in the network of terminals. A cost comparison of different vehicles systems is further analysed in order to identify the best choice of vehicle system for a given scenario.

Keywords

Inter-terminal transportation, Container terminals, Automated guided vehicle, Agent based simulation.

1 INTRODUCTION

Maritime logistics centres, such as large ports, often consist of a number of container terminals (CTs). We investigated different road transport modalities for container transportation between the terminals of Massvlakte area of port of Rotterdam. The Inter-Terminal Transportation (ITT) volume and other processes of transportation have changed since the recent extension of Massvlakte, e.g., Massvlakte II (MV2) will increase ITT volume nearly 5 million TUE/year.

The aim of our work is to provide decision support to ITT planners, who are responsible for scheduling and planning resources in handling containers by providing alternatives on choice of resources employed. In ITT various equipment is used (vehicles, cranes) for improved planning and estimation of ITT, using present truck and MTS systems, and automated vehicle system, which includes automated guided vehicles (AGVs). For this purpose, an agent based simulation model of the ITT system at the Maasvlakte has been designed and developed. According to [1] processes of ITT can be summarized in the following.

- Punctual (neither too early nor late) pickup of containers from source
- Punctual delivery of containers at destination
- Possible bridging of discrepancies in both these tasks by providing buffer areas

According to our best knowledge, limited research has been conducted that focuses on ITT. We found most studies focused on the movement of containers inside container terminals; called intra terminal transportation. On the other hand, none of the studies used multi agents to solve ITT problems except Albert Douma but he only considers barge handling problems in his studies [2-5] This research space provides us an opportunity to propose an agent based solution for ITT planning, and evaluate it by comparing different transportation vehicles.

2 REVIEW OF LITERATURE

An extensive review of literature for container transportation and classification of research published between 2007 and 2014 was conducted. According to Drewry, a maritime research organization, [6] over 90% of the world's general cargo is handled through containers. The main modalities between CTs are road, rail, short-sea, deep-sea, and inland waterway [7]. The importance of improving container terminal (CT) operations and demands for transporting cargo in containers are increasing in parallel. The CTs must be able to effectively and efficiently act as an integral part of transport chain from origin to destination [8].

A comprehensive literature review on terminal operations and their classification was presented by Dirk Steenken et. al. [9] and was further updated in [10]. It has been observed that most research mainly focused on specific part(s) of the terminal system. For instance yard cranes using mathematical modelling (11], yard operations [12], train load planning problem in terminals [13] and berth scheduling [14] are some examples of this type of research. On other hand, the use of simulation is very popular among researchers when previous data is unavailable or when they have to communicate to non-technical staff. In [1], [7] [15], [16], [17], [18] [19], [20], and [21] simulation is adopted to evaluate the container terminals at an aggregate level. Many studies concerning container terminals focus on CT transport using an agent based approach, for example [22], [16], [18] and [8]. Researchers also have used agent based modelling to model different type of transportation modes. For example, Automated Guided Vehicles (AGVs) and Rubber Tired Gantry (RTGs) are modelled as agents to evaluate their performance in a CT by Hoshino et al [23]. Agent based simulation in which a number of actors are involved in the CT are simulated with set of design theory by Henesey et al in ([24].

In artificial intelligence research, use of distributed control mechanism has increased since the introduction of multi-agent systems. Multi-agent systems serve as platform for distributed planning or distributed control. Multi-agent systems allow us to split a complex problem into multiple sub-problems to simplify the problems and achieve the overall goal. Multi-agent based applications can be found in different fields such as logistics, economics and computer science [2]. Furthermore the efficient management of a container terminal using multi-agent model seems to be an adequate framework for dealing with the design and development of an application [25]. Furthermore the efficiency of CT operations can be improved by considering multi-agent model in a seaport ([26], [20]). Both Albert Douma and Henesey et al. have modelled barge handling problem and overall terminal operations using multi agents respectively [2], [3], [22] and [27].

Multi-terminal environment introduced movement of containers between terminals of the same container port. It introduces new challenges for container transportation planners and researchers. According to our best knowledge, not many researches focused on ITT till 2006. However, after 2006 we can find some studies focusing this area of transportation. Very first study focusing on ITT is published in 1996 [20] in which simulation concepts were introduced. These concepts were further updated in [7]. In later work, simulation of multi-terminal container port, considering port of Rotterdam, was presented by the same research group [7]. A comparison of three transport systems of ITT, including AGVs, Automated Lifting Vehicle (ALV), and MTS, was then published in the same year considering same area of port of Rotterdam as a case [28]. Albert Douma presented his PhD. thesis considering one part of ITT, i.e. barge, in 2008 and introduced new concepts for barge handling problem and used multi agents to model this problem [2]. Other publications, in following years, by Douma et al. [3-5] were also used multi agents focusing on the barge-handling problem at port of Rotterdam. In 2013, Sterzikn, and Kopfer [29] presented a tabu search based heuristic algorithm for inland container transportation focusing on vehicle routing, scheduling, and optimization of number of vehicles. Most recent study focusing on ITT was presented in 2014 by [30]. It presents a mathematical model for analysing inter-terminal transportation. The focus was to minimize container delivery delay considering key components of ITT, including traffic congestion, multiple vehicle types and loading/unloading times, and arbitrary terminal configurations.

Most of the work published on the ITT domain is written by two research groups, that includes both Ottjes et al. [7] and [20] and Douma et al. [2-5] Both research groups considered port of Rotterdam as a case. However, latest work presented by Ottjes et al., [7] published in 2007, which requires to be updated because of recent changes in port of Rotterdam, while work published by [2-5] focused only on barge handling problem at the same container port. Among these studies research presented by [7] is most relevant to our work. However, this paper differs as we are aiming to apply multi agents to model ITT considering different vehicles system. Our work also differs from research published by Tierney et al. [30] as they use mathematical modelling to address different ITT problems and focus more on a strategic time horizon as we focus more on operational time span, i.e. real-time.

3 AGENT TECHNOLOGY

Agent technology has gained a lot of interest by variety of disciplines in computer science since its introduction. According to Wooldridge and Jennings [31], an agent is usually defined as a hardware or software based object with key properties, autonomy, social ability, reactivity, and pro-activeness. Autonomous behaviour of an agent identifies that an agent can operate without direct external intervention. Social ability ensures that an agent can interact with other agents or actors of its environment. It also perceives the information from the environment and reactive property ensures its response to the environment. Its ability of pro-activeness makes it able to take initiatives and exhibit a goal-oriented behaviour. MAS can be defined as a loosely coupled network of actors working together to solve problem or a combination of problems that are beyond the individual capabilities or [32]). Additionally, literature also endorses our point as number of researchers have applied agent technology in transhipment of containers like [2-5], [22], [24], [16], [33] and [34].

To define the agents we follow the suggestions given in [35] and decompose our problem to ensure that agents represent entities in the physical world. We have identified two types of actors involved in ITT operations; container terminal, and transportation vehicles. Transportation vehicles include barge, train, and road vehicle. Road vehicles have three different types of vehicles including truck, AGV, and MTS. Therefore; six (Terminal agent, Barge agent, Truck agent, AGV agent, MTS agent, and Train agent) different agents have been defined in our ITT system. All agents are categorized into two different categories including, terminal agents and transport agents according to their behaviour. All transport agents communicate with terminal agents by messages passing and event triggering. All agents of the system will have a certain degree of opportunistic behaviour so that they collaborate without hurting each other to get the main goal of the system. Following is the description of all the agents identified in the system.

A terminal agent represents the container terminal of physical world. We only consider those operations that are relevant to ITT. The terminal agent can communicate with all transport agents to accomplish different sub-goals.

Transport Agents under this category are mapping of physical vehicles that are being used for transportation in this ITT model. These vehicles include road vehicles (Truck, AGV, and MTS), trains, and water vehicles (barge). All transport agents can communicate with the terminal agents. They also negotiate with terminal agent for getting orders for transhipment

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Although we have used barges and trains on our ITT model, we mainly focus on three types of road vehicles during evaluation of our ITT model.

1. Truck: It is a non-automated vehicles used for container transportation with maximum capacity of 2 TEU (Twenty foot Equivalent Unit; box).
2. MTS: A single vehicle that is manned by one driver pulling a number of trailers (with a capacity of 10 TEU), called a multi transport system (MTS).
3. AGV: It is an automated system of vehicle used for container transportation. We consider double stacking AGVs shown with capacity of 4 TEU.

4 SIMULATION METHOD

According to our best knowledge there are three ways to develop a simulation model; code each and every thing by your own, use development toolkit, and use a full simulation tool. In [36] they believe that using Agent Based Simulation (ABS) software for agent simulation modelling is better than using toolkits, due to availability of complete modelling functionalities, professional technical support, user-friendly interfaces, and simplified modelling process in simulation software packages. There are number of free, educational, and/or commercial simulation tools available to facilitate ABS modelling.

We identified a simulation tool called Netlogo that was been used on container terminal problems [37]. In parallel we conducted thin review of some other simulation software packages and selected Anylogic. Both NetLogo and AnyLogic were then compared and analysed to select best suitable tool for our simulation model. In short summery of this comparison in given in Table 1.

NetLogo. NetLogo [37] is a multi-agent programmable modelling environment developed by the Centre for Connected Learning & Computer-Based Modelling at the Northwestern University. It is an improved version of StarLogo [37], which was developed by media lab at Massachusetts Institute of Technology (MIT).

AnyLogic. AnyLogic (“AnyLogic,” 2014) is a simulation package developed by XJ Technologies Company. It is based on the Eclipse framework, and ensures cross-platform development environment. Programming environment is purely Java oriented in this software package.

	AnyLogic	NetLogo
Programming Language	Java	Scripting
Programming Paradigm	Object Oriented	Procedural
3D animation	Yes	Yes
Drag and Drop Components	Yes	NO
Data Analysis	Yes (Powerful)	Yes (Limited)
Data Import/ Export	Easy and several methods	Limited (Text Files Only)
Model Export	Java Applet	Java Applet
Developer Guide	Yes	Yes
Help	Limited Training videos, Paid training sessions	Big online Social media Community

Table 1. Comparison of AnyLogic and NetLogo

Table 1 shows that AnyLogic provides Java based Object Oriented programming (OOP) environment opposing NetLogo, which has procedural scripting environment. Having a good background knowledge and experience with Java technologies, and to avoid putting time on learning NetLogo scripting, we chose AnyLogic 6.9 to implement our ABS model. Furthermore, easy data import and export feature was also convincing factor to choose AnyLogic, as we had to import multiple data sets for different scenarios.

4.1 Simulation Method

The simulation model is currently, considering 10 terminals of MV area in this case study. We believe the simulation model is flexible enough and can be used with data of any network consisting several terminals.

We set number of input parameters before running simulations. In addition to loading respective datasets, input parameters determine resources of container terminals, number of vehicles being used to handle container flow, and capabilities of vehicles. Following we explain three types of parameters shown in input form.

1. Operational Hours. We use three sets (8, 16, and 24 hours) of operational hours in our experiments.
2. Save Results and Enable Validation. These parameters are Boolean (true/false) type of variables. Enable validation is used obtain data on console that is further used for validation and verification. Parameter 'save results' used to save the simulation results in the excel sheet attached with the simulation model.
3. Scenario Selection. Volume distribution changes with respect to selected scenario. This parameter helps the model to use the relevant datasets during simulation experiment. It is important to note that as distances between the terminals do not vary on the basis of selected scenario, so the same datasets for distances are always loaded into simulation for every selected scenario.

Terminal parameters are used to setup capabilities of terminals in terms of tree types of crane resources and service times to handle containers against three transport modalities. All terminals are equipped with gate resources; barges can be served on all terminals except 1, and 7 terminals are capable to handle trains except 3. Following, we define three types of resource capabilities.

1. Gate Capabilities. Includes two parameters; 'Number of vehicles served in parallel', and 'Service time per container'. Prior concerns gate points at terminal which means how many gate cranes are available at terminal to server road vehicles while later defines loading/unloading service time for a container. As all terminals have gate points, these parameters will always be set to ensure the availability of gate resources.

2. Barge Capabilities. Similar to gate resources, barge-handling resources are set by same type of parameters. All terminals serve barges except one terminal, VDCD.

3. Train Handling Capabilities. Trains often leave the container bogies at terminals, those can be unloaded/loaded afterwards in relax hours, and ties themselves with other containers bogies. Therefore, we have change over time for the trains at each terminal that has train terminal. On the other hand "number of trains served" refers to number of trains that can be facilitated for change over at the same time. Three container terminals in MV area, including KDD, VDCD, and DCS, do not train terminals and are connected through train lines.

Three main scenarios that are based on ITT volume varying from 2.1 million to 4.9 million TEU per year are identified. Distribution of volume was obtained from interviews with experts. Simulation time interval is 1 week for scenarios and sub scenarios.

A fix number of barges and trains in the ITT network are simulated. A variable number of road vehicles are employed (AGV, Truck, MTS), presented in Table 2. Only one type of road vehicle can be used in a simulation run. Vehicle settings are presented in Table 3.

Vehicles	Maximum Capacity (TEU)	Average Speed (m/s)	# of Vehicles
AGV	4 (Double Stacking)	6	Variable
MTS	10	6	Variable
Truck	2	6	Variable
Train	70	20	6
Barge	50	3	6

Table 2 Vehicle Setting

Another variable, operations hours, also have three different settings (8, 16, 24 hours) that are used with each set of simulation scenarios. Therefore, 9 sub-scenarios are generated for each three main scenarios. Weekly based simulations will have 56, 112, and 168 maximum acceptable operations hours and three daily operational hour settings. Summary of simulation scenarios is presented in Table 4.

Terminal Name	Gate		Barge		Train Terminal	
	Cranes	Loading/unloading Time per Container (Minutes)	Cranes	Loading/unloading Time per Container (Minutes)	Capacity in terms of Trains	Train Change over Time (Minutes)
RWG	20	2	2	2	3	45
APMTII	8	2	2	2	3	45
ETR	25	2	2	2	3	45
RCT	7	2	2	2	3	45
APMTR	5	2	2	2	3	45
DCS	5	2	2	2	0	NA
ECTDT	5	2	2	2	3	45
ECT-BFT	20	2	2	2	3	45
VDCD	10	2	0	NA	0	NA
KDD	20	2	2	2	0	NA

Table 3 Terminal Setting

Volume/ Week in TUE (Scenario 1 = 40385, Scenario 2 = 65385, Scenario 3 = 94231) # of Trains = 6, # of Barges = 6					
Road Vehicle	Weekly Operations Hours Threshold	Sub-Scenarios for Scenario 1	Sub-Scenarios for Scenario 2	Sub-Scenarios for Scenario 3	Total
CAGV	56	3	3	3	9
	112				
	168				
MTS	56	3	3	3	9
	112				
	168				
TRUCK	56	3	3	3	9
	112				
	168				
Total Scenarios		9	9	9	27

Table 4 Summary of all scenarios used for experiments

5 SIMULATION RESULTS

5.1 Scenario1 tested

This scenario has least value for ITT container volume among all three scenarios. Total ITT container volume in this scenario is 2.1 million TEU per year, which gives 40385 TEU per week. Results obtained from simulation experiment for all nine sub-scenarios of this main scenario are grouped with respect to operations hours and analysed in the following sections. We run 20 simulation iterations for several combinations of number of trucks in the scenarios. In Table 5 we show the container volume, average distance covered by every type of vehicles, and average time for handling the given volume of containers. Vehicle combination used in third column "Scenario 1-A (3)" of the table depicts acceptable handling time. We investigate operations hours further in order to find the best-fit value for number of trucks to handle the given scenario combining with barges and trains.

	Scenario 1-A (1)		
	Trucks	Trains	Barges
# of Vehicles	360	6	6
Total Volume in TEU	29955	5025	5294
Average Distance Covered by Vehicle (Km):	454.08	148.00	201.86
Average Travel Time (Hr):	48.46	2.04	54.80
Average Service Time (Hr):	2.80	36.18	14.72
Operation Time (Hours):	58.06	58.06	58.06
	Scenario 1-A (2)		
# of Vehicles	370	6	6
Total Volume in TEU	30199	4899	5175
Average Distance Covered by Vehicle (Km):	444.83	144.30	203.50
Average Travel Time (Hr):	47.70	1.99	54.76
Average Service Time (Hr):	2.75	35.34	14.39
Operation Time (Hours):	57.35	57.35	57.35
	Scenario 1-A (3)		
# of Vehicles	380	6	6
Total Volume in TEU	30238	4874	5162
Average Distance Covered by Vehicle (Km):	436.25	133.20	195.17
Average Travel Time (Hr):	46.48	1.84	52.73
Average Service Time (Hr):	2.69	32.44	14.35
Operation Time (Hours):	58.06	58.06	58.06

Table 5 Results for Scenario 1-A

5.2 Scenario 2 tested

Same steps were followed for "Scenario 1-B" to get best possible solution for the same container volume while using automated guided vehicles.

Results show that overall performance of AGVs is better in terms of number of vehicles as compared to trucks. Results for three combinations that are near most to the solution set are presented in Table 6. Less than half number of AGVs was required to handle the same container volume comparing with number of trucks. Reason for this difference could be two-fold; one double stacking capability of AGVs, second result shows that less average service time was required for loading/unloading container from AGVs as compared to trucks. A best configuration with respect to operations hours is 170 AGVs with 6 trains and 6 barges, where operations time is shown just near to the threshold value.

	Scenario 1-B(1)		
	AGV	Trains	Barges
# of Vehicles	150	6	6
Total Volume in TEU	27380	6299	6595
Average Distance Covered by Vehicle (Km):	503.79	178.83	260.49
Average Travel Time (Hr):	53.7	2.47	48.04
Average Service Time (Hr):	1.73	36.08	18.33
Operation Time (Hours):	58.04	58.04	58.04
	Scenario 1-B (2)		
# of Vehicles	150	6	6
Total Volume in TEU	27380	6299	6595
Average Distance Covered by Vehicle (Km):	503.79	178.83	260.49
Average Travel Time (Hr):	53.7	2.47	48.04
Average Service Time (Hr):	1.73	36.08	18.33
Operation Time (Hours):	58.04	58.04	58.04
	Scenario 1-B(3)		
# of Vehicles	170	6	6
Total Volume in TEU	28896	5435	5943
Average Distance Covered by Vehicle (Km):	466.1	175.75	250.5
Average Travel Time (Hr):	48.87	2.43	44.32
Average Service Time (Hr):	1.61	35.44	16.52
Operation Time (Hours):	55.94	55.94	55.94

Table 6 Results for Scenario 1-B

To better compare in Figure 1 the results from the various equipment types in the transport is presented.

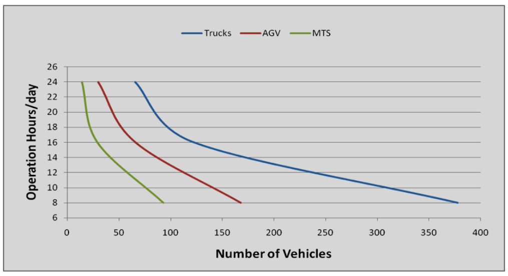

Figure1 Number of Vehicles required

To validate our model we tested it with different scenarios, such as setting 1 vehicle in the network and one crane at each terminal of the network. Preliminary results for the scenario are presented for expert feedback. Suggestions and feedback was noted and model was update accordingly.

Additionally, we did computations on how much time a vehicle should take to cover a given distance with a specific speed of vehicle. The computation results were noted. In the model, logs for time taken to travel from one point to another with specific speed of vehicle were collected and compared with the values computed before. Numbers of test scenario were run with different vehicles and speed of vehicles. Results are cross-verified with computation results for each scenario. We fixed the problems if identified at any point and tested the scenarios again until the satisfactory and expected results are not found.

We have presented and analysed the simulation results in for all possible scenarios defined. We found the most suitable number vehicles for each scenario within the range of maximum valid operations hours. At the end we present the utilization of the gate resource for different terminals in the network.

In conclusion, we found number of required vehicles decreases with increasing operations hours for given parameters of container volume. We also observed that trains and barges perform better by increasing the operations time per day in our model. We can assume it is because of trains have higher change over time and they cannot visit all the terminals within less operation hours. Delayed volume was introduced in the results, which creates more demand for road vehicles to deliver orders with in the given time. It needs more investigation and requires in depth analysis to find the additional reasons, if any.

6 SUMMARY

6.1 General appearance

Future of containerization indicates more and more transportation between the terminals due to increased demand of containerized transport. Larger terminals are being built resulting in multi-terminals in a single container port. Punctual delivery of consignments is the key of better planning of supply management. The aim of this paper was to provide an effective solution for ITT to meet the future challenges of containerization world.

Though optimization approaches exist, the use of simulation provides decision makers a faster and more intuitive approach to understanding a complex problem. With the loads in terminals varying immensely, the level of uncertainty increases, which motivates the use of simulation for planning. A simulation model was then evaluated through simulation experiments and results are presented and tested against different combination of vehicles in order to locate the best suitable number transport resource for punctual delivery of given container volume. Utilization of terminal resources is then compared while using several settings of gate cranes. These findings will help ITT planners to do better planning for ITT and related resource in the future to avoid delay in container deliveries.

In conclusion, meeting the goal of this paper we believe our findings and estimations of manned and unmanned transportation vehicles and cranes used in ITT process will help the ITT planners in better planning and estimation for ITT in MV area of port of Rotterdam.

Some pointers for the future we have noted are that research is increasing in the ITT research area. Therefore, there are definitely more opportunities to work in the field of ITT. In future, other transportation modes can be further investigated to evaluate the model and explore its applications. A detailed and through investigation can be performed to improve the performance of barges and trains.

Another improvement in the model can be introduced by integrating it with intra-terminal operations of different terminals of the network to analyse effects of different settings on trough put of individual container terminals as well as whole network of terminals. Automation seems to be a future of container terminals around the world as research paradigm is shifting towards automation. We have evaluated our model using only one type of automated vehicle, i.e. AGV

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8 ACKNOWLEDGEMENT

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