Simulation and Modelling of Roll-on/roll-off Terminal Operation

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***Abstract*—The scale of parking lot has a significant impact on the efficiency of the entire of the roll-on/roll-off terminal (RORO terminal). To determine the scale of parking lot, the theory of urban planning is used. However, the characteristics of traffic in a RORO terminal is different from the urban area. Therefore, this paper proposed a simulation model to simulate the vehicles in and out of a RORO terminal with Arena software. The application shows that the proposed simulation model is an effective tool to determine the scale of parking lot in a RORO terminal.**

Keywords-RORO terminal; simulation; stochastic; security checking

I. INTRODUCTION

The flourish of RORO transportation, has brought large number of vehicles and passengers to the RORO terminal, which will occupy more land resources for parking. While considering the scarcity of land resources in our countries, it is of great importance to balance the usage of land resources and the efficiency of the RORO terminal operations to keep the development of port in a sustainable way.

More researches focus on the optimal scale of urban parking lot. For example, Anon [1] discussed the allocation problem of parking spaces and export channels for the disabled. David, etc. [2] analyzed the demand of urban parking according to the traffic condition of Sydney, and proposed some suggestion for the location, number of parking spaces and parking price. Jvaid [3] predicted the scale of parking lot of Salt Lake City International Airport. Chen [4] build a series of parking demanding forecasting models considering the distribution of urban population and allocation of productive forces. Li [5] build an AHP-based model to determine the ration of parking facilities supply. Zhang [6] adopted critical gap theory to identify reasonable scale of parking lot. Yun etc. [7] built a driver's parking choice probability model and optimization model of scale of public parking lot. Zheng [8] establish a parking fee and scale optimization models. However, the traffic flow of the RORO terminal is driven by the harbor operation, which has a clear difference from urban transport. Therefore, the optimization theory of the scale of urban parking lot cannot be directly applied to RORO terminal.

The paper introduces computer simulation and establishes a simulation model based on the process of the RORO terminal operation with Arena. The proposed simulation is expected to provide a reference for the planning and layout of a RORO terminal.

II. RORO TERMINAL OPERATION PROCESS

As shown in fig. 1, RORO terminal consists of water area, land area, and berth and apron, which provides services including security check, boarding/ disembarkation, etc.

(1) Port water area consist of anchorage area, entrance channel, turning basin and harbor basin. They provide the RORO vessels with water areas for waiting and testing, entry and departure, turning around, berthing and unberthing.

(2) Berth and apron provides services of boarding and unboarding for passengers and vehicles. In general, the passengers board and unboard by pedestrian path or boarding ladders, while the vehicles by drawbridges.

(3) Port land area includes the parking lot for waiting to security check (PLWSC), security hall (SH), parking lot for waiting to board (PLWB), and auxiliary facilities for production and living, etc. The PLWSC is the waiting area

for vehicles to be checked before boarding, which is located between main gate and SH. The SH is the working space to check the security of the vehicles. The PLWB is a temporary parking zone for vehicle to board, which is placed at the forefront of the land area.

(4) Port main gate provide lanes for vehicles entering or leaving. So the throughput capacity and service level of the gate, will affect the operation efficiency of logistics system in the whole port area.

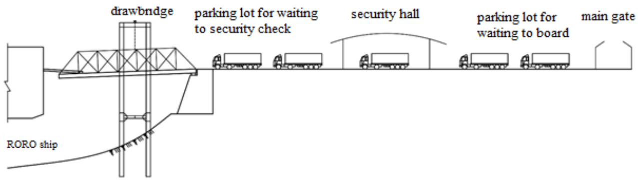

FIGURE I. THE LAYOUT OF A RORO TERMINAL.

The RORO terminal operation is organized according to sailing schedule, berth allocation, and the rules of passenger transportation. The process of RORO operation is complicated and involves passengers' embarking and disembarking, vehicles loading and unloading, and the transportation issue within the port area.

(1) Passenger Operation Process

Passenger Embarking: Passengers go through security checking and arrive at waiting hall. When the entrances for boarding are open, ticket-takers check passengers' tickets, and guide them the specified bus stop. Then the passengers reach the berth and apron by shuttle buses, and finally go aboard the ship through boarding ladders.

Passenger Disembarking: Shuttle buses are scheduled before ship arrival according the number of passengers. Passengers disembark from the ship in a line to the specified bus stop and leave the port by the shuttle bus after boarding ladders set up properly and safety net tied tightly.

(2) Vehicles Operation Process

Vehicles Loading: Vehicles enter the PLWSC through the port main gate. After general checking and inspection, they leave the PLWSC for the SH for security checking. If the vehicle pass the security checking, it enters the PLWB, and boards the ship under the command of officers.

Vehicles Unloading: Before the RORO ship arrival, port officers finish the preparation for vehicle unloading. When the ship is in place, the vehicles disembark from the ship under the command of officers, and leave the port through port road network and gate.

III. SIMULATION MODEL DESCRIPTION

The whole simulation model is composed of four systems: Passengers Embarking System (PES), Passengers Disembarking System (PDS), Vehicles Loading System (VLS) and Vehicles Unloading System (VUS). The four systems work independently as well as interacting with each other. We used Arena software to implement the modeling work. Considering VLS involving in parking issue, the modeling of VLOS is discussed in detail in this section. The VLOS consists of Vehicle Arriving System (VAS), Parking Lots System for Waiting to Security Check (PLSWDC), Security Check System (SCS), and Vehicles Boarding System (VBS).

A. *Vehicles Arriving System*

A vehicle is first created and enters the system, the Decide module classifies the vehicles into three classes (including truck, van and car). Then the Assign module initializes the load capacity and dimensions of the vehicle. Finally the vehicle enters the next Decide module to determine the operational state of SH (that is to say, NOT-START, WORKING, and STOP). If the security hall has not started work yet, the vehicle entity enters PLSWDC. If the security hall is working, the vehicle enters the waiting queue to enter SCS.

B. *Parking Lots System for Waiting to Security Check*

After the vehicle enters PLSWDC, the Decide module allocates a parking spot to the vehicle according to the type of vehicles. When security check starts working and the requirement of the waiting line is met, the vehicle leaves PLWSC and enters the SCS, finally releases the seized parking spot.

C. *Security Check System*

After the vehicle enters SCS, the Decide module separate the vehicle into different queues according to the safety distance between vehicles and the length of waiting queues. When a SH is idle, the vehicle enters the SH and occupies the security service by the Seize module. After security check is finished, the vehicle releases the resource of security service, and leaves the SH. If the vehicle passes the security checking, it enters the VBS. Otherwise, the vehicle enters the treatment zone for vehicles falling the security check. If the treatment is qualified, the vehicle enters VBS, if not, it is permitted on board, and leaves the terminal.

D. *Vehicles Boarding System*

After the vehicle enters VBS, the Decide module decides what the vehicle do according to the state of all available limited-capacity lanes to board. If there is an idle lane, the vehicle travels straight through drawbridge and enters the ship. If there is a lane which can hold another vehicle, the vehicle joins the waiting queue of this lane. Otherwise, the vehicle enters PLWB and wait until a lane is available.

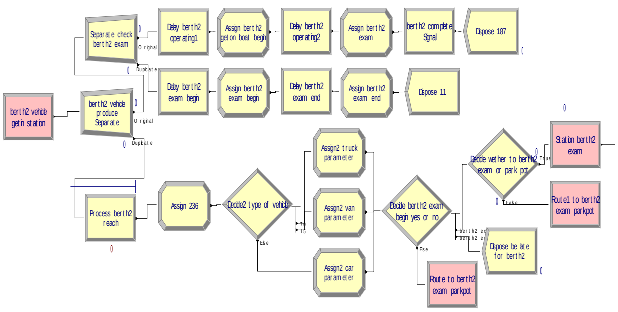

FIGURE II. VEHICLES ARRIVING SYSTEM.

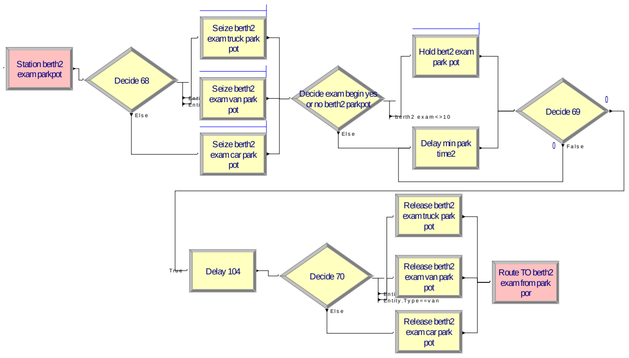

FIGURE III. PARKING LOTS SYSTEM FOR WAITING FOR SECURITY CHECK.

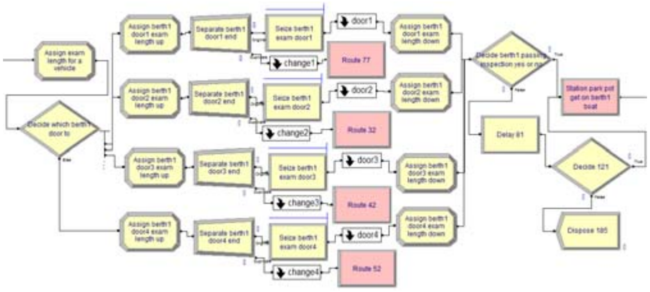

FIGURE IV. SECURITY CHECK SYSTEM.

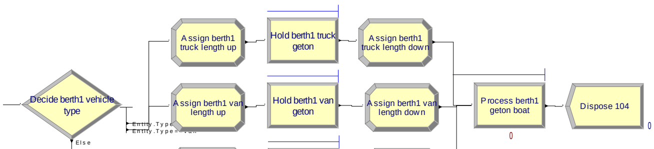

FIGURE V. VEHICLES BOARDING SYSTEM.

IV. VERIFICATION AND VALIDATION

Our model has to verify to see if it is working in the way it is planned. Above all, it is developed in steps and through four sub-systems. And each sub-system is examined individually. For example, Vehicle Arriving System is developed and examined first before the other three sub-systems. Secondly, we take good advantage of the tracing approach, which is quite convenient and effective in Arena software. Via tracing, we can know the whole life cycle of an entity and make comparison with real situations. Finally, animation is also an effective way to verify our simulation model logically [9].

For validation purposes, we have run some simulation experiments based on real data from the operator of Lushun Port. The parameters used in simulation experiments are listed as follows.

(1) The characteristic of berths and ships. This terminal has seven RORO berths, and each berth serves 4 ships per day. The design ship arriving Berth 1 to 6 carries 160 vehicles, and the design ship arriving at Berth 7 carries 240 vehicles.

(2) Vehicle arrival at port follows a beta distribution with $\alpha = 1.45$, $\beta = 4$.

(3) The entrance channel is a one-way channel, the required safe distance between two ships is 10 minutes, and the travel time in the channel is 25 minutes.

(4) The specification of security hall. This terminal has two security hall (SH1 and SH2), where the SH1 services Berth 1 to 4, and SH2 services Berth 5 to 7. Both SH1 and SH2 have four security-check equipment. The time of security checking Tsc is a continuous random variable that follows a normal distribution with a mean of μ seconds and a variance of σ 2 (we write Tsc~N (μ, σ 2)). In this case, the service time for trucks, van and car are distributed normally: N (120, 12), N (90, 9) and N (60, 6).

(5) Other parameters used in the simulation experiment are listed in table 1.

We run the simulation model for 30 replications with each replication lasting for 1 year and get the results under 0.05 confidence level. The simulated number of spots in PLWSC and PLWB as shown in table 2 and table 3. As a result of the comparisons between simulation results and actual data, the simulation model built for the RORO terminal is considered to be close to the actual system and we can use it to do more analysis.

TABLE I. OTHER PARAMETERS USED IN THE SIMULATION EXPERIMENT

Item	**Value**
Vehicle loading efficiency (car/minute)	[2, 5]
Vehicle unloading efficiency (car/minute)	[4, 10]
Time of auxiliary operation when Vessel berthing (minute)	[10, 20]
Time of auxiliary operation when vessel unberthing (minute)	[8, 15]
Vehicle binding efficiency (car/minute)	[1, 3]
Vehicle unbinding efficiency (car/minute)	[3, 5]
Time interval between loading and unloading (minute)	[5, 10]

TABLE II. SIMULATION RESULTS AND ACTUAL DATA OF THE SCALE OF PLWSC

Vehicles	**Simulation**		**Actual data**	
	Number of spots	Utilization rate (%)	Number of spots	Utilization rate (%)
Truck	285	85	275	85
Van	60	85	55	87
Car	120	90	240	40

TABLE III. SIMULATION RESULTS AND ACTUAL DATA OF THE SCALE OF PLWB

Vehicles	**Simulation**		**Actual data**	
	The length of Stop-line (m)	Utilization rate (%)	The length of Stop-line (m)	Utilization rate (%)
Truck	3050	87	4500	60
Van	430	89	1000	40
Car	330	90	600	50

V. CONCLUSIONS

In this paper, we analyze the process of RORO terminal operation systematically, and establish a simulation model for the scale of parking lot in RORO terminal with Arena. The results shows that simulation is a valuable and effective tool for port planning and scheduling. The proposed methodology can serve as a pattern to solve similar problems.

ACKNOWLEDGEMENTS

This research was supported by the National Natural Science Foundation, China (Project No. 51109030 & 51309049).

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