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A Case Study on the Design of Container Terminal in Vietnam

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Abstract : *Port development has been remarkably increasing due to the progress of industrialization in ASEAN area. Especially, Vietnam has increased the international physical distribution in this area rapidly. The main issues facing decision makers at container terminals in Vietnam are how to expand the existing container terminals and construct new container terminals. In this paper, we performed the basic design based on simulation analysis in order to support the expansion of Quy Nhon port in Vietnam as a case study. The preliminary capacity analysis was conducted on the one berth at the port to analyze the scale of C/C(Container Crane)and yard area. Alternative scenarios were created based on the preliminary capacity analysis and the detailed simulation analysis was conducted for supporting the scenarios.*

Key words : *ASEAN, Vietnam, Container terminal, Simulation*

1. Introduction

Port development can refer either to creation of a new port or to expansion of an existing one, usually aimed at increasing its capacity or upgrading port operation. Port development has been remarkably increasing due to the progress of industrialization in ASEAN area (Gim et al., 2004). Especially, Vietnam's economic growth has been so faster than any other countries among ASEAN area. Due to the increasing cargo throughput, it needs a new port and expansion of existing port.

However the design of the container terminal requires the technique with many efforts. Designing problems have to be solved by facility planners in the initial planning phase of developing terminal configuration. Most of the problems are related to investment in construction and facilities (Gunther et al., 2005). Because resources in container terminals are very expensive and limited, the usage of the resources and the impact of the operational planning systems have to be carefully evaluated in order to maximize the performance of the entire terminal configuration (Gunther et al., 2005).

VINAMARINE(Vietnam Maritime Administration) wanted the design of efficient container terminal which has efficient stevedoring system and port operation system utilizing new equipment and IT technology. And VINAMARINE pursued to establish the design of a container terminal to promote efficiency of logistics management in Vietnam as a mid-to-long term goal.

Therefore, the objective of this study is to provide a terminal plan for constructing the optimal container terminal including appropriate stevedoring system, logistics, terminal layout, traffic flow, and development plan. To make efficient plan and marketing strategy, we used various analysis and simulation tools to support the quantitative results.

2. Determination of Target Port

2.1 Vietnam Ports

Vietnam has a favorable geographical location next to major shipping routes connecting Asia to Europe, Asia to America and between Asian countries. Its coast runs along the country from the North to South, and contains many geographical favored positions to build modern ports that enable calling of big vessels and their cargo handling. But there is not yet available analysis and assessment of the importance and the potential in ports. Similar to maritime economics, Vietnam seaport system has not yet got to their position in national economy, an extravagance to Vietnam.

At this time, Vietnam has a seaport system with total berth length over 25km and tens of thousand m2 or warehouse and yards space. Throughput of Vietnam ports has increased sharply as shown in Table 1.

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Table 1 Throughput of Vietnam port system

(Unit: Million Ton)

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003
Throughput	36	39.7	45	46	63	83.3	92	103	114

To have port throughput of approximately 200 million tons in 2010 and 340 million tons in 2020; the Prime Minister of Vietnam has approved the Master Plan of Vietnam seaport system development up to 2010 by his Decision 202/1999/QD-TTg on October 12th 1999. In the context of the last 90s, The Master Plan has systemized and classified Vietnam ports with priority of major ports construction in key economic zones aiming at the forecasted throughputs. VINAMARINE has been carrying out main port projects such as Hai Phong, Cai Lan, Tien Sa-Da Nang and Cai Mep-Thi Vai.

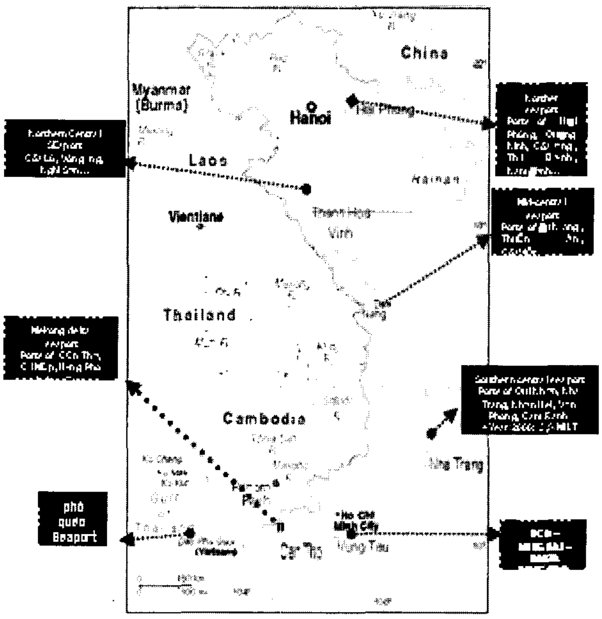

Fig. 1 The configuration of main ports in Vietnam

VINAMARINE have tried to enhance small sized container terminals in local area[1]. The candidate ports are Nha Trang port and Quy Nhon port(Fig. 1).

In order to analysis the candidate ports, we have conducted the feasibility study through field trip. We had startup-meeting on the basic plan for the status of Vietnam port at VINAMARINE in Dec. 2004. We actually visited and discussed about the future plan and their interests at the Na Trang port and the Quy Nhon port in Dec. 2004.

In case of Quy Nhon Port, in 2004 they handle 38,500TEU of containers. It was over nine times of Nha Trang's handling record. And also during 2001~2004 Quy Nhon port showed container throughput volume from 12,518TEU to 38,500TEU. With this increasing trend, container throughputs could be estimated over 100,000TEU at the year of 2010.

Together with this big increase of volume, new industry zone, named "Nhan Hace", is going to be constructed near the port. When finishing the new industry zone, the potentiality of trade increase through Quy Nhon port could be higher.

To afford this big increase of container cargos, the Quy Nhon port has a future plan of expansion of berth and yard. And also it has an idea to be equipped with efficient IT software for port management.

Considering of Nha Trang port and Quy Nhon port have almost same kind of issues such as insufficiency of handling equipments and IT software, we conclude that the Quy Nhon ports' issues for necessity of enhancement has more pressing situation for our study.

3. Analysis of Conditions for Port Design

3.1 Size of Development

The quay length of the Quy Nhon New Container Terminal is 250m. and it will be constructed in 2007 and fully operated in 2010.

The calculation of optimum handling capacity based on the simulation results indicates that a terminal with quay length of 250m and terminal depth of 356m can handle 100,000 TEU and requires 2 C/Cs(Table 2).

Table 2 Size of major facilities at the terminal

Quay wall length	Terminal depth	Terminal area	Cargo throughput	No. of C/C	Stack & Row
250 m	356 m	120,167m^2	100,000 TEU	2	4 stacks, 6 rows

3.2 Vessel Accommodation

In determining the vessels that the Quy Nhon port will accommodate current trend of operating middle-sized vessels must be taken into consideration. Thus, the port should be designed so as to accommodate size of vessels which are expected to be introduced in the year of the port's operation.

Other factors such as technology advancement levels to support introduction of middle-sized vessels, economic

1) We performed the questionnaire analysis for 7 container terminals of each ports.

benefits from operation of middle-sized vessels, securing sufficient water depth in consideration of deeper vessel draft, and size of vessels calling at domestic and foreign ports.

As a result, the 7th berth of Quy Nhon port will be designed for middle-sized vessels as Table 3.

Table 3 Vessel accommodation at the 7th berth at Quy Nhon port

Vessel	5,000 TEU	Remarks
Draft	13.5 m	Water depth
Width	35.0 m	outreach of C/C
Length	280 m	-

3.3 Analysis of Container Composition

To reflect cargo traffic fluctuations during the year(2001~2004) due to periodical factors, seasonal index of 1.2~1.4 was used, depending on the terminal's characteristics. Considering the current trend in vessel size, small sized vessels are expected to call frequently at Quy Nhon port. Thus, seasonal index of 120% was applied.

About throughput in 2010, two outlooks were forecasted. Outlook 1 is 100,000TEU by linear regression[2)] and Outlook 2 is 192,512TEU by polynomial regression[3)].

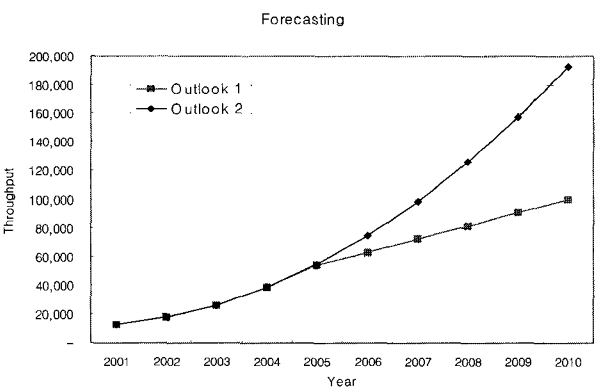

Fig. 2 Throughput forecasting in 2010

According to the Port Development Plan for 2010 announced by MOT(Ministry of Transportation), Quy Nhon port is expected to handled total 100,000TEU of containers in 2010. As a result, the plan was based on Outlook 1 by linear regression in Fig. 2. Breakdown of the total by cargo type shows that imports will account for 49.1% (49,075TEU) and exports will be 50.9% (50,925TEU) out of the total container throughputs.

2) $y = 10222x - 723.93(R^2 = 0.9938)$

3) $y = 1903.7x2 - 958.08x + 11723(R^2 = 1)$

Table 4 Outlook for Quy Nhon Port in 2010

(Unit : TEU, %)

Description	Import	Export	T/S	Coastal	Total
Volume	49,075 (49.1)	50,925 (50.9)	-	-	100,000 (100.0)

Table 5 Estimation of container composition

(Unit : TEU)

	2004	Ratio(%)	2010
20′	4,835	12.5	12,477
40′	33,916	87.5	87,523
Total	38,751	100.0	100,000
Full	24,994	64.5	64,499
Empty	13,757	35.5	35,501
Total	38,751	100.0	100,000
Import	19,017	49.1	49,075
Full	6,076	15.7	15,680
Empty	12,941	33.4	33,395
Export	19,734	50.9	50,925
Full	18,918	48.8	48,819
Empty	816	2.1	2,106
Total	38,751	100.0	100,000

Note : Based on the assumption, there are no non-standard containers in the T/S and coastal categories. Calculation is based on the annual handling volume of 38,751TEU in the year of 2004.

As regards the TEU/Box ratio of the 7th container berth of Quy Nhon port, it is deemed reasonable to apply 1.4 to the average of TEU/Box ratio at Quy Nhon port of recent year in order to reflect the rate in historical throughput.

4. Simulation Analysis and Planning

4.1 Analysis Overview

Calculation of required scale of equipment and yard area appropriate to the annual capability for the Quy Nhon port was as follows: preliminary capacity analysis was conducted on the one berth (250 m quay wall) at the port to analyze required scale of C/C and yard area; scenarios were created based on the analysis; Then, detailed simulation experiment was conducted for the scenarios (Jordan Woodman Dobson, 1998).

Throughput flows to be used in the analysis was defined as follows in order to maintain a balance among the berth, yard and gate. In designing the 7th berth of Quy Nhon port, data collection and analysis, feasibility study, capacity analysis and simulation analysis were performed using the models listed as following Table 6.

Table 6 Contents of analysis by stage

Stage	Analysis Details	Model Type
Feasibility Study	Input : Port size, Throughput, Future development plan Analysis: Determination of target port	- Site Analysis
Berth Capacity Analysis	Input : Container information, Estimated throughput, Development plan Analysis: C/C requirement, Goal productivity	- Berth Model - Spreadsheet
Yard Capacity Analysis	Input : Estimated throughput, Yard Area Analysis : Yard space requirement	- Berth Model - Spreadsheet
Terminal Simulation	Input : Terminal composition information Analysis: 1) Length by block at the yard(No. of bays per block) 2) Rows per block at the yard (No. of rows per block) 3) Required no. of yard cranes (No. of RMGCs per run) 4) No. of YT at the yard (No. of YTs per C/C)	- Terminal Model - Simulation
Gate Analysis	Input: Estimated throughput Analysis : No. of entrance/exit lanes	- Gate Model - Spreadsheet

4.2 Berth Capacity Analysis

The following Table 7 shows the breakdown of container throughputs by the types of container.

We assumed that following assumptions are reasonable in the target port.

- 1.4 is applied for the TEU/Box ratio, which was estimated during design condition analysis.
- C/C gross productivity[4] is set at 20lifts/hr, which is the average productivity of 13 rows C/C.
- 1.2 is used as the seasonal peak index.
- 1.5 hours each is applied for the preparation time for berthing and de-berthing, respectively.
- Distance between vessels during berthing/de-berthing is set at 20 meters, regardless of vessel type.

Table 7 Vessel Calls and Container Information(2004)

No	Call	Import				Export				Total	
		Full		Empty		Full		Empty		TEU	Ratio
		20'	40'	20'	40'	20'	40'	20'	40'		
1	61	356	466	956	1,463	978	2,806	200	272	12,864	33.20
2	57	122	738	317	1,587	453	2,477	0	14	10,524	27.16
3	65	180	1,351	235	1,433	668	1,733	1	9	10,136	26.16
4	19	5	27	10	260	58	356	14	1	1,375	3.55
5	28	17	90	0	584	237	694	1	4	2,999	7.74
6	6	0	26	1	204	26	183	0	0	853	2.20
Count	236	680	2,698	1,519	5,711	2,420	8,249	216	300		
TEUs		680	5,396	1,519	11,422	2,420	16,498	216	600	38,751	

The quayside container handling capacity depends on the number of quayside gantry crane as well as on their average handling productivity in terms of moves per hour. The number of C/C that can be deployed at maximum is limited by the length of quay wall.

According to the existing analysis experience (Korea Port Engineering Corp, 2004), in most case, one C/C per 100 meters quay wall is the maximum configuration that still provides the required flexibility at the quayside for vessel loading and discharging in case of downtimes. But the 7th berth of Quy Nhon port can support with 2 C/Cs for 250 meters quay wall due to low annual throughputs.

The quayside handling figures are show in Table 8, which did not considered transshipment container throughputs. As under normal circumstances empty containers will also be stored in the full container yard, this assumption made has been without consequences for the terminal planning.

It is planned to operate in total 2 C/Cs at the quayside. Considering a total amount of 100,000TEU(71,429 boxes) per year. Table 8 and Table 9 are reasonable in terms of number of required cranes as well as regarding the assumed crane performance.

Table 8 Quayside handling figures

	Import		Export		Transhipment		Total	
	TEU	Lifts	TEU	Lifts	TEU	Lifts	TEU	Lifts
Full	15,680	11,200	48,819	34,871	0	0	64,499	46,071
Empty	33,395	23,854	2,106	1,504	0	0	35,501	25,358
Total	49,075	35,053	50,925	36,375	0	0	100,000	71,429

4) Gross productivity is based on a crane productivity measure. The number of containers moved per net crane hour.

Table 9 C/C requirement

	Import		Export		Transhipment		Total	
	Lifts	%	Lifts	%	Lifts	%	Lifts	%
Full	11,200	15.68	34,871	48.82	0	0	46,071	64.50
Empty	23,854	33.40	1,504	2.11	0	0	25,358	35.50
Total	35,053	49.07	36,375	50.93	0	0	71,429	100.00

High concentration of container cargo must be taken into account as result of operation of container vessels. service level should be met in the 250 m berth in each of the throughput-based scenarios. Thus, appropriate number of C/C is set at 2 for 100,000TEU per year.

If the 7th berth uses two C/Cs, we can expect that the crane productivity is 28TEU/hr under the condition of 45% crane utilization.

4.3 Yard Capacity Analysis

At the yard, a transfer crane system, which is making use of RTGC(Rubber Tyred Gantry Crane) at one side, shall be used for all container stacking (Standard, Reefer, IMO), except for empty containers, which will be stores by empty handling equipment in separated areas.

The direction of the container blocks in the yard as planned here is parallel to the quay wall as a consequence of the shape of the available piece of land.

In total, 8 standard container blocks are planned, having a width of 6 containers and a length of 28TEU uniformly, thus comprising 168TEU ground slots capacity each.

This leads to an overall number of 1,296TEU ground slots for standard containers.

Using the handling figures below Table 10, the dwell time given per category, the peak factor, the maximum yard utilization factor, and the required stacking capacity can easily calculated as shown for full import boxes:

Table 10 Required storage capacity(Gross)

	TEU/ year	Dwell time (day)	Peak	Max. Utility	TGS (slots)
Import Full	15,680	8	1.2	0.8	222
Export Full	48,819	6	1.2	0.8	518
T/S	0	3.5	1.2	0.8	0
Total Full	64,499	6.468	1.2	0.8	737
Import Empty	33,395	8	1.2	0.8	472
Export Empty	2,106	6	1.2	0.8	22
Total Empty	35,501	6.468	1.2	0.8	406
Total					1,143

In order to handle 100,000TEU annually based on the results, 1,143TGS(Twenty Ground Slot) will be required. But 1,296TGS will be constructed by the plan ; therefore, there is surplus of TGS. Both general CY(Container Yard) block and special CY block satisfy the planned TGS.

Required storage capacity was calculated to be 1,143TGS, of which loaded containers for export account for 737TGS and empty container for import accounted for 406TGS.

4.4 Terminal Simulation

Simulation analysis comprises the work-type of the Quy Nhon container terminal, which is C/C⇔YT⇔RTGC and was designed in consideration of the linkage of tasks among stevedoring equipments.

Basic stevedoring concept is that C/C and YT work together as a team. Multiple YTs are assigned to a C/C in performing stevedoring work (Choi, 2005). In designing the RTGC, operation of YT(for loading/unloading of cargo onto/from the vessel) as well as RT(for gate in/out transport of cargo) was taken into account.

Following issues are basic terminal configuration items and to be decided through simulation analysis (Choi et al., 2005):

Table 11 Terminal Configuration and Simulation Results

Description	Item	Detail
Terminal Configuration	Length of block	Considering berth length, space between block, No. of berths etc.
	No. of rows	6 rows
Simulation Contents	No. of RTGC	Decide number of RTGCs equipment in yard
	No. of YT	Decide number of YTs equipment per C/C
	C/C Productivity	Analyze Net productivity of C/C

Assuming that required TGS can be secured in both Design Proposals, Design Proposal II is better than Design Proposal I in terms of the number of yard equipment.

Simulation analysis for calculating the equipment needed is carried out on Design Proposal II. For each berth, initial yard structure with 1 section is used to calculate RTGC number in yard and number of YTs per C/C at apron.

Table 12 Comparative Analysis of Initial Yard Bock Arrangement

Description	6 Row Structure	
	Design Proposal I	Design Proposal II
Total no. of blocks	7	8
Distance between berth and block	35.5m	35.5m
Sum of block width	119.20m	132.22m
Sum of block lane	56m	64m
Total block length	175.20m	196.22m
Space occupancy rate	56.20%	62.29%
Total planned TGS	1,134 TGS	1,296 TGS
Required TGS	1,143 TGS (Annual Throughput: 100,000 TEU)	
Surplus TGS	- 9 TGS	+ 153 TGS
Allowance Rate	- 0.7%	+ 11.8%

As regards C/C productivity, that single trolley crane is set at around 91% of mechanical productivity, which is the reference value applied in calculating net productivity[5] for the Liftech's Crane Sim Model.

As the mechanical productivity is 39.00lifts/hr, net productivity turns out to be 35.49lifts/hr, and 90% of this net productivity translates into 31.94lifts/hr. Hence, input productivity of C/C for the simulation is set at 31.94lifts/hr.

Table 13 Calculation of C/C productivity

Description	Work Hour (sec/lift)	Productivity (lifts/hr)	Calculation Basis
Mechanical productivity	92.31	39.00	- Considered mechanical cycle time only
Gross productivity	180.00	20.00	- Considered break bulk work, crane breakdown, and work hour shifts

Net productivity of RTGC is, for each cycle of equipment, stands at a maximum of 40.00lifts/hr.

When the terminal regulation speed of 20km/hr is applied, traveling speed for YT is 5.5m/sec. However, in consideration of the container yard conditions and the acceleration/deceleration zones, traveling speed of 5.0m/sec is applied. Basic scenario for simulation analysis by equipment type is as follows: regards RTGC, 2~3 RTGCs can be assigned the container yard. Also, 3~6 YTs were considered per C/C in the simulation.

Fig. 3 shows the result of simulation experiment. The change in C/C productivity according to number of YTs assigned shows that productivity grew significantly up to 4 YTs, but from 5 YTs onward, the grow slowed or stagnated. Such simulation result indicates that 5 YTs per C/C is most appropriate.

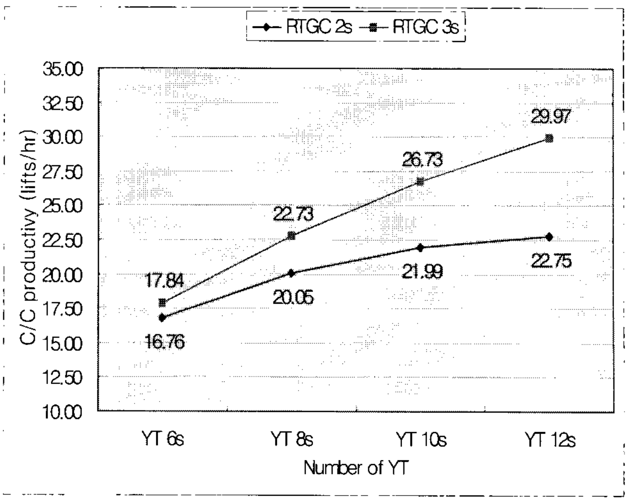

Fig. 3 Simulation analysis of C/C productivity according to number of RTGC & YT

The change in C/C productivity according to number of RTGCs assigned shows that RTGC 3s stevedoring system are is superior than RTGC 2s stevedoring in C/C Productivity[6]. Such simulation result indicates than 3 RTGCs in yard operation system are recommended to achieve C/C gross productivity(20.00lifts/hr) at least.

Table 14 Final Plan Pursuant to the Terminal Operation Simulation Analysis

Equipment	Specification	Description
Quay Crane	Single Hoist Container Crane (C/C) Input No.: 2s (for 100,000TEU) Outreach: 40m (13 rows)	Net Productivity: 26.73 lifts/hr Gross Productivity: 21.49 lifts/hr
Yard Design	Block length ; 27 bays Block width : 6 rows No. of stacks : 4 stacks	No. of section: only one No. of runs: 8 runs Total blocks: 8 blocks
Yard Crane	RTGC (6-wide) 1 over 4 type	Total No. of input: 3 cranes
Vehicle	General Yard Tractor Combined Chassis (20/40/45ft)	No. of YT: 10s No. of Chassis: 10s
Stevedoring System	C/C-YT-RTGC	YTs assignment per C/C

5) Net productivity is based on a ship productivity measure.
6) This productivity means that combined productivity to minimize the waiting time between equipments.

4.5 Gate Analysis

The number of waiting trucks on the queue at peak time may be changed depends on the physical design of the gate. However, with respect to enhancing the service for the shippers, it will be limited to a ceiling of 2 trucks.

Assuming that on average trucks carry a single container only, in peak hours, 7 loaded trucks have to be dispatched as gate-in traffic and 7 trucks as gate-out traffic.

Dispatch time for unloaded trucks and for all outgoing trucks is considered to be 20 seconds, time requirement for all loaded incoming trucks is considered to be 110 seconds plus 10 seconds for truck maneuvering between two truck dispatches[7] (Choi et al., 2006). The table below shows the results of the necessary gate lanes.

Assumptions:

- Truck dispatch time: 20 seconds
- Handling time for empty truck: 20 seconds
- Handling time for loaded truck: 110 seconds
- Maneuvering time between trucks: 10 seconds

This leads to a total requirement of 3 gate lanes, but it seems to be doubtful, whether the assumption of 7 days gate operation with 2 shifts of 10 hour each is correct or not. Assuming that gate operation hours are shorter and that therefore the peaks are higher, consequently the number of required gate lanes is higher.

A second method is based on the assumption that, with *complete container check, according to the Consultants* experience a single gate lane can handle around 55,000 containers per annual and that gate out procedures are four times faster.

As a result, two Gate-In lanes including a flexible dispatch lane and one Gate-Out lane require. The total number of lane required in gate is three.

5. Master Plan

In order to establish the operation layout plan for the terminal, the logistics flow, equipment used, and work alignment methods were first analyzed. Based on the terminal logistics flow[8], the terminal operation plan, the function of each zone, and the plane arrangement plan based on the components and functions of each zone were established. The container flow can be expressed as following Fig. 4. It shows the transport route, the interlinking points, equipments for handling general, refrigerated and dangerous containers at the New Container Terminal.

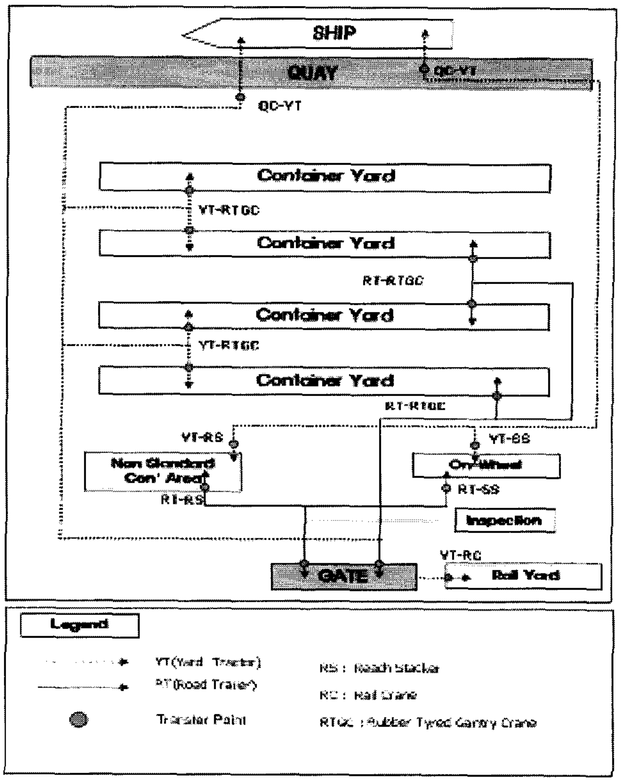

Fig. 4 Logistics for terminal operation

Fig. 5 shows the layout of container terminal focused on facilities. The Service Zone Plan presents the functions and basic plot arrangement for the major buildings and operation facilities that are necessary to operate the container terminal.

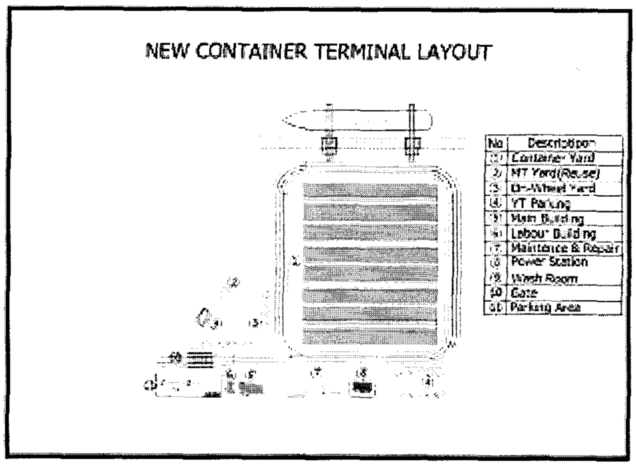

Fig. 5 Layout of container terminal

The size and detailed layout plans for the buildings and major operation facilities have taken into account the functional characteristics, traffic flow and aesthetics.

7) The empirical values gathered in field study.

8) The transport routes and the interlinking points made for handling general, refrigerated, and dangerous containers.

As facilities, the following have been planned for layout: main operation building to support terminal works (MB), maintenance and repair shop (M&RS), labour building (LB), container cleaning facility - wash room (WR), refueling station (RS), custom office (CO), main power station (MS), etc.

6. Conclusion

This is a case study that performs the establishment of master plan to construct a feasible port container terminal using the developed port planning tools. The objective of this study is to provide the master plan for operating the new container terminal in Vietnam. To make the developed master plan, various analysis and simulation are conducted using the historical data of container throughputs. In order to establish the master plan of small sized container terminal, the tools we developed will be useful. For further study, we are developing more detailed simulation model in which large sized container terminals are used.

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