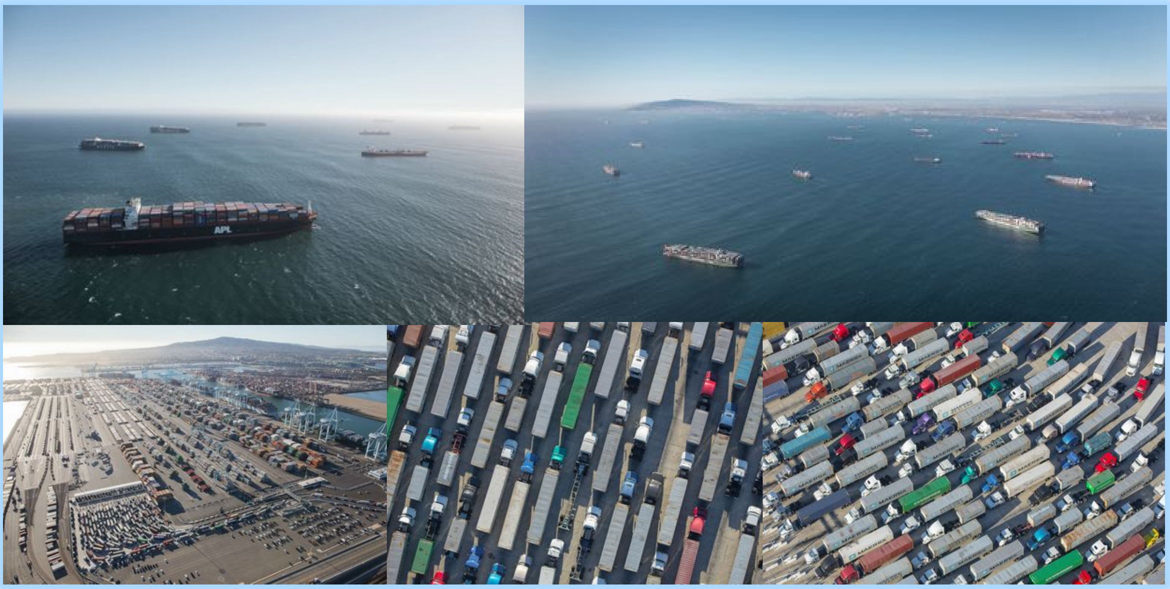
Guidance to trailers' behavior at landside terminal gates

<FINAL REPORT>



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PPDC (Port Planning and Development Committee)

IAPH (International Association of Ports and Harbors)

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1. Mission of the Project

1.1 Background

Newly delivered container ships, most of which have capacities exceeding 20,000TEUs, have been deployed on the main routes. The tendency to introduce larger container ships means that more containers are being loaded/discharged at the same time which has exacerbated terminal congestion. As a result, container ships often have to wait for port entry offshore. To compensate for the lost time, they must increase sailing speeds on route to their next destination, imposing additional costs to shipping lines as well as shippers. Consequently, container terminal landside and quayside congestion has recently caused significant delays in the supply chain and has become a crucial issue throughout the world. Moreover, infrastructure expansion projects such as access roads and terminal gate cannot keep pace with the ever-increasing size of container ships. Therefore, port authorities and/or public sectors are keen to introduce countermeasures to alleviate congestion (e.g. terminal appointment system, extension of gate operation hours, authentication gate system and peak hour pricing system). Those measures are based on the assumption that all the trailers are properly prepared before approaching the gate, however, in this study, the authors divide trailers into two types: one is proper document trailers (PDTs) and the other is improper document trailers (IDTs). The IDTs take additional time to clear the check at the terminal gates, thereby reducing the limited gate capacity.

In this study, the authors apply the social dilemma theory to the landside congestion, and propose an effective strategy of the measures. The authors begin with a literature review on the landside congestion phenomenon and its measures in line with the queueing theory. In particular, the trailer driver's behavior control is outlines in the section 3. Methodology of the research is outlined in the section 4. The authors hypothesize the effective congestion measures are explained by the social dilemma theory, of which typical strategies are outlined in this section. The congestion measures which have been applied by Hakata port and Nagoya port, where the landside congestions were successfully mitigated, in Japan are reviewed in the light of the social dilemma theory in the sections 5 and 6. Finally, the findings and conclusions are in the last section.

1.2 Structure of Taskforce and PPDC

(1) Masahiko FURUICHI, Vice-chair of PPDC, Professor, Graduate School of Management, Kyoto University, Japan

(2) Ichio MOTONO, Deputy Director-General, Shikoku Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Japan

(3) Tamotsu NINOMIYA, General Manager, Project Planning Department, Hakata Port Terminal Co., Ltd., Japan

2. Introduction

Timely and speedy transport services at a reasonable freight rate are highly needed in the global supply chain inevitably requires such services throughout the world. In this regard, efficient quayside and landside operations have been the crucial issues to be resolved in the container terminals. Port competitiveness is definitely subject to its hinterland connectivity. For instance, Aronietis et al (2010) interviewed eleven (11) shipping liners calling at ports of Hamburg-Le Havre range concerning port competitiveness. The interview revealed that quality of hinterland connectivity was the second most important factor following the transport cost. Similarly, port authorities in the east and west coasts of the U.S. indicated that poor hinterland connectivity became a bottleneck of the port growth (Maloni, 2005). Wan et al (2013) numerically developed the liner's port choice model taking the road congestion into account among eleven (11) major ports in the U.S. The simulation results revealed that the liners preferred to choose less congested port among alternative ports.

In addition, the introduction of the larger containerships results in more containers to be loaded/discharged at each port call, which has exacerbated the terminal congestion. The larger containerships on the longer-distance routes tend to cascade down to the medium-distance routes. Similarly, the medium-size containerships on the medium-distance routes tend to cascade down to the shorter-distance routes, and so on. Accordingly, the higher peaks at the container terminals which cause the landside congestion, may take place at any container ports in the world, regardless of whether their throughputs are large or small (Furuichi and Shibasaki, 2015).

The trailer drivers and truck companies are also facing at the landside congestion at a terminal (Tsuchiya, 2015). For instance, a gate opens 8:00 through 16:30 excluding 90-minute lunchbreak in Tokyo port. The trailer drivers are generally paid on a piece work basis by a turnaround of the container delivery. The drivers make every effort to earn additional turnaround within the limited gate hours, and head to the queue at earliest possible in the morning so as to enter the gate at 8:00. Furthermore, they make another effort to arrive at the gates before the gates close at 16:30 so as to finish the final turnaround of the day. This trailer drivers' behavior generates higher peaks early in the morning and late in the afternoon, and consequently they spend a huge amount of idling time in the queue leading to the gates.

Therefore, many ports attempt to ease the landside congestion by controlling the peak-hour traffic of the arrival trailers or obtaining additional capacity at the terminal gates in various ways as a quick-impact measure. Even though these measures are to alter the trailer driver's behavior, few papers discussed on the trailer driver's behavioral change. It is, therefore, necessary to formulate an analytical framework for the driver's behavior and generalize the results of the successful measures.

In this paper, the authors apply the social dilemma theory to the landside congestion, and propose an effective strategy of the measures. The authors begin with a literature review on the landside congestion phenomenon and its measures in line with the queueing theory. In particular, the trailer driver’s behavior control is outlines in the section 3. Methodology of the research is outlined in the section 4. The authors hypothesize the effective congestion measures are explained by the social dilemma theory, of which typical strategies are outlined in this section. The congestion measures which have been applied by Hakata port and Nagoya port, where the landside congestions were successfully mitigated, in Japan are reviewed in the light of the social dilemma theory in the sections 5 and 6. Finally, the findings and conclusions are summarized in the last section.

3. Literature review

In this section, the authors review the landside congestion measures taken at various ports in the world. The congestion is defined as a status that a trailer takes additional waiting time in the queue either at the destination terminal gate or on the access road to the gate. The status of the landside congestion is explained generally by the queueing theory. It is commonly understood that both the trailer arrival rate (representing λ) and the gate capacity (representing sμ) are the key parameters to define the landside congestion.

$$\rho = \frac{\lambda}{s\mu} \tag{1}$$

λ: the average trailer arrival rate (trailers/second)
μ: the average gate service rate (trailers/second)
s: the number of gate lanes
ρ: the utilization rate (%)

The queueing theory tells that congestion will occur if the utilization rate (ρ) becomes 1.0 or larger. The congestion measures are outlined by the queueing theory in the following three categories. First category is to control the trailer arrival rate (representing λ) by; (a) dispersing the number of the arrival trailers by shifting to the other modes, (b) limiting the number of the hourly arrival trailers by the terminal appointment system (TAS), and (c) extending the gate hours. The second category is to increase the number of the gate lanes (representing s). Third category is to improve the gate service rate (μ) by; (a) shortening the gate service time by introducing IT system, and (b) eliminating the trailers carrying improper documents at the gate.

3.1. Controlling the trailer arrival rate

3.1.1. Dispersing the number of the arrival trailers by shifting to the other modes

The option (a) of the first category is to reduce the number of the arrival trailers through shifting a certain number of the trailers to rail or inland/coastal water transport. For instance, 32kmdedicated railway called Alameda Corridor was developed in 2002 to directly connect the ports of Los Angeles and Long Beach (LA/LB) with continental gateway terminal bypassing the downtown in Los Angeles. It cost US$2.4 billion and took 20 years (Alameda Corridor Transportation Authority, 2016). Betuwe line that connects Rotterdam port with Emmerich, western border of Germany, by 160km-dedicated railway started its operation in 2007. It cost Euro4.7 billion and took 14 years since Dutch Congress approved the project (Koeste & Rouwendal, 2010; Innovation and Network Executive Agency, 2016). Besides the railway projects, a new terminal is being developed at outer harbor in Tokyo port to accommodate the increasing demand and disperse the trailer traffic to the off-shore away from the downtown in Tokyo. The terminal is scheduled to be open in 2017 and cost JPY113 billion. The access road directly linked with highway in 2012. It cost JPY264 billion and took more than twenty years (Port of Tokyo, 2016).

These three examples indicate that physical development cannot be quick-impact measures even though they fundamentally ease the landside congestion. In addition, inland waterway as modal shift is only applicable option when a port is located near the potentially navigable canal or river without a huge investment.

3.1.2. Limiting the number of the hourly arrival trailers by TAS

The option (b) of the first category is the TAS, which assigns the number of the arrival trailer to the hourly slots and control the peak traffic. A typical TAS was introduced in the ports of California. A unique state regulation named Assembly Bill 2650 was introduced in California in 2003. It permitted the terminals to implement either the TAS or the peak pricing system to avoid the longer trailer queues. The bill also imposed a penalty to the terminal operators with US$250 per trailer if the trailers are idling more than 30 minutes in front of the terminal gates. Giuliano and O’Brien (2007) and Giuliano, Hayden, Dell’Aquila, and O’Brien (2008) evaluated the effects of the TAS in the ports of Los Angeles (8.16 million TEUs in 2105) and Long Beach (7.19 million TEUs in 2015). They concluded that no evidence was found that the TAS had reduced the queue lengths or the transaction times. The following reasons were presented why the TAS had resulted in failure. Firstly, nine (9) terminals among thirteen (13) in the ports adopted the TAS, of which operational frameworks were different. The trailer drivers were confused when making each appointment in the different operational frameworks. Secondly, priority gates were not prepared to make the arrival trailers who made an advance-appointment smoothly come to the gates. Thirdly, the ports of LA/LB did not accept appointments less than 24 hours before their arrival, whereas the trailer drivers could not inform the exact arrival time unless they were approaching just before the gate. Fourthly, an appointment was made not for a container but for a trailer driver, which accordingly caused overbookings or no-shows. The said situation made the trailer drivers difficult join the TAS program.

On the other hand, the port of Oakland (2.39million TEUs in 2014) in California took a different approach. An appointment was made not for a trailer driver but for a container, to avoid no-shows and overbookings. The port accepted an appointment even 15 minutes before their arrival. The port also introduced the gate automation system. Consequently, the program achieved labor cost reduction by 65% at the terminals (Morais and Lord, 2006).

Botany port (2.29 million TEUs in FY2014) in Sydney, Australia had developed the TAS system (Cox, Mahoney, and Smart, 2009; Davies, 2009, 2013), which was originally introduced at both DP World terminal and Patrick terminal in 1990s. There had been controversial discussions among the terminal operators and the users since the introduction of the TAS. New South Wales state government launched a mediation effort over the dispute. The terminal operators stressed the effect of the TAS, however, the trailer drivers and the forwarders complained the negative impact of the TAS. They alleged that unclear slot allocation by the terminal operators and oppressive penalty to the trailer's late gate arrival. Finally, the Sydney Port Corporation (SPC) as the port authority of the Botany port proposed a new framework that imposes penalty on both the trailer drivers and the terminal operators. The trailer drivers are charged for their late or early gate arrivals and no show at the gates. The terminal operators are charged for their turnaround time delay in a yard as well. The trailers were also equipped with RFIDs to record their movement. The cost of monitoring the movement was compensated by newly introduced port wharfage fee AUS$10 per TEU for both import and export containers. The SPC also had prepared the trailer parking slot near the terminals in order that the trailers are able to adjust early arrival at the gate and avoid late arrival at the gate. The program had promoted the trailer drivers' trustworthy to behave cooperatively. Finally, the turnaround time has been reduced and the landside congestion has been also eased since the program started in February 2011.

3.1.3. Extending the gate hours

The option (c) of the first category is to disperse the number of the arrival trailers by extending the gate hours, which particularly intends to shift the arrival trailers from the peak hour to the off-peak hour through an incentive. Cao *et al* (2013) developed a traffic simulation model for Port Newark Container Terminal in the ports of NY/NJ (5.77million TEUs in 2014) and concluded that the gate hour extension was an effective measure to ease the landside congestion. On the other hand, Giuliano and O'Brien (2008a, 2008b) pointed out that the gate hour extension may cause relatively higher yard and gate operational costs on the stevedore businesses. Thus, a terminal operator or a shipping line preferred the daytime operation hours.

Meanwhile, the ports of LA/LB introduced the PierPASS program that imposes the consignee (the purchaser of the cargo) Traffic Mitigation Fee (TMF) on the trailer's gate-in or gate-out during the peak hours in July 2005 (Giuliano and O'Brien, 2008a). The amount of TMF fee was US$50.0 per TEU. (The program was originally designed and proposed by the terminal operators as a counter proposal to avoid a new bill. The new bill was proposed in the state assembly in order to reinforce the dysfunctional TAS. The bill included establishment of a new public authority that monitors the gate traffic and fines the penalty to the terminal operators for the idling trailer traffic in front of their gates.) Additional operational costs for extending the gate hours were compensated by the collected TMF from the consignees. The consignees are able to choose whether to carry the container in the daytime with the fee or the night time without the fee. The trailer drivers cannot deliver containers in the daytime without paying the fee. When the PierPASS was introduced in July 2005, all the thirteen (13) terminal operators joined the program. The program has been successfully in operation so far. The number of containers which moved in and out the terminals by paying the TMF was 2,155,359 TEUs which equals to approximately 15 % of the total throughput of the ports in 2014 (PierPASS financial overview, October, 2015). A 16% of the frequent callers made four (4) or more moves per day in December 2015 (PierPASS, 2016).

3.2. Increasing the number of the gate lanes

The second category is to add the gate lanes to dynamically accommodate the peak-hour traffic. However, the flexible operations of the gate lanes to accommodate the peak-hour traffic are not permitted based on the labor contract agreements in some ports. Adversely a terminal cannot fully utilize its gate capacity if the number of lanes is fixed all day long ignoring the peak-hour traffic. Guan and Liu (2009) developed a multi-server queueing model to analyze the landside congestion and quantify the trailer's cost in the queue. The model was developed to balance the gate operation cost and the trailer's cost associated with excessive waiting time. They pointed out that the TAS seems to be the most viable way to reduce the landside congestion, which can fully utilize the gate capacity.

3.3. Improving the gate service rate

3.3.1. Shortening the gate service time by introducing IT system

The option (a) of the third category is to increase the gate capacity by introducing IT system. The IT system has realized information integration on port activities and provided the users with real time logistics information. For instance, TraPac terminal of the port of Los Angeles introduced the IT system with GPS, OCR and RFID and converted the yard operation into

RTG system, since the TAS had resulted in failure (Morais and Load, 2006). The number of the trailers per day was approximately 1,500-1,800 before the IT system introduction, and increased up to 7,500 with the IT system operation. Accordingly the trailer's waiting time successfully reduced from over six (6) hours to ten (10) minutes in average. Since Savannah port (3.67 million TEUs in 2015, nine (9) berths) in the U.S. provided real-time container information at all hours to the users, the gate service time has reduced by 30% and eased the landside congestion (Maguire *et al*, 2010). Hakata port (860 thousand TEUs in 2014, two terminals) in Japan introduced an IT system named 'HiTS' (Hakata Port Logistics IT system) in 2000, in which the trailer drivers can obtain the container delivery order status and the traffic congestion on the access road and notify the terminal with quick gate check-in information. In addition, the port introduced a one-day advance information registration regulation in 2001, in which all the trailers have to register their trailer ID number and the container ID number at least one day before their appearance at the gates. This regulation also has reduced the transaction time at the gates and avoided the unnecessary traffic (Motono *et al*, 2014).

3.3.2. Eliminating the trailers carrying improper documents at the gate

The option (b) of the third category is to eliminate the Trailers which carry Improper Documents (IDTs) which require significantly longer gate service time. Transportation Research Board (TRB) in the U.S. (2011) pointed out that "approximately 5% of all the transactions result in trouble tickets". Motono *et al* (2014) conducted a survey at Chennai port in India, which has long suffered from heavy traffic congestion in and around the port, and discovered that only a half of import container trailer drivers carried the proper set of documents. Motono *et al* (2016) discovered that the IDTs accounted for approximately 12.7 % and 10% of the trailers in Nagoya port and Hakata port respectively. Motono *et al* (2016) revealed that landside congestion is caused partly by those IDTs. Both Nagoya and Hakata ports in Japan succeeded in reducing the landside congestion by eliminating the IDTs.

Above-mentioned congestion measures are systematically outlined by the parameters in the queueing theory. These measures are assumed that all of the players (trailer drivers or terminal operators) understand the purposes and effects of the measures and behave normally. If the players, however, did not always understand them or behave normally in the practical cases, how should we arrange the measures so that all of the players behave normally? The experiences of the ports of LA/LB and the Botany port suggest that the players' cooperation is essential to obtain the expected results. To the best of our knowledge, none of the abovementioned studies referred the players' behavior.

4. Methodology: The social dilemma and its solution

4.1. Missing an initiative body in the landside congestion problem

It is hard to identify a contributor who causes the landside congestion among the various stakeholders in the port activities. This also makes it difficult to point out a responsible body that can solve the landside congestion. Main stakeholder's attitude toward the landside congestion was described in the following papers (For instance, Giuliano and O'Brien, 2008a, Lubulwa *et al,* 2011, Merk and Notteboom, 2015).

A terminal operator is a responsible body to maximize its profit through efficient terminal operation. It takes care of an efficiency of the quayside operation in which main revenue is generated. It pays, however, few attentions to the landside where no fee is collected at its operation and to the trailers waiting outside the terminal. In addition, some of the container terminals suffer from the shortage of access road capacity or traffic congestion at downtown which are out of their control and cannot be managed by themselves. In addition, each terminal operator independently operates its terminal among competitors. A port also competes with the other neighboring ports to attract customers. The terminal operators will not take cooperative actions unless they share a common strong interest. Neither will do the ports.

Truck operators, who undertake the container delivery from the forwarders or the shippers, surely suffer from the landside congestion. As they are paid on a piece work basis, their revenue will be directly lost once the landside congestion occurs. Since they are usually an individual operator or a small company, their voices are relatively small among the port stakeholders. These situations make the truck operators not claim at the terminal operators for the lost revenue by the landside congestion. Both shippers and forwarders have a way of choosing a terminal or a port where lower costs and timely transport services are secured. They will change the terminal or the port, if they feel unsatisfied with the services.

Port authorities should be a coordinator among the stakeholders to raise the whole benefit of the port users. However, their initiatives are limited such as hinterland access network development (road, railway and inland water transport) from their ports to the nearest cities. The above discussions indicate that the landside congestion is mainly a part of the external diseconomy for each stakeholder. The structures make it hard to identify a responsible body that manages and solves the landside congestion. In order to solve the landside congestion, the first action is to identify or form a responsible body that can build a mechanism to coordinate their interests among the stakeholders. The way of building the coordination mechanism will be discussed in the next sub-section.

4.2. The meaning of the social dilemma

A social dilemma means that problems arise when too many group members choose to pursue an individual profit and immediate satisfaction rather than behave in the group's best long-term interests (Dawes, 1980, Yamagishi, 1990a, 1998b). The authors hypothesize that the term and its solution could be applied to understand the landside congestion at the container terminal gates.

In a normal situation, the trailer drivers should identify their documents, the container ID number and congestion status before heading to their destination terminals even though it takes additional time. For instance, once the landside congestion status was provided with the trailer drivers by the HiTS at Hakata port, they could choose more convenient time to head to their destination terminals and would avoid their unnecessarily waiting in the queue. This behavioral change would eventually reduce the landside congestion at the port. However, they tend to instinctively behave short-sighted manner, in other words, to join the queue at their earliest time without carefully identifying their documents and the container ID number.

4.3. Solution for the social dilemma problem

The ways of solving a social dilemma are widely discussed in the social psychology, sociology and economic fields. There are two options to change people's behavior to be cooperative (Yamagishi, 1998, Fujii, 2001a, 2003b). The first option is to gain the cooperation through a structural strategy, in other words, a carrot and stick strategy. The strategy is to build an incentive structure that all can willingly behave cooperatively. In other words, those who take a cooperative action can get more profit and those who take a non-cooperative action will be punished. This will change the situation that an individual who takes a cooperative action can get more profit than the one who takes a non-cooperative action. It looks easy to change people's behavior and solve the dilemma. It is, however, problematic for the following reasons. The first is that it is needed to monitor and control the individual behavior. In addition, who should pay the cost? The second is that individual's motivation to act cooperatively will be gradually lowered, if they are continuously monitored and their behaviors are controlled. For instance, if the trailer drivers did not make appointment properly after the TAS was introduced, the additional measures would be required. This would also require the additional costs. The negative spiral will be inevitable as long as the structural strategy is taken.

The second option is a psychological strategy. In order to overcome the limitation of the structural strategy, a psychologist proposes to change an individual's mind to behave cooperatively through education. This is only the way to terminate the negative spiral caused by the structural strategy. However, the education raises another dilemma: people who are educated may become exploited by the non-educated. Accordingly, a trustworthy situation that the cooperative people will not be exploited should be secured. The situation is that those who take care of others and behave for the public benefit can get more than those who pursue and behave for the individual's benefit do. When the situation is set, all of the members will be expected to take cooperative behaviors.

In addition, if the ratio of the members who take cooperative action exceeds a certain level (limiting mass), all the members will choose to behave cooperatively like an avalanche by the crowded mind. On the other hand, the social dilemma will continue if the ratio of the members who take cooperative action is less than the limiting mass in the beginning. Therefore, it is essential to prepare the conditions in the beginning that more than the limiting mass of players can easily join.

5. Congestion Alleviation Measures at Hakata Port

5.1. Outline of measures at Hakata port

At first, measures to alleviate terminal gate congestion at Hakata port are examined. The port handled 861 thousand TEUs of international containers in 2014. Two terminals are in operation in Hakata port, namely Kashii terminal and IC terminal (Figure 1). With the rapid increase of the container cargo volume since 1998, chronic gate congestion and traffic jams on the surrounding roads became a major issue at Hakata port. The trailers had to wait for about four (4) to five (5) hours to enter the container terminal gate at peak times of congestion, and shippers and logistics-related industries requested an immediate solution to the problem. Hakata port tried to solve this problem by introducing additional cargo handling equipment and expanding the terminal area, however, neither of these measures was very effective. When the port reinvestigated the causes of the congestion, it was discovered that about 10% of the arrival trailers were waiting at the gate with incorrect cargo information or improper documents.

To remedy the problem, the port introduced an IT system named 'HiTS' (Hakata port Logistics IT system) in 2000 in which trailer drivers can obtain container delivery order status and traffic congestion status on the road and notify the terminal with quick gate check-in information (Table 1). Since then, the gate waiting time has decreased from two (2) hours to 15 minutes, gate check-in time decreased from four (4) minutes to less than one (1) minute. In addition, the port introduced a one-day advance information registration regulation in 2001 in which all the trailers have to register their trailer ID number and container number at least one day before they appear at the gates. This regulation also has reduced the transaction time at the terminal gates.

Table 1 Information shared in the HiTS

Information	Specification
Import/export container information	This service is to offer real-time information on container cargo status when user sends the container number. The information includes container cargo status information, vessel information, customs information and in/out information.
Import container delivery status	This IT service delivers the specified container cargo status through e-mail. This service can provide the latest container cargo status even if the user is out of the office.
Arrival & departure information	This IT service offers real-time vessel information including shipping line, route, estimated arrival date, actual arrival/departure time, etc.
CY congestion live information	This IT service provides a real-time view of the gates. The service helps a trucking companies to dispatch trailers in a timely manner.

5.2. Numerical Analysis of Queueing Model at Landside Gate-Case of Hakata port

5.2.1. Development of Hakata port simulation model

The WITNESS discrete model is introduced to evaluate the effectiveness of the HiTS in Hakata port. A model layout is drafted for Hakata port. The port entrance is a virtual point 10,740 meters upstream of the Kashii terminal and 14,220 meters upstream of the IC terminal. A dedicated access lane is prepared to each terminal gate (Figure 1). Table 2 shows the gate service conditions at Hakata port. Gate operation hours are from 7:00 to 18:00 plus overtime. Datasets, particularly for the gate service time and the number of arrival trailers, will be prepared in the simulation described below.

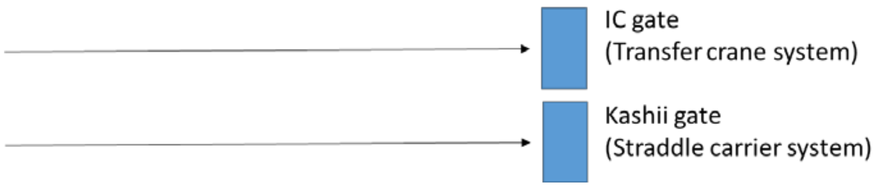

Figure 1 Simulation model layout in Hakata port

Table 2 Gate service conditions at the Kashii terminal and the IC terminal

Gate	Type of trailers	Number of lanes
Kashii terminal (yard operation: straddle carrier)	Import/export/empty trailers	4
IC terminal (yard operation: transfer crane)	Import/export/empty trailers	4

5.2.2. Distribution of arrival trailers at the terminal gates

Table 3 shows the hourly traffic distribution of arrival trailers for each destination terminal in one day. The table indicates that full loaded container trailer traffic peaks just before noon and again in the late afternoon. The hourly proportion of arrival trailers is based on the survey at the terminal gates on five weekdays from 2nd to 6th February 2015. The probability distribution of daily traffic volume of trailers was based on the actual data on containers handled at the terminal gates from 6th January to 25th November 2014. The trailer arrival interval is defined to be evenly distributed in each time band in the simulation. The 95th percentile of the total daily traffic volume of trailers was 1,831 and the 97.5th percentile was 1,889 (Table 4).

Table 3 Hourly traffic distribution of the arrival trailers in Hakata port

Time band	Kashii terminal	IC terminal
7:00～8:00	5.00%	5.10%
8:00～9:00	7.90%	7.50%
9:00～10:00	9.10%	11.90%
10:00～11:00	10.40%	17.50%
11:00～12:00	11.50%	9.00%
12:00～13:00	9.10%	4.40%
13:00～14:00	10.50%	12.70%
14:00～15:00	10.40%	15.00%
15:00～16:00	13.00%	9.70%
16:00～17:00	11.70%	7.10%
17:00～18:00	1.40%	0.10%
Total	100%	100%

Table 4　Percentile of daily traffic volume of the arrival trailers in Hakata port

Percentile	Daily traffic volume of the arrival trailers	Kashii terminal	IC terminal
50th	1,563	516	1,047
95th	1,831	626	1,205
97.5th	1,889	648	1,241

5.2.3. Gate service time at the terminal gates

Data on gate service time at these gates are collected on five weekdays from 2nd to 6th in February 2015 when the HiTS system had already been introduced at both gates. The service time was counted from the time a trailer checked in to the time it checked out of the gate. The average gate service times were 53.2 seconds at the IC terminal and 129.6 seconds at the Kashii terminal. The gate service time distribution at each gate was exponential rather than normal (Figure 2 and Table 5). The gate service times before the introduction of the HiTS were not recorded.

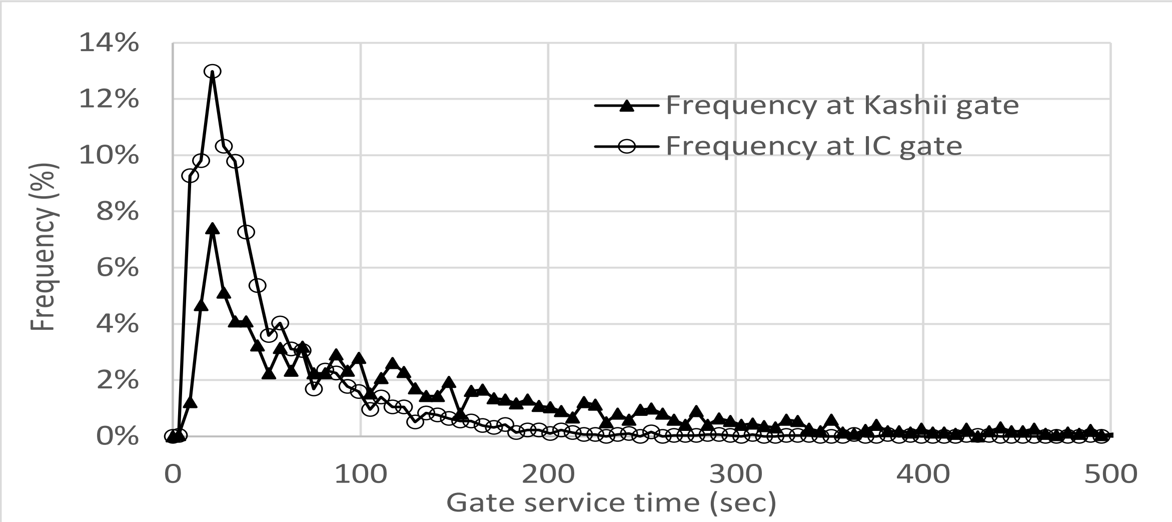

Figure 2 Gate service time distribution at the Kashii terminal and the IC terminal (with the HiTS)

Table 5 Average gate service time at the Kashii terminal and the IC terminal (with the HiTS)

Service time (data from 2nd to 6th February 2015)	Kashii terminal	IC terminal
Average gate service time (sec)	129.6	53.2
Standard deviation (sec)	116.8	62.9
Number of samples	2,238	3,154
Container yard operation	Straddle carrier	Transfer crane

The gate service time difference between Kashii (129.6 seconds) and IC (53.2 seconds) is observed. The difference is due to the different yard operation systems employed at each terminal. The yard operation system in the Kashii terminal employs a straddle carrier system while that in the IC terminal employs a transfer crane. In case of the straddle carrier system (Figure 3), even though a loaded trailer is allowed to pass the gate, the trailer heads to a transferring point where a straddle carrier picks up the container from the trailer. The trailer has to wait at the point until the carrier picks up the container. If the number of points is insufficient or the straddle carrier is delayed in picking up the container for some reason, the following trailers have to wait at the terminal gate until the point is cleared. This also requires additional gate service time. If the number of points is limited, the trailer is obliged to take additional time to pass the gate until the slot is cleared. In case of the transfer crane system, once a loaded trailer is allowed to enter a gate, the trailer will head to his container slot to unload his container. This system will not impose any additional waiting time to pass the gate. It should be noted that yard operation is another factor which affects the gate service time.

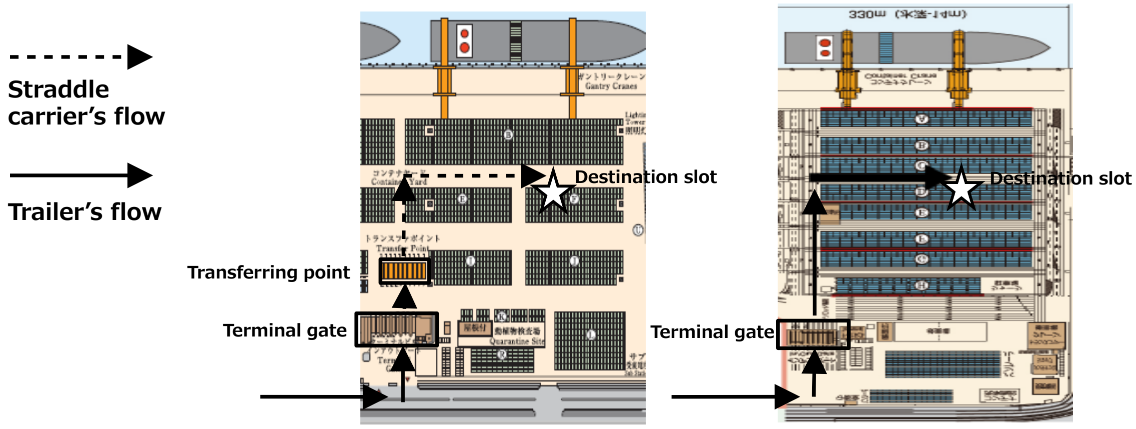

Figure 3 Trailer's flow in a terminal

5.2.4. Gate service time setting in the simulation

Data on the present gate service time distribution were collected from both the Kashii gate and the IC gate where the HiTS system has already been installed. However, data on the gate service time distribution before the HiTS was installed were not recorded. The data on gate service time distribution both with and without the HiTS are essential to evaluate the effect of the HiTS. Since the gate service time was recorded at the TCB in Nagoya port (as described in section 5.), we assumed that the gate service time distribution at the TCB before the SCS was introduced in Nagoya port would represent that at the IC terminal before the HiTS was introduced in Hakata port (Figure 4 and Table 6).

Table 6 Average gate service time settings at each gate in the WITNESS simulation (Unit: second)

	with the HiTS (recorded)	without the HiTS (assumed)	Remarks
IC terminal	53.2	158.4 [1)]	1) The average gate service time at the TCB without the SCS is applied.
Kashii terminal	129.7	215.9 [2)]	2) Gate service time difference at the IC terminal (105.2 sec) between with/without the HiTS is added to the gate service time at the Kashii terminal with the HiTS.

Under this assumption, the average service time at the IC gate without the HiTS (158.4 seconds) is 105.2 seconds longer than that with the HiTS (53.2 seconds). The Kashii terminal employs a straddle carrier system, so the gate service time distribution of the TCB cannot be substituted for that of the Kashii directly. Instead, the gate service time distribution of the

Kashii without the HiTS is assumed to be 105.2 seconds longer than that with the HiTS. Therefore, the reduction of the average gate service time thanks to the introduction of the HiTS is assumed to be the same in both terminals.

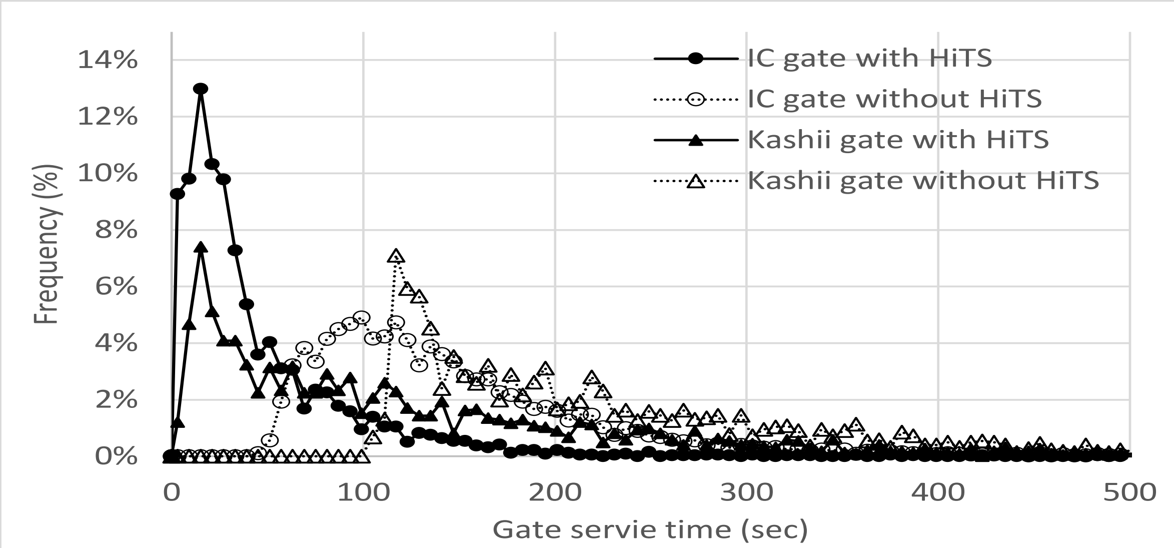

Figure 4 Gate service time distribution settings in the simulation

5.3. Simulation Results on Hakata port Model

5.3.1. Overview of simulation results

The average travel times from the port entrance to the gate entry in each terminal are listed in Table 7. The travel times with and without the HiTS are compared. The travel time with the HiTS is shorter than that without the HiTS for both terminals. In addition, as the daily traffic volume of arrival trailers becomes greater, the average travel time without the HiTS gets longer while that with the HiTS remains stable. For instance, at the IC terminal, the average travel time without the HiTS increases from 5,813.1 seconds at the 50th traffic to 8,865.3 seconds at the 97.5th traffic while the average travel time with the HiTS remains stable even though the daily traffic volume of arrival trailers increases. This simulation results indicate that the HiTS has effectively reduced the travel time for both terminals.

Table 7 Average travel time from the port entrance to terminal gate entry by the WITNESS (unit: second)

Percentile of daily traffic volume of arrival trailers	without the HiTS		With the HiTS	
	Kashii terminal	IC terminal	Kashii terminal	IC terminal
50th	1,893.90	5,813.10	1,568.60	1,760.60
95th	2,226.30	8,116.70	1,580.40	1,762.60
97.5th	2,589.80	8,865.30	1,578.10	1,763.40

5.3.2. Simulation results- travel time at the IC terminal

The transition of the travel time from the port entrance to terminal gate entry of the IC terminal in a day in a simulation is shown in Figure 5. Daily traffic volume of arrival trailers at the terminal in a day is 1,205 which is equal to the 95th percentile. Horizontal axis represents the time at which each trailer entered the port. The vertical axis indicates the travel time for each trailer to enter the terminal gate from the port entrance. The travel times from 7:00 to 9:00 remain stable at approximately 2,000 seconds for both cases (with and without the HiTS). This shows there is no delay during this period in both cases. However, the travel time in the case without the HiTS rapidly increases from 9:00, recording a maximum of 14,487.3 seconds at 16:35. This means that the HiTS effectively prevents delays. In addition, a close relationship between ρ calculated by the queueing theory (Table 8) and travel times obtained by the WITNESS simulation is observed. In the case without the HiTS, the travel times start gradually increasing due to accumulated queue length when the utilization rate ρ becomes 0.99 at 8:00. The travel times start to increase clearly when the utilization rate ρ becomes 1.58 at 9:00. The travel times decrease from approximately 9,000 seconds to 8,000 seconds after the utilization rate ρ becomes 0.58 at noon. However, when the utilization rate ρ becomes 1.68 at 13:00, the travel times begin to increase once again, recording a maximum of 14,487.3 seconds at 16:35. On the other hand, in the case with the HiTS, the utilization rate ρ remain less than 1.0 all day long. So that the travel times obtained by the simulation remain similarly stable all day long.

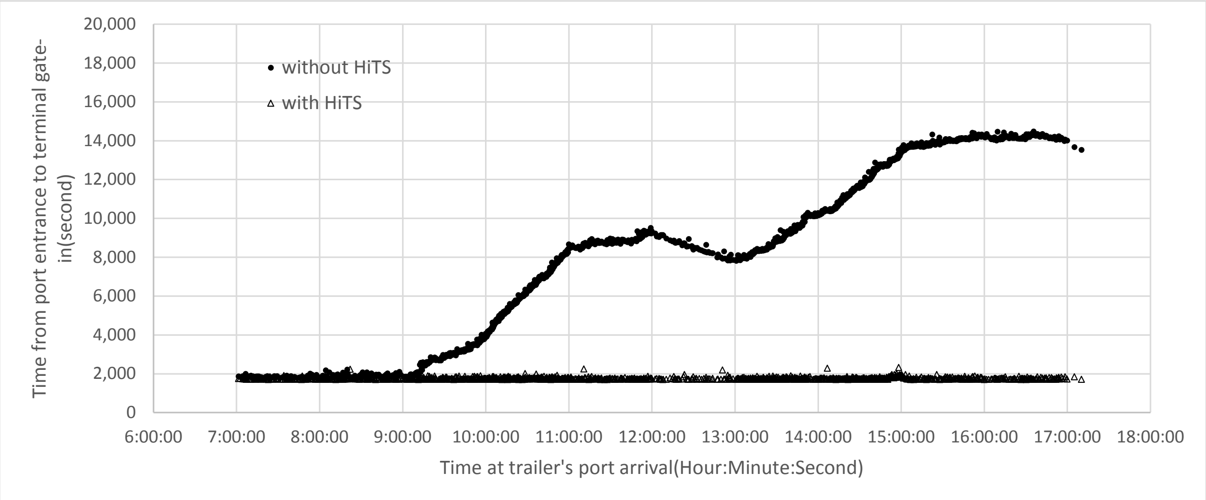

Figure 5 Travel time from the port entrance to terminal gate entry at IC terminal by the WITNESS (daily traffic volume of arrival trailers: the 95th percentile)

Table 8 Utilization rate ρ at the IC terminal by queueing theory (daily traffic volume of arrival trailers: the 95th percentile)

ρ	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
With the HiTS	0.02	0.33	0.53	0.78	0.40	0.20	0.56	0.67	0.43	0.32	0.01
without the HiTS	0.68	0.99	1.58	2.32	1.19	0.58	1.68	1.99	1.29	0.94	0.02

5.3.3. Simulation results- travel time at Kashii terminal

Transition of the travel time from the port entrance to terminal gate entry of the Kashii terminal is shown in Figure 6. Daily traffic volume of arrival trailers at the terminal in the day is 626 which is equal to the 95th percentile. The travel time in the case without the HiTS gradually increases from 9:00, recording a maximum of 3,657.7 seconds at 16:50 while the travel time in the case with the HiTS remains stable, recoding around 2,000 seconds. In addition, a close relationship between ρ calculated by the queueing theory and travel times obtained by the WITNESS simulation are observed (Table 9). In the case without the HiTS, the travel times gradually start to increase when the utilization rate ρ becomes 1.02 at 10:00. The travel times decrease from approximately 2,500 seconds to 1,800 seconds after the utilization rate ρ becomes 0.90 at noon. Then, the travel times begin to increase once again when the utilization rate ρ becomes 1.03 at 13:00. On the other hand, in the case with the HiTS, the utilization rate ρ remains less than 1.0 all day long. Accordingly, the travel times obtained by the simulation are stable all day long.

The results of the simulation at the IC and Kashii terminals have revealed that the HiTS can effectively prevent delays and that the utilization rate ρ is a useful indicator for predicting the congestion occurrence and alleviation.

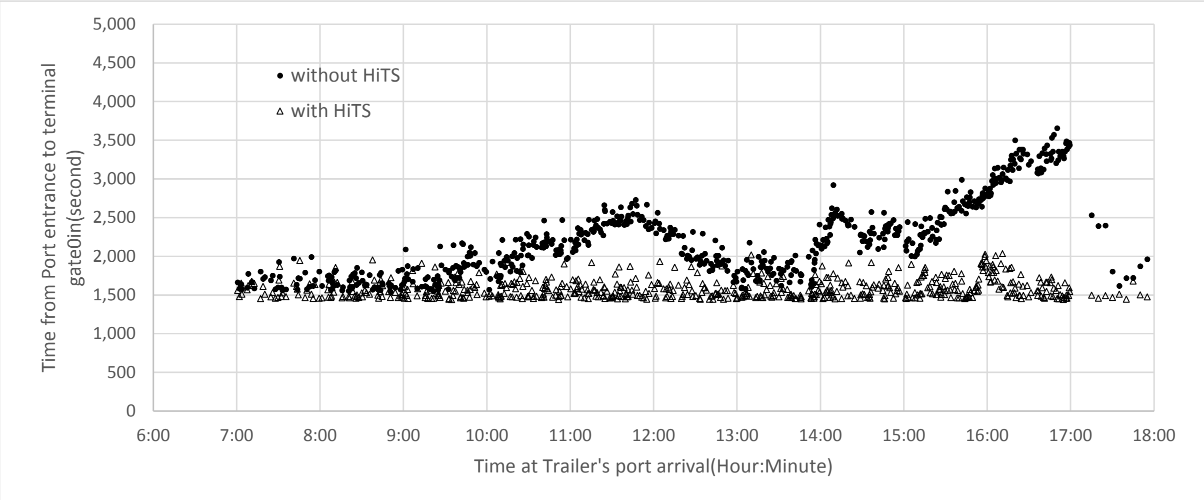

Figure 6 Travel time from the port entrance to terminal gate entry at the Kashii terminal by the WITNESS (daily traffic volume of arrival trailers: the 95th percentile)

Table 9 Utilization rate ρ at the Kashii terminal by queueing theory (daily traffic volume of arrival trailers: the 95th percentile)

ρ	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
with the HiTS	0.28	0.44	0.51	0.58	0.65	0.51	0.59	0.59	0.73	0.66	0.08
without the HiTS	0.50	0.78	0.90	1.02	1.13	0.90	1.03	1.02	1.27	1.15	0.14

6. Congestion Alleviation Measures at Nagoya port

6.1. Outline of measures at Nagoya port

A different approach to alleviate congestion was taken at Nagoya port. The port handled 2.57 million TEUs in 2014. Four terminals are in operation in Tobishima dock, namely Tobishima North, NCB, Tobishima South and TCB (Figure 7). In a survey conducted on July 24th, 2012, 290 out of 2,198 drivers, in other words 13.19% of all the drivers, were carrying the improper documents, which are regarded as the IDTs. In addition, some trailers chose the wrong terminal by mistake because the four terminals are located on the same dock (Wada and Tsuchida, 2013).

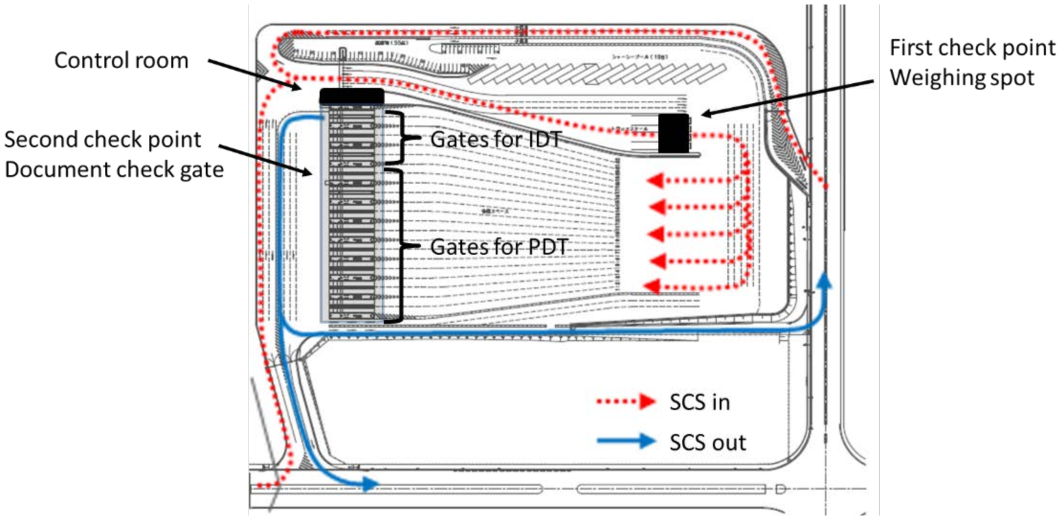

Figure 7 Trailer's routes at the SCS in the Tobishima Dock

The SCS was established at the end of March 2011, having 22 lanes at the gates with an area of 5.7 ha (see Figure 11). The trailer's routes at the SCS is as follows; a trailer approaches to

1) the weighing spot (the first check point) where a container is weighed and its information is reported to the control room in the SCS,
2) the control room where a clerk checks if the reported container information matches the information obtained from the Nagoya United Terminal System (the NUTS) or not,
3) the second check point where the appearance of the container is inspected and the container number is verified, after being sorted into two categories (the PDTs and the IDTs), and
4) finally the trailer receives instructions regarding which terminal he is to go.

A trailer which cleared the SCS is able to move forward to the terminal gate without any delay because the container information on the trailer has already been sent to the terminal directly through the NUTS. A queue length of 1,000 meters was frequently observed at the terminal gate before introducing the SCS, but since it began operations, the queue length in front of the TCB gate has been dramatically reduced (Wada and Tsuchida, 2013).

6.2. Numerical Analysis of Queueing Model at Landside Gate-Case of Nagoya port

6.2.1. Development of the Nagoya port simulation model

In order to evaluate the effectiveness of the SCS, a numerical analysis is carried out. Table 10 shows the gate service time at the TCB before and after the SCS was introduced. The data collected on Thursday, January 12th, 2012 indicates that the average gate service time at the TCB was 158.4 seconds, resulting in 0.006 of μ at the TCB. On the other hand, the data collected on Thursday, September 4th, 2014 indicated that the average gate service time at the TCB was 14.9 seconds, resulting in 0.067 of μ at the TCB. As a result, the average gate service rate μ increased ten (10) times (as 0.067/ 0.006=10.7) at the TCB after the SCS was introduced. This is because procedure at the gates is simplified and the IDTs are totally eliminated by the SCS.

Table 10 Comparison of gate service time at the TCB before and after the SCS was introduced

Gate service time (data on 12th January, 2012)	Before the SCS was introduced	After the SCS was introduced
Average gate service time (sec)	158.4	14.9
Standard deviation (sec)	157.8	13.1
Number of samples	12,200	12,363
Gate service time rate μ (trailers/sec)	0.006	0.067

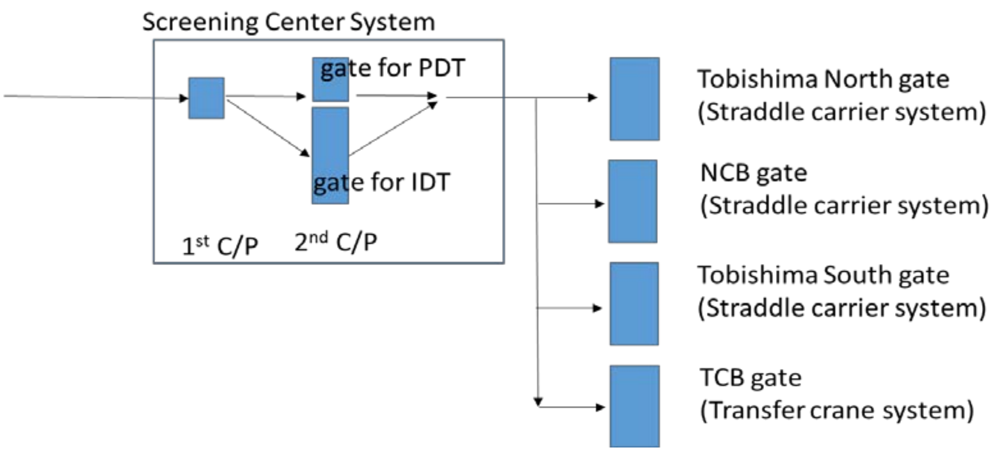

Figure 8 Simulation model layout in the Tobishima Dock

The WITNESS discrete model is introduced to simulate trailer's travel time with and without the SCS. Simulation model layout is drafted at Nagoya port where four terminals are located in the Tobishima dock, namely Tobishima North, NCB, Tobishima South and TCB terminals. The port entrance is a virtual point 10.0 kilometers from the SCS. The SCS is located at the entrance of the Tobishima dock in the model layout. A trailer carrying an export container directly heading to each terminal was originally inspected at each terminal gate before the SCS was introduced. However, the trailer carrying an export container first comes to the SCS and then moves toward the destination terminal after clearing the SCS in the model layout. In addition, the following gate conditions are defined in the model layout (Figure 8 and Table 11).

Table 11 Gate condition at the SCS and four terminals in the Tobishima Dock

Gate	Type of trailer	Number of lanes
First check point in SCS	All trailers for Export	4
Second check point in SCS	Improper document trailer for Export	3
	Proper document trailer for Export	11
	Hazardous container trailer etc. for Export	2
Tobishima North Terminal gate (yard operation: straddle carrier)	Export container	2
	Others	3
NCB terminal gate (yard operation: straddle carrier)	Export container	5
	Others	4
Tobishima South Terminal gate (yard operation: straddle carrier)	Export container	3
	Others	3
TCB terminal gate (yard operation: transfer crane)	Export container	4
	Others	2

6.2.2. Distribution of arrival trailers at the SCS

Table 12 shows the hourly traffic distribution of arrival trailers carrying export containers for each destination terminal in one day based on data collected from 1^{st} to 30^{th} of September 2014. Gate operation hours were from 07:00 to 18:00 plus overtime. The table indicates that traffic peaks were observed from 15:00 to 17:00 and, to a lesser degree, from 11:00 to 12:00. The trailer arrival interval is defined to be evenly distributed in each time band in the simulation. Table 13 shows percentiles of the daily traffic volume of arrival trailers, 1,707 for the 50^{th}, 2,198 for the 95^{th}, and 2,258 for the 97.5^{th} respectively.

Table 12 Hourly traffic distribution of the arrival trailers in Tobishima Dock

Time band	Tobishima North	NCB	Tobishima South	TCB
7:00	0.40%	0.50%	0.40%	0.40%
8:00	1.40%	1.80%	1.70%	1.80%
9:00	4.10%	4.80%	4.70%	4.80%
10:00	7.90%	7.80%	9.80%	7.60%
11:00	9.80%	9.90%	11.00%	10.10%
12:00	8.80%	9.20%	9.70%	10.00%
13:00	4.80%	4.60%	4.40%	5.90%
14:00	13.60%	11.70%	11.10%	10.90%
15:00	15.70%	12.60%	12.30%	12.60%
16:00	13.70%	13.40%	12.60%	13.40%
17:00	9.40%	10.60%	9.90%	10.10%
18:00	6.00%	7.80%	7.60%	8.00%
19:00	4.00%	4.10%	3.90%	3.80%
20:00	0.60%	1.20%	1.00%	0.70%
Total	100.00%	100.00%	100.00%	100.00%

Table 13 Percentile of daily traffic volume of the arrival trailers in Tobishima Dock

Percentile	Daily traffic volume of arrival trailers	Tobishima North	NCB	Tobishima South	TCB
50^{th}	1,707	205	552	445	504
95^{th}	2,198	264	711	574	650
97.5^{th}	2,258	272	730	589	667

6.2.3. Gate service time at the SCS and its setting in the simulation

Two-step trailer check system was introduced at the SCS in the Tobishima dock. All in-coming trailers carrying export containers are obliged to have their documents examined at the first check point of the SCS. Gate service time at the first check point was 30.9 seconds on average at the SCS. There was no distinct difference in gate service time between the PDTs and the IDTs because a trailer driver was preliminarily screened regardless of whether the driver carries a full set of documents or not. The verification of numbers on the documents is carried out at the second check point. The IDTs accounted for 12.65 % and similarly trailers carrying hazardous containers for 0.50 % among all the trailers carrying export containers in September 2014. In-coming trailers carrying export empty containers or receiving import containers were able to directly head to the destination terminal gates. Out-going trailers carrying import containers were obliged to go to the SCS to have their documents checked on the return way from the destination terminal gates. This traffic did not interfere with the gate entry of in-coming trailers carrying full loaded containers at the SCS. (It should be noted that only the trailers carrying full loaded export containers are simulated in this study.)

Figure 9 and Table 14 show gate service time distribution at the second check point of the SCS. All in-coming trailers which had already completed the first-step were obliged to have their container number, trailer ID and the destination terminal verified by the documentation inspection at the second check point of the SCS.

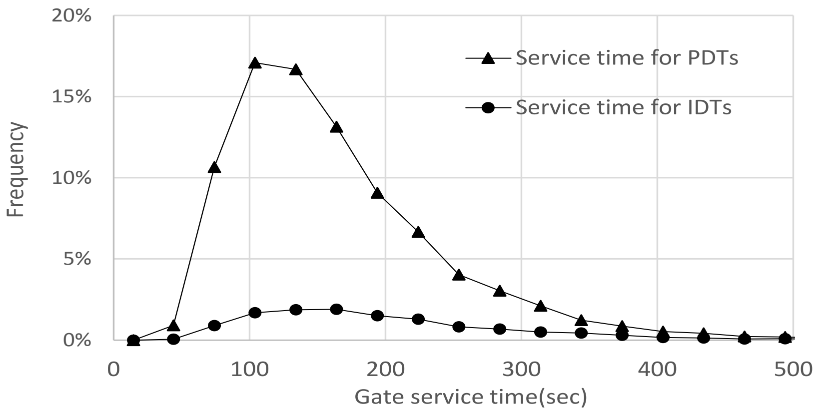

Figure 9 Gate service time distribution at the second check point of the SCS

Table 14 Gate service time at the second check point of the SCS

Gate service time at the second check point of the SCS	PDTs	IDTs	Total
Average gate service time (sec)	165.4	204.5	170.4
Standard deviation (sec)	87.0	114.8	91.9
Number of samples	35,373	5,123	40,496

Gate service time at the second check point was 165.4 seconds on average for the PDTs and 204.5 seconds on average for the IDTs respectively. The total gate service time of the PDTs was 211.2 seconds which broke down as 30.9 seconds at the first check point, 165.4 seconds at the second check point and 14.9 seconds at the destination terminal gate. By contrast, the average gate service time spent at the destination terminal before the introduction of the SCS was 158.4 seconds (note: the average gate service time at the destination terminal before introduction of the SCS represented the gate service time when both the PDTs and the IDTs were inspected). At first glance, the introduction of the SCS has increased the total gate service time by 52.8 seconds. However, despite the extra gate service time spent at the SCS, the SCS succeeded in effectively reducing the total travel time to the destination terminal gate as shown in the next sub-section.

6.2.4. Gate service time at the terminal gate and its setting in the simulation

There are four terminals, Tobishima North, NCB, Tobishima South and TCB in the Tobishima dock. However, the gate service time was only recorded at the TCB gate in January 2012 (before the SCS was introduced) and in September 2014 (after the SCS was introduced). Average gate service time at the TCB gate before the SCS was introduced was 158.4 seconds while it improved to 14.9 seconds after the SCS was introduced (Figure 10 and Table 15). The gate service time variance with the SCS was less than one tenth of that without the SCS because container inspection was simplified and the IDTs were eliminated at the destination terminal after the SCS was introduced.

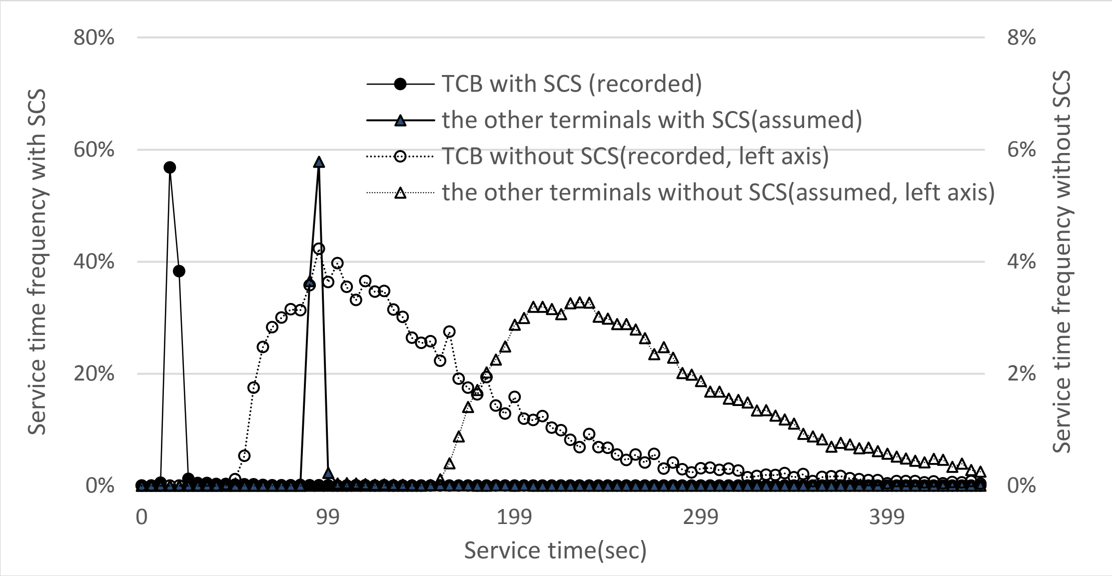

Figure 10 Gate service time distribution settings in the simulation

The TCB employs a transfer crane system for its yard operation while the other three terminals adopt a straddle carrier system. The different yard operation systems resulted in different gate service times. In the simulation, 76.4 seconds are added to the gate service time distribution of the three terminals with the SCS, assuming that the gate service time difference between the transfer crane system and the straddle carrier system is the same as Hakata port (See sub-section 5.2.3). The gate service time distribution of the three terminals without the SCS is represented by the gate service distribution at the second check point of the SCS plus 76.4 seconds.

Table 15 Average gate service time settings in the simulation

Terminal gate (yard operation)	With the SCS	Without the SCS
TCB (transfer crane system)	14.9 (recorded)	158.4 (recorded)
Tobishima North, NCB, Tobishima South (straddle carrier system)	91.3 (assumed) 1) 14.9 sec: service time at TCB with SCS 2) 76.4 sec: service time difference between straddle carrier system and transfer crane system at Hakata port.	277.7 (assumed) 1) 30.9sec + 170.4sec: service times at the SCS 2) 76.4 sec: service time difference between straddle carrier system and transfer crane system at Hakata port.

6.3. Simulation Results on Nagoya port Model

6.3.1. Overview of simulation results

The average travel times from the port entry to terminal gate entry in each terminal are listed in Table 16. The required times with and without the SCS center are compared. As the percentile of number of arrival trailers becomes higher, the average travel time increases more in each terminal. The travel time with the SCS is less than that without the SCS in every terminal gate. Accordingly, the SCS can effectively reduce the travel time in every terminal even though the individual trailer's total service time with the SCS is longer than without the SCS as previously mentioned in sub-section 6.2.3.

Table 16 Average travel time from the port entrance to terminal gate entry by the WITNESS (unit: second)

Percentile	without the SCS				with the SCS			
	Tobishima North	NCB	Tobishima South	TCB	Tobishima North	NCB	Tobishima South	TCB
50th	1,992.0	1,845.4	3,295.7	1,950.3	1,649.0	1,737.6	1,863.7	1,988.4
95th	3,972.2	4,610.7	7,911.2	5,519.1	1,719.7	1,818.0	1,930.7	2,054.9
97.5th	4,398.3	5,171.8	8,476.0	6,138.7	1,751.2	1,836.7	1,942.3	2,074.5

6.3.2. Simulation results-travel time at the Tobishima South terminal

Close relationships between ρ calculated by the queueing theory and travel times obtained by the WITNESS simulation are observed among all except the TCB terminal. For instance, the transition of the travel time from the port entry to terminal gate entry at the Tobishima South terminal in a day is shown in Figure 11. The travel time in the case without the SCS starts to increase between 10:00 to 13:00 and rapidly increases from 14:00, recording a maximum of

11,171.7 seconds at 18:38. On the other hand, the travel time with the SCS is stable, recording approximately 2,000 seconds all day long. Furthermore, the delay is consistent with the utilization rate ρ (Table 17). The utilization rate ρ without the SCS exceeds 1.0 from 10:00 to 18:00 except 13:00. The utilization rate ρ with the SCS is less than 1.0 all day long. These simulations show that the SCS can effectively reduce congestion. In addition, the utilization rate ρ can simply indicate whether congestion occurs or not at a terminal gate.

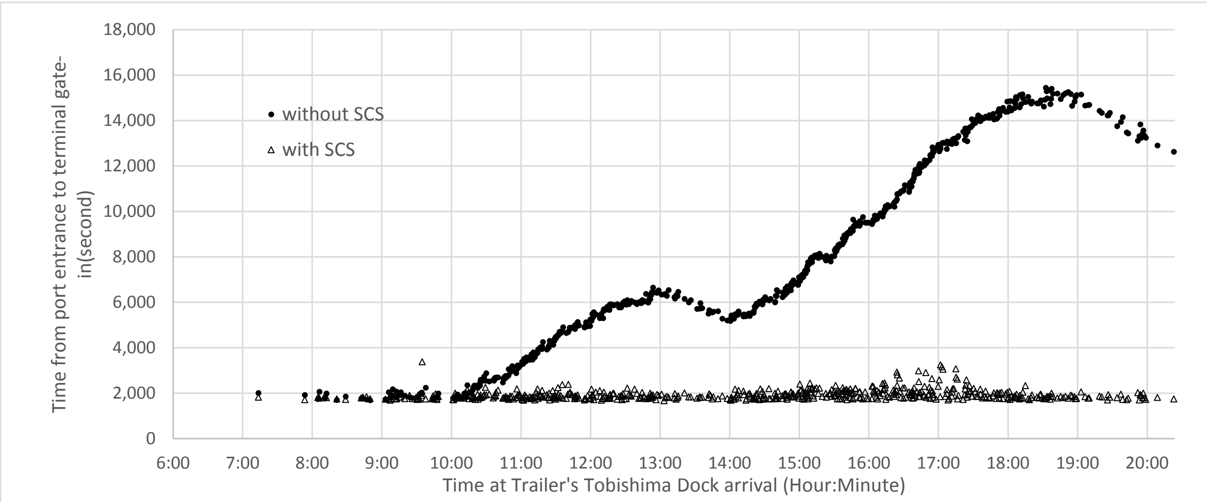

Figure 11 Travel time from the port entrance to terminal gate entry at the Tobishima South terminal by the WITNESS (daily traffic volume of arrival trailers: the 95th percentile)

Table 17 Utilization rate ρ at the Tobishima South terminal obtained by the queueing theory (daily traffic volume of arrival trailers: the 95th percentile)

ρ	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00
with the SCS	0.017	0.085	0.228	0.473	0.533	0.473	0.211	0.533	0.600	0.609	0.482	0.364	0.186	0.051
without the SCS	0.051	0.257	0.694	1.440	1.620	1.440	0.643	1.620	1.826	1.851	1.466	1.106	0.566	0.154

6.3.3. Simulation results-travel time at the TCB terminal

Apart from the results of the three terminal (Tobishima North, NCB, Tobishima South), the utilization rate ρ calculated by the queueing theory is not able to indicate the queue development correctly in the case of the TCB terminal. Even though the utilization rate ρ at the TCB gate, in the case without the SCS, is sufficiently low that congestion would not be expected, the simulation indicates that a heavy delay starts from 12:00 (Figure 12 and Table

18). The travel time without the SCS increases from 12:00, recording a maximum of 12,181.5 seconds at 18:18. This is because the queue formed at the gate of Tobishima South, the next terminal to the TCB, blocks the road to the TCB. This suggests that the queue at another gate may impede the TCB trailer traffic even though the actual traffic volume at the TCB is less than its gate capacity.

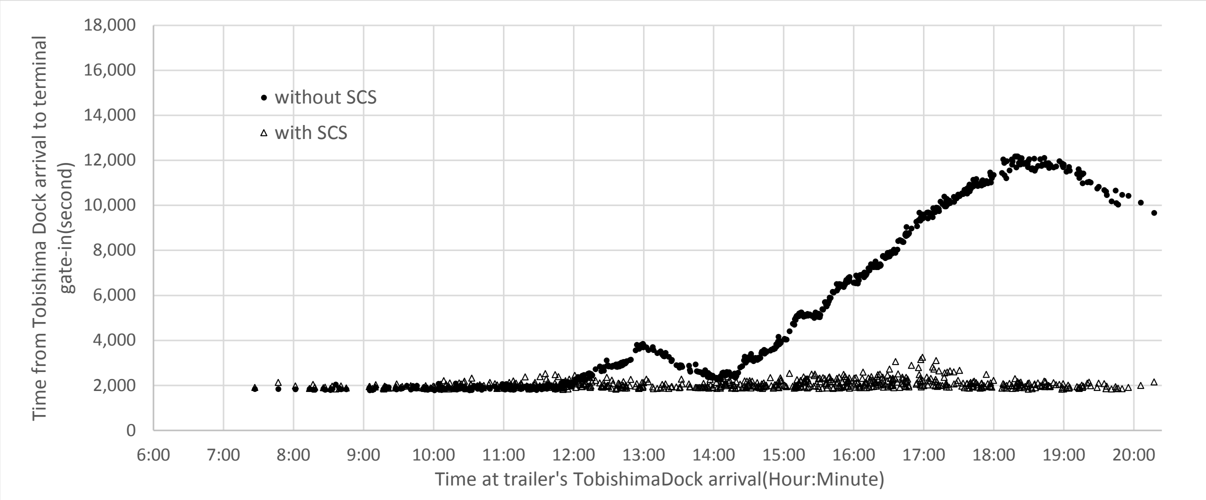

Figure 12 Travel time from the port entrance to terminal gate entry at the TCB terminal by the WITNESS (daily traffic volume of arrival trailers: the 95th percentile)

Table 18 Utilization rate *ρ* at the TCB terminal obtained by the queueing theory (daily traffic volume of arrival trailers: the 95th percentile)

ρ	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00
with the SCS	0.002	0.012	0.032	0.051	0.067	0.067	0.039	0.073	0.085	0.090	0.068	0.054	0.026	0.004
without the SCS	0.022	0.132	0.341	0.539	0.715	0.715	0.418	0.781	0.902	0.957	0.726	0.572	0.275	0.044

7. Application of the social dilemma theory to the landside congestion measures

The authors apply the social dilemma theory to the landside congestion measures introduced in Hakata port and Nagoya port in Japan (Table 19, Figures 13 and 14). These are only the ports that the histories and results of the measures are traceable. The authors examine whether the structural strategy and psychological strategy are reasonably applied to the landside congestion measures at these ports.

Table 19 Landside congestion measure in each port

Port	Number of terminals	Landside congestion measure
Hakata	2 (gates are controlled by a single operator)	IT system with one day before registration, providing container and gate status information
Nagoya	4 (at Tobishima Dock)	Screening Center System (SCS)

Figure 13 Trailer's routes to the terminal gates in Hakata port

Figure 14 Trailer's routes to four container terminals and the SCS in Tobishima Dock, Nagoya port

7.1. Case study of Hakata port

7.1.1. Background of the landside congestion

Hakata port handled 861 thousand TEUs of international containers in 2014. Two terminals are in operation in Hakata port, namely Kashii terminal and IC terminal (Figure 1). With the rapid increase of the container cargo volume since 1998, chronic landside congestion and traffic jams on the surrounding roads became a major issue for the port. The trailers had to wait for about four (4) to five (5) hours to enter the container terminals at a peak-hour of the congestion, and shippers and logistics-related industries requested an immediate solution to the problem. The port made various efforts to ease the landside congestion by increasing the number of gate lanes and straddle carriers as well as other possible attempts, but those efforts eventually ended in failure. Then the port carefully observed the gate service behavior at the terminals, and found that the trailer drivers tried to join the queues at the earliest possible time and the IDTs accounted for 10% of all the arrival trailers. These significantly worsened the gate capacity.

7.1.2. A structural strategy

The port introduced an IT system called the HiTS in 2000, which provides the trailer drivers with the latest container status in a container yard. This system enabled the trucking companies or the trailer drivers to check whether their containers are ready or not in a container yard by sending their container ID numbers or Bill of Lading (BL) numbers. In addition, the HiTS has provided the trailer drivers with the gate and access road congestion status since 2003. The port expected that the trailer drivers or the trucking companies would see the congestion status whether the gate was congested or not before their departure.

In addition to the users' benefits, the port regulated all the arrival trailers to register their container ID numbers and trailer ID numbers one day before their gate arrivals in 2003. All the terminal gates of the port are uniformly and exclusively managed by the Hakata Port Terminal (HPT), while the terminal gates in other major ports are usually managed independently by the terminal operators. Hakata Port Authority (HPA) entrusted the gate operation to the HPT. This exclusive and unified gate operation by the HPT could make the trailer drivers follow the HPT's rule.

7.1.3. A psychological strategy

When the HPT proposed to introduce the new web system in Hakata port, the HPT faced resistance from each stakeholder. For instance, a terminal operator worried about spreading their customer's information to the web system. A freight forwarder feared that cargo owners would request something because they can check their container status through the web system by themselves. Some trucking companies resisted the system which would require them to install PCs, set up an IT network and train their staff all at their own expenses. It was expensive to set up an IT system in those days. At the same time, however, all the stakeholders had a common understanding that the increasing congestion in Hakata port would eventually result in losing the customers.

Accordingly, the HPT had to exercise its ingenuity in developing the system. First, the HPT tried to ensure that the system should be user-oriented. The HPT organized a task force team on the system development with stakeholders such as the HPA, the terminal operators, the forwarding agents, the trucking companies to ensure that the system could meet the needs of the users. The HPT also encouraged the trucking companies and the trailer drivers to join the team. Members of the team were assigned their work to materialize the concept (Table 20). Second, the HPT aimed to design a system that would be simple and easy to use. The system was programmed to provide the minimum required information of the cargo delivery with the registered trucking companies or the trailer drivers in order to make it attractive for the users. Third, the financial support was expected to be vital to make the system more user-friendly. The system's initial cost was approximately JPY 64 million or US$ 640 thousand and was funded by the HPA and the HPT evenly. No fees were levied on the trucking companies or the trailer drivers. Finally, the HPT has provided the guidance to use the system and explained the expected benefits and its non-compulsory system.

Table 20 Roles among the stakeholders to develop the HiTS

Roles	Stakeholders
Web system development, gate control	Hakata Port Terminal (gate controller)
Modification of terminal layout to cope with the web system, tariff setting for web system	Hakata Port Authority
Modification of IT system in yard operation	Terminal operators (yard operators)
Install PC and connect the web system	Trucking companies

7.1.4. Results observation of the measures

The measures have effectively reduced the landside congestion. The HPT had received more than one hundred phone calls from the users in a day until the HiTS was introduced. However, the number of phone calls has significantly reduced to less than five (5) calls per day since the HiTS was introduced. This means that the HPT can successfully change the trailer driver's behavior and let them check the gate congestion status and their container status information before their port entry.

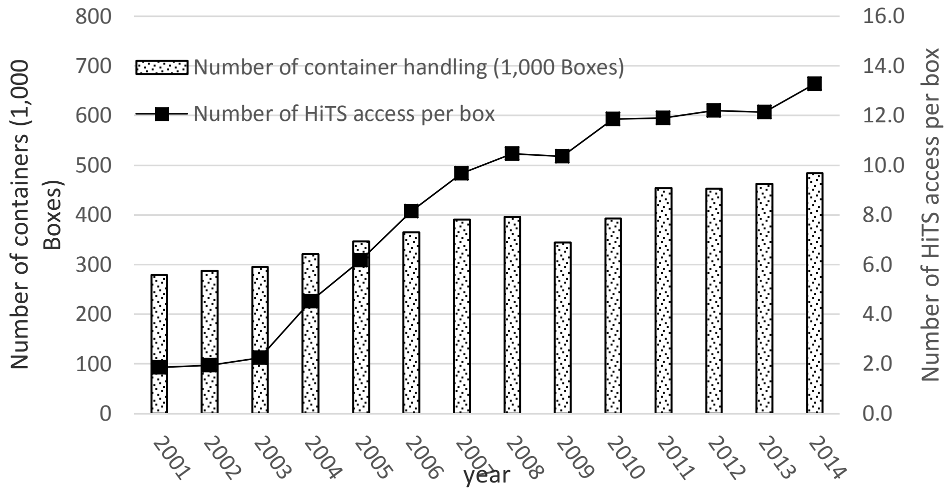

Figure 15 – Transition of the number of HiTS accesses per box and the number of containers handled at Kashii and IC terminals

In addition, the HiTS has been accepted among the trailer drivers year by year. Figure 15 indicates that the number of the HiTS access per box. During the HiTS beginning period, from 2001 to 2003, the trailer drivers including trucking companies accessed the HiTS only two times per box to get container information in a container yard. Since the HPT regulated the one-day in advance registration and introduced free terminal gate live in 2003, the number of the HiTS accesses per box has been increasing steadily and reached 13.3 times in 2014. This proves that the trailer drivers have fully utilized the HiTS for their port entry. The HPT successfully reduced the landside congestion and increased the number of container handling as well.

7.2. Case study of Nagoya port

7.2.1. Background of the landside congestion

Nagoya port handled 2.57 million TEUs in 2014. Tobishima dock consists of four (4) terminals achieving a throughput of 1.47 million TEUs in 2014, namely Tobishima North, NCB, Tobishima South and TCB (See Figure 1). Nagoya port had suffered from a certain number of lost trailers due to complicated road alignment in the Tobishima dock as well as shortage of the yard space, which resulted in long queues of the arrival trailers on the access road to the destination terminals. In addition, four (4) terminals at Tobishima Dock are independently operated by the different terminal operators. Common information sharing system, called Nagoya United Terminal System (NUTS), had already been introduced by the Nagoya Harbor Transportation Association (NHTA) in 2005. This system enabled the users to access the information on ship arrival, container status and customs clearance information. The NUTS can be connected with Nippon Automated Cargo and Port Consolidated System (NACCS) which is an online system for customs procedures and other authorities or private-sector services for arriving/departing ships or import/export cargoes. Even though the NUTS had been introduced, the landside congestion was not disappeared unlike Hakata. Thus the NHTA proposed to establish a Screening Center System (SCS) upstream of the destination terminals to identify and evacuate the IDTs and notify the proper document trailers (PDTs) an appropriate route to the destination terminals. The IDTs accounted for 12.7 % among all the trailers carrying export containers in September 2014. (The import container trailers have to head to the SCS after picking up their import containers at the terminal yard. They don't need to visit the SCS before their destination terminal entry.)

The SCS was established at the end of March 2011, having 22 gate lanes with an area of 5.7 ha (Figure 16). The trailer's routes at the SCS are as follows; a trailer approaches to

1) The weighing spot (the first check point) where a container is weighed and its information is reported to the control room in the SCS,
2) The control room where a clerk checks if the reported container information matches the information obtained from the NUTS or not,
3) The second check point where the appearance of the container is inspected and the container ID is verified, after being sorted into two categories (the PDTs and the IDTs), and
4) The IDT is detained at a parking until all of its documents and trailer ID are corrected while the PDT receives instructions regarding which terminal he is to go.

As a result, this system eliminates the IDTs and all of the arrival trailers at the terminal gates have been verified. In addition, a trailer which cleared the SCS is able to move forward to the terminal gates without any delay because the container information on the trailer has already been sent to the terminal directly through the NUTS.

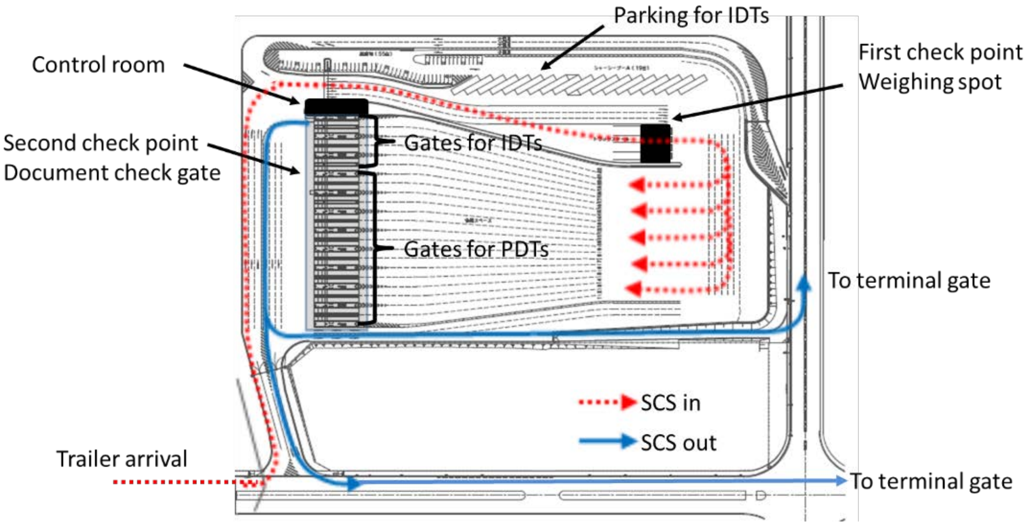

Figure 16 Layout of the Screening Center System (SCS) at Nagoya Port

7.2.2. A structural strategy

A different approach to alleviate the landside congestion was taken at Nagoya port. Situation to change the trailer driver's behavior in Nagoya port is more difficult than that in Hakata port. The four (4) terminal gates are independently operated by the different terminal operators. This means that two tiers of dilemma should be solved. One is the dilemma among the terminal operators and the other is the dilemma among the trailer drivers.

The first tier of the dilemma was solved by the terminal operators by themselves through introducing the SCS as a unified measure. The NHTA including the terminal operators shared the causes of the landside congestion and reached a conclusion to propose a new concept of the SCS by themselves. The NHTA's intensive negotiation with the government, the SCS with 5.7 hectare of land was provided by Nagoya Port Authority (NPA) and Ministry of Land and Infrastructure, Transport and Tourism (MLIT), even though the facility cost JPY 2.0 billion or US$ 20 million. After the completion of the SCS facility construction, the NHTA requested all the arrival trailers should first head to the SCS instead of heading to the destination terminal gates directly. No user fee is collected from the users at the SCS. If a trailer arrives at the terminal gate without verifying its container ID number or documents, it would be rejected to enter the gate. The four (4) terminal operators, which are the members of the NHTA, jointly dispatch their clerks at the SCS to check the arrival trailers and the containers. Consequently, the SCS unexpectedly contributed to a considerable reduction in the landside congestion at the destination terminals, because all the trailers entered the SCS and the IDTs were eliminated by the SCS.

7.2.3. A psychological strategy

The second tier of the dilemma among the trailer drivers was complicated. The NHTA is a voluntary aggregation of the private companies, not be granted a corporate personality yet. Neither compulsory participation nor fine for violation was enforced. None the less, the NHTA requested all the arrival trailers should first visit the SCS. The members of the NHTA had continuously explained their trailer drivers to follow the new scheme which was originally proposed from the user side. In addition to the SCS, the NHTA had proposed several measures to improve the landside congestion: it developed the NUTS, proposed the trailer ID to be marked on the top of the trailers head, and installed the RFID onto the trailers. These grass-root works had built trusted partnership among the trailer drivers and the trucking companies, and resulted in a 100 % of the arrival trailers visiting the SCS at present.

7.2.4. Results observation of the measure

The MLIT and the NHTA jointly carried out the questionnaire surveys to see how the trailer drivers evaluate the SCS and how their consciousness for their behaviors has been changed. The surveys were conducted in September 2012 (just three months after all the export trailers regulated to head to the SCS) and January 2014 (twenty months after the inauguration). The first survey (Figure 16) on the landside congestion perceived by the trailer drivers showed that the number of the positive answers dropped from 75.7 % (32.3% says getting better and 43.4 % says getting relatively better) in 2012 to 56.2% (19.4% says getting better and 36.8 % says getting relatively better) in 2014. On the other hand, the number of the negative answers rose from 6.0 % (2.4% says getting worse and 3.6 % says getting relatively worse) in 2012 to 11.8% (4.7% says getting worse and 7.1 % says getting relatively worse) in 2014.

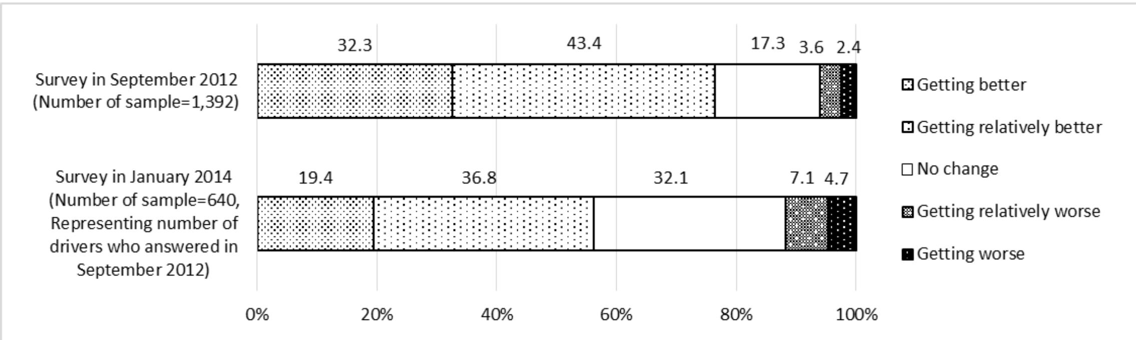

Figure 16 Do the trailer drivers think the landside congestion become eased at Tobishima Dock?

Another survey questions whether the trailer drivers were satisfied with the SCS or not. The result indicates (Figure 17) that the number of the positive answers dropped from 48.2% (15.4% satisfied and 32.8% relatively satisfied) in 2012 to 30.6% (6.8 % satisfied and 23.8%

relatively satisfied). The number of the negative answers rose from 13.5% (5.4% dissatisfied and 8.1% relatively dissatisfied) in 2012 to 31.1% (10.8% dissatisfied and 20.3% relatively dissatisfied) in 2014.

These two surveys indicate that even though all the trailer drivers in fact headed to the SCS, they gradually less evaluated the present situation. As the authors mentioned previously, the psychologist has reported that this phenomena often occur when a regulation is enforced. Hence, it is essential for the NHTA to carefully examine the causes of their complaints and patiently explain them the causes and effects of the landside congestion. Continuous monitoring and numerical stimulation for the drivers' cooperation should also be required to maintain the effective SCS operation until the trailer drivers unconsciously behave cooperatively.

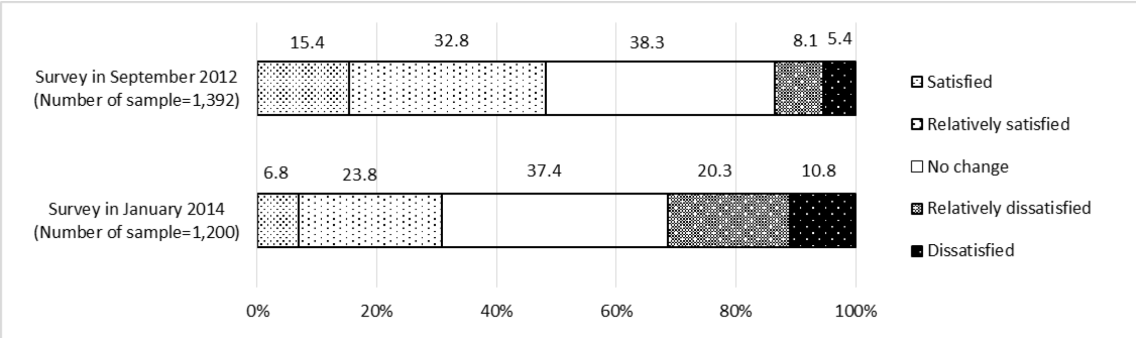

Figure 17 Are the trailer drivers satisfied with the SCS?

7.3. Case study of LA / LB port

7.3.1 Introduction of TAS

Giuliano et al. (2008) pointed out that a clear reduction in waiting time at the gate or turnaround time was not observed when the TAS was introduced at the ports of LA/LB. Assembly Bill AB 2650 requested terminal operators to choose either the TAS or the gate operational hour extension. The Assembly Bill can be regarded as a structural strategy. When the TAS was introduced in nine terminals at the ports, each terminal introduced its own appointment procedure and web system program. Accordingly, trailer drivers had to familiarize themselves with nine different appointment procedures and web systems. In addition, the terminal operators allowed idling trailers to wait in their terminal yard to avoid the fine imposed when congestions occurs at a terminal gate. Furthermore, since only a limited number of inspectors were dispatched to the ports, many violations went un-penalized. This situation allowed the terminal operators to be less than fully cooperative which betrayed trailer drivers' efforts to change their behavior. As a result, the TAS did not succeed in easing congestion.

7.3.2 Introduction of Extended Gate hours (PierPASS program)

A new bill was proposed in California state assembly in order to reinforce the dysfunctional TAS. The bill included the establishment of a new public authority that monitors the gate traffic and levies fines on terminal operators for idling trailer traffic in front of their gates. The ports of LA/LB introduced the PierPASS program against the new bill in 2005 which imposed a traffic management fee (TMF) on consignees and forwarders who bring their cargoes in/out during peak gate hours (Giuliano and O'Brien, 2008). The program was originally designed and proposed by the terminal operators as a counter proposal to the new bill. The additional costs incurred by terminal operators due to opening gates at night or on weekends were compensated for by the TMF. Consignees were able to choose whether to bring a container during peak hours (3 pm to 6 pm on weekdays), paying the TMF, or to bring the container a night or on the weekend without paying the TMF. Terminal operators can reject the trailers arriving during peak hours if the TMF is not paid which eliminated non-cooperative behavior. Since all the terminals joined the program at the same time and participated in good faith, congestion was dramatically reduced. The program guided the terminal operators and trailer drivers to take cooperative actions together. We regard this program as a structural strategy.

7.4. Case study of Botany port

The Botany port reviewed the entry fee and penalty fee charged for late arrivals and no-shows after their initial TAS program failed in the 1990s. Sydney Ports Corporation (SPC), as the port authority of the Botany port, introduced new measures after listening to the opinions of port users. The SPC imposed penalty fees on both trailer drivers for their late or early arrivals and terminal operators for their late operation in their yards. Then, the SPC prepared time risk sharing between trailer drivers and terminal operators. A mandatory RFID system was also introduced which enabled the SPC to effectively monitor cargo movements and impose penalties on violating parties. This effectively eliminated non-cooperative behavior. Monitoring costs were borne by the SPC. In addition, the SPC prepared trailer's parking slot near the terminals so as the trailers can enter the gate at the scheduled time. We regard these measures as a structural strategy.

In addition, the SPC reflected user's opinions when setting the fees and penalties of the TAS as we noted above. This measure gained trailer drivers' trust in the program. We regard this measure as a psychological strategy. Consequently, the turnaround time at the DP world was reduced from 48.2 minutes in 2010 to 30.0 minutes in 2012 (Gilfillan, 2013). The two strategies worked successfully.

8. Conclusions

The authors examined whether the landside congestion measures can be explained by the social dilemma theory, and revealed that the congestion measures can be elaborated by combining the structural and psychological strategies when facilitating the trailer driver's and/or terminal operator's behavior normalization. Even though the preconditions vary between Hakata and Nagoya ports, under which the congestion measures were applied, both ports succeeded in achieving a cooperative behavior of the various stakeholders through the social dilemma theory.

All the container terminal gates are managed and controlled by a single terminal operator, the HPT, in Hakata port. Its structural strategy is to directly provide the trailer drivers with up-dated container status and real-time landside congestion information, and strictly refuse the gate entry of the trailer drivers without the advance registration on their arrivals. At the same time, its psychological strategy is to design a user-oriented HiTS system which enables all the users easily join the system. Furthermore, the HPT emphasized that the cooperative actions among the users have been achieved mainly by elaborately explaining them how to join the system. These vital efforts succeeded in both increasing the cooperatives among the stakeholders and reducing the landside congestion.

On the other hand, four (4) terminals are independently managed and operated by each terminal operator within Tobishima dock in Nagoya port. The port developed the SCS which was located upstream of the dock for pre-checks of the trailer drivers prior to the destination terminals. Its structural strategy is that the trailer drivers with the pre-checks of their containers at the SCS are allowed to proceed and enter the destination terminals, otherwise, those without the pre-checks are not allowed. All the terminals in the dock participated in developing the concept of the SCS, so that the user's requests are carefully reflected in the detail design of the SCS as much as possible. Its psychological strategy is that the NHTA also had made every effort to explain the importance of cooperative actions to properly function the SCS, to both the trucking companies and the trailer drivers. In addition, no fee is levied to the trailer drivers, which succeeded in gaining more involvement in cooperative action.

Due to the limited availability of the case studies, quantitative analysis had not been fully achieved on the user's consciousness survey or the participants before/after the landside congestion measures. The paper also did refer neither how to allocate the time window in the TAS, how long the gate hour be extended, nor how to set a level of the TMF or penalty fee. No papers were found except the cases in the ports of LA/LB and the Botany port referring the failed causes of the congestion measures. The quantitative analysis in the framework of the social dilemma theory has been applied only in the field of passenger traffic or automobile traffic, while few discussed container trailer traffic control in the light of the social dilemma theory. The further academic and practical studies are strongly encouraged to help the ports which are suffering from the landside congestion.

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