Fuel Consumption within Cargo Operations at the Port Industry

- A simulation analysis on the case of S Port company in the UK -

Alarcon Hernandez JA* · Sung-woo CHO** · Myong-sop PAK***

Contents

Abstract

The principal objective of this study is to analyze the consumption of fuel in the port industry, in order to identify some possible solutions or improvements that might reduce costs. The increment of the total operation costs, and especially fuel, has affected company profits; thus, this study focused on improving the utilization of internal vehicles, reducing transportation time, and changing people skills, in order to achieve maximum savings.

To fill this gap, we attempt to establish efficient simulation models using the Witness software in order to identify the optimal scenarios for the optimization of port operations and the maximal reduction of travelled distances. This research is largely concerned with four improvements: (1) the empty container park process, (2) the new operation pads, (3) driving skills, and (4) the heavy lift zone's position.

Key words : Fuel Consumption, Port Industry, Simulation, Cargo Operations, Cost Reduction

* Senior Manager of Schlumberger Surenco S. A., Colombia, Email: zetajhons81@hotmail.com
** Assistant Professor of Kunsan National University, Korea, Email: swcho@kunsan.ac.kr, Corresponding Author
*** Professor of Sungkyunkwan University, Korea, Email: mspak@skku.edu

I. Introduction

The port industry has been recognized as a vital step in the supply chain, and efficient port operations are critical to improving flow through the supply network. The container terminal is a place where vessels and external lorries can be connected to one another via the use of handling equipment. Additionally, a container terminal serves as a storage place for containers until the vessel or external vehicles come to pick them up.[1)]

Ports are an important part of the economy and industry of many countries, and the UK is no exception.[2)] The UK port industry, the largest industry in Europe in 2007, handled 600 million tons of cargo. Imports and exports represent over 95% of the volume of British freight. Container operations have been growing at a rate of 190% during the past two decades, due to global trade between large factories and companies.[3)]

Price effects largely define fuel-use strategies, and can be altered by specific improvements such as traffic conditions, driving skills, and the reduction of distances in operations.[4)] As a consequence, fuel consumption has been considered much more carefully in recent years in the port industry, due to the noted variations in operating costs. This might affect the profit and benefits of the whole company from a financial perspective. A new hybrid drive system for RTGs (Rubber-Tyred Gantry Cranes) based on new technology can be used to reduce fuel consumption as well as engine maintenance, engine speed, and the maintenance of electrical parts.[5)]

This research has several objectives, principal among which is the reduction in the percentage of fuel consumption at the S Ports Company in the UK. These objectives are characterized by a variety of scopes in terms of layout, distances travelled, operating time, and utilization of equipment, as well as cost-saving. The objectives are measurable and may affect the main internal vehicles at the port significantly by comparing the current operations versus the proposed operation.

1) Zhang et al.(2003), p.884.
2) House of Commons Transport Committee(2007), p.23.
3) British Port Association(2010).
4) Goodwin et al.(2004), p.280.
5) Freight Industry Times(2010).

II. Literature Review

1. Port's optimization at the container port

A major concern in the port industry has been the increment of the number of containers that internal vehicles have to handle, in order to optimize the port's performance. When container traffic increases as the result of international trade between companies, congestion in the internal operations in the port increases, as does the demand for the handling equipment. Over the past 20 years, the transportation of containers for general cargo has increased rapidly.[6)]

In a new container terminal, the synchronization of internal vehicles and handling equipment might help to smooth internal operations. This synchronization between the vessels and the storage of the containers might reduce land transportation traffic to the port and might also save resources, including fuel and labor.[7)]

The rapid storage and retrieval of containers in port operations could improve economic performance; if the storage time is reduced, the possibility of reallocating containers is also reduced. The reallocation of containers may increase traffic, as well as operating costs including maintenance, fuel, and labor. Additionally, the efficiency of the container terminal might be reduced as the result of increased transportation costs and reduced productivity.[8)]

The optimization of ports involves a variety of operational aspects, including appropriate container crane scheduling, planning optimization, the synchronization of internal vehicles, and the allocation of resources. The optimization at ports may entail the alteration of a large number of internal processes in order to achieve its objectives in terms of efficiency and productivity; this is why ports have maximized their space and the protocols for the internal handling of their vehicles, with the ultimate objective of increasing profit. One of the most critical aspects in this regard is the allocation of containers at storage, a factor relevant to the furtherance of attempts at port optimization. This problem can be divided into two different stages; the first involves the number of containers placed at each storage block during a specific period of time, and the second is the number of containers

6) Cordeau et al.(2007), p.264.
7) Cordeau et al.(2007), p.269.
8) Bazzazi et al.(2009), p.46.

involved in each vessel at each block over a specific period of time.[9)]

The optimization of ports involves the implementation of various measures to increase productivity and reduce costs. By evaluating the numbers of loaded and discharged containers, this measure can be used to assess the speed of cargo moving between the quayside and the container yard. Additionally, the capacity of cargo moved per hour, or over a specified period of time, represents another measure for the optimization of port operations using internal vehicles and handling equipment.[10)] These types of measures depend on the quality and quantity of the handling equipment and the relevant infrastructure; the correct assignation of handling equipment might improve the quality of port services by reducing unnecessary costs such as extra labor, excessive fuel consumption, and extra time in the vessel schedules.

A variety of problems have been associated with the port optimization effort; these problems, largely, center around internal vehicles, infrastructure, planning, space, and time schedules. The Hong Kong International Terminal has begun to experiment with some issues involved with massive container volumes and limited available space, in response to an increase in the volume of containers moved at 11% from 1988.[11)] The effort to optimize the ports is based on the circulation of the containers between the quayside, the container yard, and the gates; the efficient flow of containers using internal vehicles and handling equipment will increase both productivity and service quality. The congestion of the vehicles at Hong Kong Terminal has affected the flow of containers and the productivity as a result of increased waiting time with regard to the cranes and external vehicles.

2. Fuel consumption at the port industry

An important resource used by equipment at the ports, fuel has been considered an essential part of the process for handling operations by using internal vehicles. Consumption of fuel is necessary at the port industry; however, it is one of the most expensive resources, along with maintenance, tyres and IT systems. The total fuel consumption cost is between 15% and 25% of the total cost of operations, and any variability of fuel will bring financial benefits in operations and transport.[12)]

9) Bazzazi et al.(2009), p.48.
10) Poitras et al.(1996).
11) Murty et al.(2005), p.65.
12) Rentokil Initial(2010).

Price is a significant issue in financial terms; if there is a small variability, the operating cost could change rapidly due to the number of liters of fuel consumed at the port industry. The effect of the price defines the strategy of using fuel by combining specific improvements such as traffic conditions, driving skills and reduction of distances in operations.[13)]

The port industry invests huge amounts of money in IT systems with the objective of optimizing resources such as people, equipment, fuel and processes. By using an IT system, the port industry is attempting to improve the consumption of resources such as fuel. Better fuel efficiency has been achieved by combining technological measures such as distances travelled, operation time and consumption of fuel, with the objective of these measures obtaining a great improvement in fuel consumption, operations and CO_2 emissions at the transport system.[14)] Additionally, there are other aspects that ports must consider in order to reduce fuel consumption and improve operations. The number of vehicles, the total number of kilometers travelled and consumption of fuel based on time and distances are aspects that can lead to a better performance in terms of the fuel consumed in a specific time, and therefore an improvement in cost/profit performance.[15)]

Innovation has helped to achieve a higher profile of fuel consumption at the port industry. Manufacturers of handling equipment have developed a new concept for improving the consumption of fuel. The hybrid drive is a combination of fuel and electricity. By combining these two types of energy, the reduction of fuel at the port industry increases due to the construction and designs of smaller engines. Additionally, the new generation of straddle carriers and internal vehicles could increase the profit of each operation by reducing fuel consumption by 36%.[16)]

There are several options that concern the port industry regarding the cost of fuel; the port operations are trying to implement basic improvements on this issue; however, it is somewhat complex due to the number of jobs involved. Carrying extra weight, maintaining the correct tyre pressure and the same speed, stopping breaking hard, using reasonable acceleration, driving when necessary and maintaining the vehicle well are essential points for the reduction of fuel consumption. Finally, the most important consideration

13) Goodwin et al.(2004), p.284.
14) Banister(2007), p.5.
15) Rentokil Initial(2010).
16) Wijlhuizen and Julialei(2008), p.3.

regarding fuel consumption is the combination of the number of jobs and distances travelled; this factor concerns the assigning of the nearest job after an internal vehicle has finished the previous one. The combining of small trips are one of the solutions to reducing distances and increasing the number of jobs; this will help the consumption of fuel in order to improve the gas mileage.[17)]

As a result, the consumption of fuel has been more considered at the port industry due to the variation of the operating cost. This could affect the profit and the benefits of the whole company in financial terms.

3. Operations modeling at the port industry

A great deal of research has been conducted into the improvement of port operations, and some of this research has utilized technologies such as IT systems and simulation software. Modeling and simulation have been recognized by the port industry in recent years, with the purpose of exploiting the maximum capacity of resources such as people, vehicles, and handling equipment. These types of approaches may allow the company to compare different measures via the application of several operations and resources. Simulations may describe and model various scenarios that can provide insights into process behaviors. Additionally, these types of simulations have reduced implementation costs owing to the number of improvements studied prior to the occurrence of any physical changes to the current process.[18)]

Over the past 10 years, research in this area has increased in response to rapid increases in container productivity. The port of Hamburg in Germany and the Europe Container Terminal in Rotterdam evidence a high level of performance as the consequence of the introduction of state-of-the-art automation.[19)] In addition, these ports, as well as others, have continually introduced new technologies and been open to continuous improvements.

The article “A Simulation Model of Port Operations during Crisis Conditions”, a study of several US ports, describes a simulation model that might reduce disruptions in the supply network induced by external conditions such as natural catastrophes or terrorist attacks. The model was built using the ProModel simulator. This study contains a statistical analysis conducted to

17) Weinger(2009).
18) Onut and Saglam(2008), p.1838.
19) Zhu et al.(2010), p.953.

evaluate relevant variables such as lead times, operational times, and delays.[20)]

In international trade, small- and medium-sized ports are becoming an important part of the supply network, serving as local logistical nodes. Some of them are situated strategically to supply specific regions with a high level of economy; this is why small and medium ports have been investing in new resources and facilities with the objective of increasing efficiency via the use of simulation models. Additionally, simulations can facilitate the assignation of equipment and layout planning. A simulation model may be used to devise the best ways of investing in the proper resources, processes, and equipment, which is very important for small and medium ports, which lack the kind of financial muscle found in larger ports; proper allocation of resources is all the more important, then, for these smaller operations.[21)] Solving problems rapidly and effectively at small and medium sized ports has improved efficiency, specifically via the use of simulation programs in addition to actual experience. This approach may improve the use of human resources, vehicles, flow of goods and information flow, as well as improving the commercial opportunities available for local exporters and importers.[22)]

Finally, ports have been analyzing productivity situations in their efforts to identify the principal problems surrounding the flow of materials (bottlenecks), using historical data. However, ports have also recently attempted to improve their internal operations by combining the aforementioned historic data with simulation programs, owing to the necessity for continuous improvement of the internal transport of containers.[23)]

III. Current Fuel Consumption within Cargo Operations at S Port Company

1. Current situation

During the last twelve months (from June 2009 to May 2010), a company S has consumed a large amount of fuel for internal vehicles, in attempting to improve customer satisfaction and operations processes. The port industry

20) Martagan(2009), p.2834.
21) Schmidt(2010), p.9.
22) Schmidt(2010), p.10.
23) Shammoon(2009).

employs special and heavy handling equipment for the transport of heavy containers and general cargo; however, these internal vehicles must consume large amounts of fuel to complete the number of jobs assigned.

Company S' fuel consumption from June 2009 to May 2010 was measured at 1,999,377.80 liters of fuel consumed by internal vehicles such as straddle carriers, tug masters, lift-trucks, and handlers. Based on the average market price and current agreements between the company S and suppliers, the cost of fuel in the year referenced was roughly £999,688.9.

Straddle carriers are the most important vehicles at this company, and accounted for approximately 78.96% of the total fuel consumption. Other internal vehicles consumed 21.04% of the total fuel; however, along with the straddle carriers, the entirety of fuel consumption at the port was financially enormous.

As a consequence of this excessive consumption of fuel, company S is attempting to achieve improvements based on layout, distances travelled, maintenance procedures and types of jobs done by internal vehicles, in an overall effort to reduce fuel consumption.

2. Factors of consumption for SC, TM, and ECH[24)]

To achieve the objective of this study, we focused on historic data such as fuel consumption and operating times. These two variables are necessary to calculate the fuel consumed over a specific period of time. In addition, this quantity will be used for comparisons of the current state and the improvements realized by using SC, TM & ECH. The factor was calculated using data collected during the same period of time in the current state: the average fuel consumption in terms of liters of fuel, and the average operating time in hours. These data were calculated for SC, TM and ECH, which are the internal vehicles analyzed in company S' operations.

The relevant characteristics of the company can be determined using data acquired from advanced IT systems regarding internal equipment. However, the company did not collect data such as fuel consumed for specific distances travelled for a long time. For this reason, our case focused on fuel consumed over a specific period of time (operating time).

The following calculations explain the consumption of fuel over operating time. This means that our fuel consumption figures are reliant on the

24) SC(Straddle Carrier), TM(Tug Masters), ECH(Empty Container Handler).

number of operating hours for each type of internal handling vehicle. Besides, these calculations are based on the average operating time and fuel consumption of each type of vehicle in the year mentioned. In this case, the final results obtained by the calculated factor will be used in the final stage (improvements); these results will be the basis of all comparisons between the current operations and improvements.

<Table 1> Average fuel consumption of SC, TM, and ECH

	SC	TM	ECH
Formulation	Average fuel consumption per hour = fuel (liters) / time (hours)		
Average operating time (hours/year)	2,533.38	643.85	1,378.67
Average fuel consumption (liters/year)	46,423.00	2,779.23	5,638.03
Average fuel consumption (per hour)	18.32	5.87	4.09

Source : Bob Jones extracted from fuel management in Merridale system in 2010.

The calculations show the combination of the operating time in hours and the fuel consumption in liters, allowing the consumption of fuel in one hour to be calculated. Based on the data mentioned, a SC consumes 18.32 liters/hour, a TM consumes 5.87 liters/hour, and an ECH consumes 4.09 liters/hour. The analysis conducted herein was based on these factors calculated, due to the constraints on the company's data, in terms of fuel consumption based on distances travelled.

3. Labor cost and running cost

There are other costs that the analysis must consider: in this case, the labor cost (driver costs) and running cost. If any improvements are made in operating time and fuel consumption, the running cost and labor cost are automatically affected, as they are costs based both on the use of vehicles and human resources. The following table shows the labor costs depending on the number of hours. The driver receives a different salary depending on the type of vehicle and its variable, due to the number of hours registered during a week.

<Table 2> Labor costs

Labor cost (£/hours)		
	35.5 hours	Over 35.5 hours
SC	18.02	19.22
TM	15.20	16.20
ECH	16.28	16.28

Source: Bob Jones extracted from fuel management in Merridale system in 2010.

Table 2 shows that the driver of the SC earns the highest salary, followed by the TM driver, as well as the ECH driver. Additionally, the data shows that after 35.5 hours/week, the drivers of the SC and TM may obtain additional extra pay; this is in contrast to the ECH driver, who always makes the same amount. As a result, the labor cost is a comparison point between the current process and the proposed process. This research took into consideration this type of cost because the analysis was based on the operating time (the labor time spent on the manipulation of the internal vehicles).

The following table contains the running costs for SC, TM and ECH based on historic data. The data for this particular case were from January 1, 2009 to December 31, 2009, in terms of maintenance cost and operating time.

<Table 3> Running cost

Running cost (£/hours)		
	Mean	SD (Standard Deviation)
SC	18.80	10.60
TM	14.57	5.74
ECH	9.06	4.28

Table 3 shows that the SC has the highest running cost, due to the driver cost and the operating time. The running costs achieved a level of £18.80/hour with a standard deviation(SD) at £10.60/hour, due to the fact that the port operates with a mix of old and new SCs, and a TM consumes £14.57/hour, with a standard deviation of £5.74/hour, due to the reduction in operational hours. Finally, the ECH is the internal vehicle at S Port company that consumes the least in terms of running costs - it consumes £9.06/hour due to the number and types of jobs that it does, such as lifting empty containers.

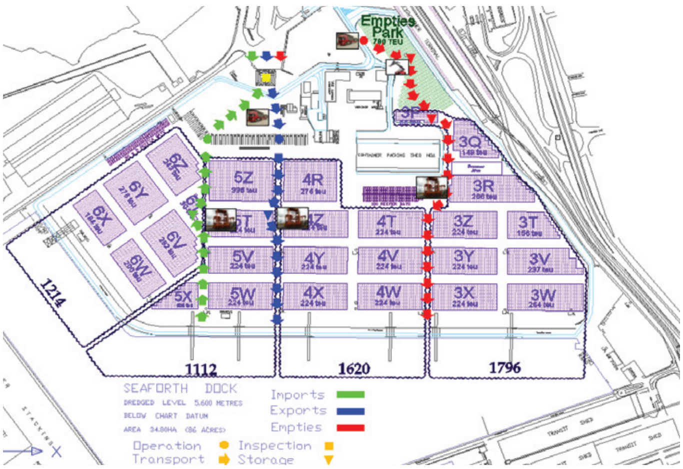
4. Mapping of current process

Here, we explain the current operations and the most important processes at the Container Terminal in Port company S. Generally speaking, these processes are considered by this company to be an essential part of the terminal, and critical to normal daily operations. A firmer understanding of these processes might help in devising better ways to improve current operations. In this section, the analysis utilized the "flow diagram form", one of the simplest techniques, in order to clarify the current situation at the port. By mapping these processes in a standard form, this research demonstrates the achievements at each improvement by comparing the proposal and the current operations at the Container Terminal of Port company S.

It is important to note that the transportation times of this analysis vary widely, due to the long distances between different places inside the port as well as the number of operations undertaken at the port; for this reason, the data on these standard forms must be updated more frequently to obtain accurate information for Port company S.

In addition to this analysis, the flow diagram uses the "map of the terminal" to illustrate the current layout that might help other later analyses. The objective of utilizing the current terminal map is to understand the advantages of changing current operations as well as swapping the internal vehicles. The research focuses on transport time, which is why a firmer understanding of the map might help clarify the improvements. These improvements may result in reductions in labor, running costs, and fuel costs (see Figure 1).

<Figure 1> Current flow diagram of the terminal



IV. Improvements and Results

The case explains several improvements that have been realized at company S; each type of improvement was tested in the field using internal vehicles as well as cargo. The results were compared based on the current analysis and the data calculated. The case has been divided into four important improvements that will be explained in more detail later on. The final results may show comparisons between the current and proposed scenarios; these results involve the fuel consumption, labor costs and running costs of each type of vehicle. Analyses and comparisons between these three factors will demonstrate the benefits from a cost-saving perspective.

1. Empty container park

1) Improvements of empty container park

This improvement was based on the changes to the current areas of the port. This process has been tested at different points in the container terminal using different types of internal vehicles such as SC and TM, as well as different cargo types. The analysis was based on the transport of empty containers; however, the improvement was tested by moving a full container of 30 tons to smooth the driving conditions and the traffic in the port.

The improvement considers several assumptions, with the objective of demonstrating the current conditions of the process. These assumptions are as follows:

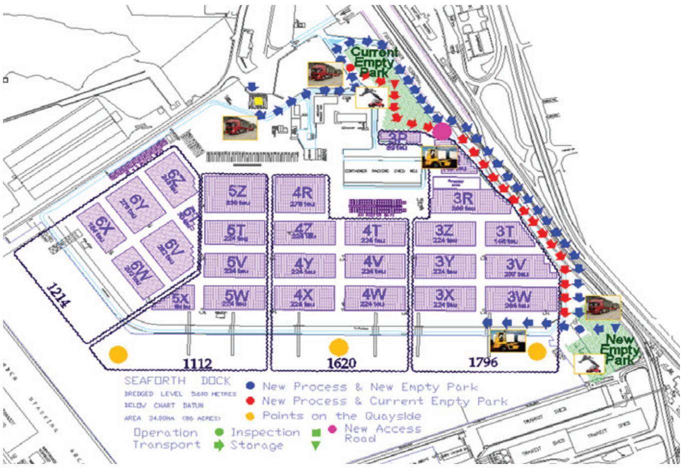
1. The current operation involves moving empty containers to the quayside; however, the new improvement was probed using full 30 tons containers.
2. The analysis focuses on transportation time between different places in the port. If the time increases, the distances travelled also increase. This assumption was made due to the missing data regarding fuel consumption based on distances travelled.
3. Traffic and congestion were smoothed by stopping vehicles once during the testing, between different points of the process.
4. The testing did not use the speed limit; also, the route to the final point was left up to the driver’s judgment.

First of all, to identify this improvement, the analysis was made by employing a new zone located next to the quayside. The improvement was tested with a TM, conducting the same operation as the SC. In this case, the TM used a semi-trailer, with the intention of moving the loaded container. Besides, this process at the empty container park was analyzed at the current position using a new access point on the road, for ready access to the quayside. This analysis was realized in the new proposed process, using a TM to feed the cranes on the quayside (see Figure 2).

The improvement may reduce the “3P Area” shown on the map in Figure 2. This is the current breaking area used by SC; however, by using a TM for this improvement, the layout does not need to include this area. The new process has been explained in flow diagram form, as well as flow diagrams superimposed on the terminal plan.

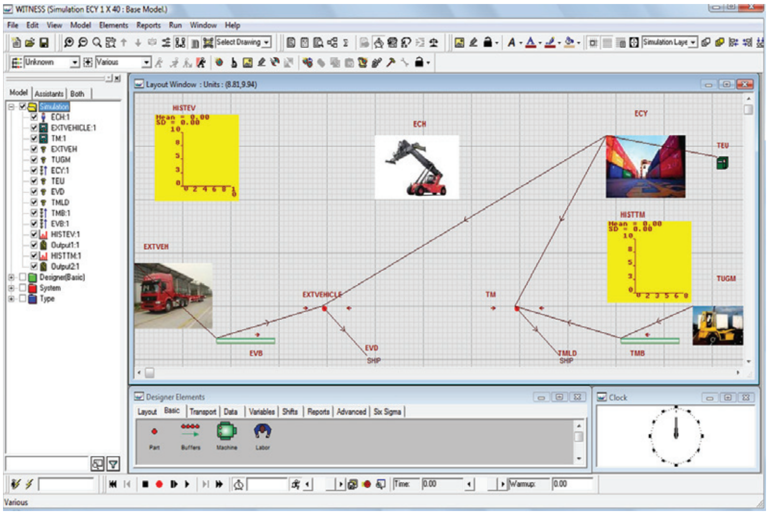
Another important point that specifies points on the quayside was used to define the final point. All vessels, however, may have different positions on the quay due to the sequence and bookings of arrivals. In this case, the research defined three different points along the quay with the objective of smoothing the transport time during the distances travelled. The new improvement requires an empty handler with the intention of loading, as well as discharging, external vehicles. However, the TM also requires the same handler. This is why the new process has to demonstrate that this empty handler is available to serve these two operations without affecting internal operations on the quayside and the queue of external vehicles (customers).

<Figure 2> A new proposed process flow diagram



To demonstrate this improvement, a simulation was conducted during this research by using “witness software”; this simulation might explain various scenarios involving one or two handlers, as well as changing the cycle time at the TM point, due to the load of (1 X FEU) or (2 X TEU).

<Figure 3> A simulation model of Witness program



2) Results of empty container park

The improvement at the empty container park involves two options to improve the current process; first, the improvement proposes a new zone next to the quayside; secondly, the current zone using a new access road is proposed. The following table, Table 4, explains the savings achieved by using up to two semi-trailers and combining two sizes of containers, such as TEU and FEU units. Moreover, the results show that the percentage of reduction of costs has decreased for each option, and can be compared with the costs of the current process.

In order to understand these results, it is important to note that the improvements are based on transportation time; however, on the other hand, the savings obtained are based on the number of movements, due to the fact that the new process has changed an internal vehicle with the objective of transporting more than one container during a single trip.

<Table 4> Saving cost effects of a new proposed route

New Area	Current	1 semi-trailer		2 semi-trailer	
		1 × 40	2 × 20	2 × 40	4 × 20
Fuel cost(£)	23,756.39	11,368.34	10,018.57	10,018.57	7,176.49
Labor cost(£)	141,382.27	116,403.08	73,611.85	78,883.56	54,973.62
Running cost(£)	112,590.04	78,845.02	50,360.97	53,870.09	283.57
Total operation cost (£/year)	277,728.71	206,616.44	133,991.40	142,772.22	62,433.67
Saving Cost (£/year)		71,112.26	143,737.31	134,956.49	215,295.04
Reduction(%)		25.60 %	51.75 %	48.59 %	77.52%
Current Area & New Access	Current	1 semi-trailer		2 semi-trailer	
		1 × 40	2 × 20	2 × 40	4 × 20
Fuel cost(£)	23,756.39	24,923.79	16,796.30	16,796.30	10,565.35
Labor cost(£)	141,382.27	175,222.64	103,021.63	114.175.29	72,023.00
Running cost(£)	112,590.04	117,998.35	69,937.64	77,362.09	283.57
Total operation cost (£/year)	277,728.71	318,144.78	189,755.56	208,333.67	194,856.79
Saving Cost (£/year)		-40,416.07	87,973.14	69,395.04	194,856.79
Reduction(%)		-14.55 %	31.68 %	24.99 %	70.16 %

As a result, by using the zone next to the quayside, the total savings rose from £71,112.26 to £215,295.04, with a minimum reduction of 25.60% and a maximum reduction of 77.52%. On the other hand, the current zone using the new access road achieved an increase in costs of £40,416,07 by transporting one container at each trip; however, by moving two containers or by using a second semi-trailer, the process increases the savings from £69,395,04 to 194,856,79; in other words, by using a new access road, the savings might start at 24.99% and go up to 70.16%; this depends on the sizes of containers the customer requires.

This improvement demonstrates that the empty handler that loads the external vehicles (customers) might load the TM at the same time, without affecting normal operation on the quayside as well as the queue of the external vehicles. For this reason, this improvement has been supported by a simulation model in order to assess the optimal use of the vehicles involved in the process.

Table 5 shows the results of various scenarios in the simulation by combining the external vehicles, the empty handler and the tug master. The simulation helps in this case by determining whether the empty handler is able to do the jobs simultaneously; for this reason, the model shows the results for both improvement options.

<Table 5> Results of the simulation model

Scenarios (New zone)	% Busy of ECH	Queue TMB	Queue EVB	Scenarios (Current zone)	% Busy of ECH	Queue TMB	Queue EVB
1 ECH & 1×40	80.44%	4	6	1 ECH & 1×40	47.15%	1	2
1 TM 2×20	73.7%	1	3	1 TM 2×20	67.77%	1	2
1 ECH & 1×40	100%	329	348	1 ECH & 1×40	100%	9	216
2 TM 2×20	100%	75	425	2 TM 2×20	100%	2	296
2 ECH & 1×40	52.21%	319	1	2 ECH & 1×40	53.21%	11	2
2 2×20	36.79%	69	1	2 2×20	56.78%	2	1
2 ECH & 1×40	**52.21%**	**3**	**1**	2 ECH & 1×40	53.10%	1	2
2 2×20	**63.38%**	**1**	**1**	2 2×20	56.67%	1	1
2 ECH & 1×40	53.24%	56	2	**2 ECH & 1×40**	**53.05%**	**3**	**1**
3 2×20	90.02%	3	2	**3 2×20**	**79.92%**	**1**	**2**
				2 ECH & 1×40	53.09%	47	3
				4 2×20	97.37%	60	5

As a result, the best combination is “2 ECH & 2 TM2”, due to the fact that the handlers have been busy at a utilization rate of over 50%, and the queue of the external vehicles (as well as the tug master) does not increase significantly; additionally, by operating two TMs, the vessels are not required to wait for long periods of time, because the TM can feed the cranes constantly.

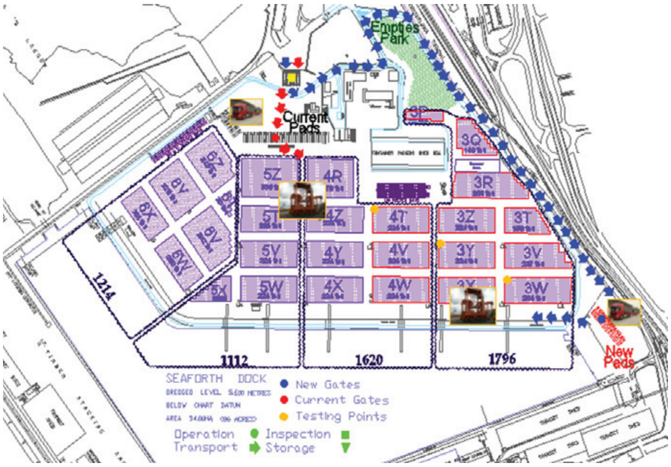
2. New operation pads

1) Improvements of new operation pads

The improvement in company S consists in dividing the pads where the external vehicles wait to be served. The analysis shows the benefits of the SC with the objective of reducing the time of transportation between the gates and the storage. The terminal plan illustrates the new position of the gates and the areas that need to be served by the SC.

According to the number of movements in these zones, the improvement requires 16 new gates situated on one of the sides of the terminal layout. These gates have to cover the following areas: 3W, 3V, 3T, 3R, 3Q, 3P, 3X, 3Y, 3Z, 4W, 4V and 4T. These zones have been shown on the map (see Figure 4).

<Figure 4> A new proposed route for pads



On the other hand, the current pads might cover the rest of the zones. By reducing the transportation time of the SC, and based on the number of movements, the operations reduce fuel consumption, running costs, and labor costs by increasing the number of movements over the same time period. This improvement compares to the current and the proposed situation regarding transportation time, running costs, and labor costs, based on the number of movements per month. The proposed and current operations entail several assumptions, premised on smoothing the traffic and the distances travelled at different points of storage. The aforementioned assumptions are as follows:

1. The SCs were tested in the field by transporting a 40ft full container of 30 tons.
2. The implementation was decided on three different points over the storage time to compare the shortest and longest distances.
3. The driver determined the way between the current pads and the points at the storage, as well as the roadway from the proposed gates.
4. The SC stopped once between the pads and the points at the storage, and vice versa.
5. At each point, the SC unloaded the container on the floor in addition to lifting it.

2) Results of empty container park

The results of this improvement could demonstrate savings in financial terms, by including fuel costs, labor costs, and running costs. In this subsection, the results explain the comparison between the current process and the proposed process, in order to demonstrate clearly the performance of the data obtained. Using this information, company S may consider the implementation of this improvement. The following table 6 shows the final results by explaining the total savings over a time period of one year; additionally, the data shows the benefits of this improvement.

<Table 6> Savings at the new operation pads

Number of movements: 8,220 per month				
	Current process	Proposed process	Savings/year	Reduction(%)
Fuel costs(£)	76,066.89	64,518.78	11,548.11	15.18 %
Labor costs(£)	157,523.48	133,298.60	24,224.89	15.38 %
Running costs(£)	156,121.51	132,419.89	23,701.61	15.18 %
Total(£)	**389,711.88**	**330,237.27**	**59,474.61**	
Transportation Time (sec/move)	303.00	257.00	46.00	15.18 %

By considering the new process and assigning the areas at the container park (storage), the process could save £59,474.61 a year. It is important to recognize that these savings include the fuel costs, the labor costs (driver), and the running costs of the SC. Moreover, due to the fact that the improvement was based on transportation time, the reduction of these types of costs is similar; this is why the total cost has been reduced by 15.18%. On the other hand, if company S elects to increase the productivity and the number of movements in this part of the container park, the saving costs could increase automatically. Finally, by showing the analysis from a different perspective, if the proposed operation takes the same amount of time, the company could increase productivity by 15.18%; as a result, the number of movements that the SC could conduct in the container park, using the new pads, could rise from 8,220 to 9,692 a month.

3. Driving skills

1) Improvements of driving skills

The case analyzed improvements in several ways via the implementation of different operations, processes and handling vehicles. The improvement discussed herein is based on driving skills, involving the training of internal SC drivers at company S. The case described in this section illustrates a strategic idea for the reduction of fuel consumption without the need for any type of financial investment; this idea might be explored to develop simple techniques to reduce fuel consumption by empowering drivers and combining their experience.

Another new concept has contributed to increases in productivity and reductions in fuel consumption costs, by changing the driver's behavior. "ECOLOMIC" is a combination of ecological and economic progress in driving skills; this concept might ultimately reduce the consumption of fuel by up to 20%. In addition to this, by educating a full truck fleet of drivers, fuel consumption might be reduced by up to 45%.[25)]

The following table shows two different teams; "Drivers Trained" is the team that received instructions with the objective of reducing fuel, and on the other side, drivers without knowledge of this exercise; in the end, the data was compared using the same operation conditions and the same operating time conditions. Table 7 shows the data analyzed in terms of operating time, number of movements per hour, idle time, and the number of movements for each driver. In addition, the table shows the average rate of (movements/hour) obtained by the system. This data has been compared between the two teams with the purpose of determining variations in fuel consumption, based on the factor calculated previously; this factor shows the number of liters of fuel consumed by an SC per hour.

25) Muster(2000).

<Table 7> A comparison fuel consumption between trained and other drivers

Drivers trained						Other drivers					
Observ	SC	Time (min)	Mov/ hr	Idle time (min)	Tot. mov	Observ	SC	Time (min)	Mov/ hr	Idle time (min)	Tot. Mov
1	64	110	14.20	12	26	1	83	105	13.70	10	24
2	85	47	9.00	8	7	2	88	106	13.00	24	23
3	90	108	12.20	20	22	3	90	104	11.00	39	19
4	91	78	13.80	18	18	4	92	104	11.60	32	20
5	84	95	12.00	17	21	5	77	70	4.30	43	5
6	85	104	12.70	22	22	6	78	43	11.10	12	8
7	63	35	10.30	4	6	7	90	107	6.50	41	8
8	64	90	14.00	18	21	8	77	115	6.80	49	13
9	91	72	14.10	13	17	9	91	109	8.80	27	16
10	82	108	7.80	35	14	10	83	110	12.50	40	23
11	85	105	9.10	28	16	11	83	107	10.60	14	19
12	86	109	10.00	27	18	12	86	109	12.10	30	22
13	88	113	12.20	17	23	13	87	86	7.70	51	11
14	91	110	11.00	20	20	14	82	55	6.90	9	6
15	93	58	10.30	11	10	15	93	200	8.60	34	10
16	64	102	8.80	15	15	16	95	108	10.80	7	8
17	73	70	8.50	17	10	17	83	60	9.10	33	9
18	93	85	10.80	33	15	18	86	114	4.50	66	7
19	73	109	9.40	6	17	19	89	112	10.50	29	11
20	91	59	13.20	15	13	20	85	109	12.10	24	22
21	62	54	13.30	17	12	21	83	105	8.60	34	15
22	83	104	11.50	15	20	22	86	76	7.10	41	9
23	82	112	12.80	27	24	23	88	66	6.30	30	7
24	85	108	10.50	26	19	24	84	69	15.60	16	18
25	87	101	10.10	29	17	25	94	109	6.10	56	11
26	91	106	8.00	34	14	26	95	103	6.80	39	9
27	93	44	8.10	14	6	27	95	77	8.60	30	11
28	95	108	8.90	19	16	28	83	105	8.60	34	15
29	85	120	9.00	22	18	29	85	111	8.70	52	16
30	85	57	10.50	15	10	30	84	110	9.30	36	17
Rate (mov/hr): 10.87						Rate (mov/hr): 9.26					

The following calculations demonstrate the comparison between the driving skills of two different teams. It is worth noting that the total time includes the idle time in this exercise; idle time comprises the time that the SC consumes in waiting for a specific job. In this case, the time that the SC consumes in one movement (hours/movement) is calculated; on one side, the team trained consumed 0.0920 (hours/movement), and on the other side, the drivers consumed 0.1080 (hours/movement). As a result, the trained team consumed less time per movement than the other team, owing to the fact that the trained team adopted the following assumptions:

1. Do not use the maximum speed.
2. Do not brake hard.
3. Stop if there is no job assigned.
4. Go slow if there is a lot of traffic.
5. Do not make unnecessary movements.

2) Results of driving skills

In this improvement, the final results show savings in terms of fuel. After training a team of drivers in specific assumptions and conditions, as explained in the previous section, the trained drivers show improvements as compared to the untrained drivers. The analysis compared the drivers during the same shift, as well as the same conditions of operation, at the container park.

The table 8 shows the number of movements/hour and the number of liters of fuel consumed/movement. Based on these results and using the factor calculated in the previous chapter, which is 18.32 liters/hour, the final results show the total number of liters consumed based on the number of movements per year. Table 9 explains the comparison between two types of drivers using a SC. The trained drivers saved up to 196,065 liters of fuel per year; in other words, assuming that the cost per liter is £0.50, a total savings of £98,032.27 in a one-year period could be achieved. In addition to the final results, and based on the number of liters of fuel consumed in the past 12 months, a reduction of fuel of up to 9.81% of total fuel consumption could be achieved at the port company.

<Table 8> The preliminary data for calculation

	Basic data	Unit
Number of movements	670,560	Movements/year
Average consumption per hour (SC)	18.32	Liters/year
Costs per liter of fuel	0.50	£/liter
Total costs a year	999,688.90	Liters/year

<Table 9> Savings by implementing driving skills

	Drivers trained	Other drivers	Savings	Reduction(%)
Movements/hour	10.87	9.26	1.61	14.78%
Operating time(hours)	44.68	49.40	4.72	9.55%
Liters of fuel/movement	1.69	1.98	0.29	14.78%
Liters of fuel/year	1,130,422	1,326,486	196,065	
Costs/year	£565,210.93	£663,243.19	£98,032.27	
Total reduction				9.81%

Finally, by implementing driving skills as a technique without financial investment, the data shows a reduction of 14.78% in terms of movement/hour and liters of fuel consumed/movement. From a different perspective, by improving driving skills, company S may increase productivity by assuming the same total consumption of fuel in one year; the number of movements could rise from 670,560 to 785,627 movements per year.

4. Heavy lift area

1) Improvements of heavy lift area

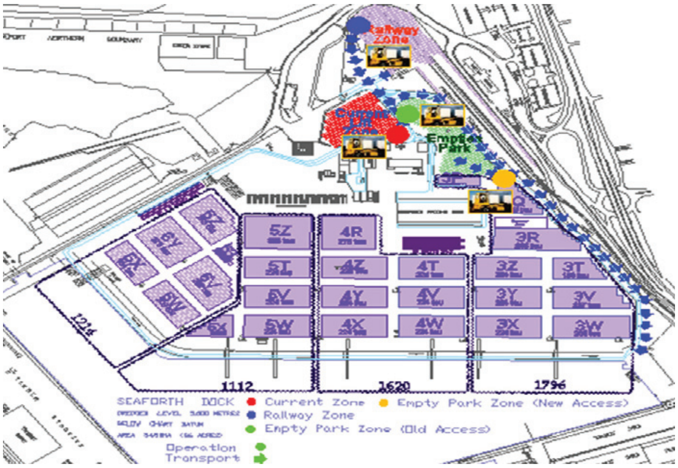
Company S has a heavy lift area; this area involves some of the most complex operations due to the types of cargo handles. However, the number of movements is not representative for the company; the case involves different options on the current layout to reduce transportation time in terms of fuel costs, labor costs, and running costs.

This operation has to transport general cargo to the quayside when the customer requires the product. This case compares the current position of the heavy lift area with three other different positions in the port. These positions are listed on the map in Figure 5.

The case was based on transportation time between the quayside and the zones explained on the map. The current operation was compared with the proposed positions, and the data used for proposal and current positions were collected in the field; the data analysis conducted will be explained in the next subsection. This improvement is reliant on the following assumptions:

1. The transportation time was tested using a tug master with a 40ft container, holding a total of 30 tons.
2. Between positions the driver stopped twice in order to reduce the traffic conditions in the port.
3. During testing the speed limit was not considered and the analysis was not focused on the operation time. The analysis was focused expressly on transportation time.
4. The cost analysis was based on the number of movements per month over the last month.

<Figure 5> The three different positions of the heavy lift area



2) Results of the heavy lift area

The improvement has considered different positions of the heavy lift area at the port, and the analyzed data was compared with the final results in terms of savings and transportation time. In addition to this, the results obtained were analyzed in comparison with the current position in order to gain understanding of the benefits of this improvement.

Table 9 shows the total savings for each position point of the heavy lift zone; the savings represent reductions in terms of transportation times between the positions analyzed and the quayside; additionally, the results are based on the number of movements, in order to calculate the final saving in terms of time and costs.

<Table 9> Results of heavy lift area improvement

Number of movements/month 240				
	Current zone	Railway zone	Empty zone (old access road)	Empty zone (new access road)
Fuel cost	£1,486.62	£1,355.13	£1,182.17	£626.11
Labour cost	£7,699.31	£7,018.35	£6,122.56	£3,242.67
Running cost	£7,379.19	£6,726.54	£5,868.00	£3,107.84
Total operation cost (£/year)	**£16,565.11**	**£15,100.02**	**£13,172.73**	**£6,976.62**
Saving cost (£/year)		**£1,465.09**	**£3,392.38**	**£9,588.49**
Reduction(%)		**8.84%**	**20.48%**	**57.88%**
Transportation time (sec/move)	633	577	504	267

Firstly, the results demonstrate that the railway zone evidences the lowest reduction, with an achieved savings of 8.84%, owing to the fact that the distance travelled decreased very gradually. Secondly, the empty zone created by using the old access road could reduce up to 20.48% of the costs, due to the fact that the position reduces the distances travelled in comparison with the railway zone. Thirdly, the empty zone created using a new access road, could reduce the costs by up to 57.88% in comparison with the current position of the heavy lift area. This means that a reduction of roughly £9,588.49 could be achieved by using the empty zone and reducing the distances travelled via the establishment of a new access road. Additionally, it is important to remember that the costs include the fuel costs, labor costs, and running costs of the TM. This reduction was based on transportation time; the research did not make any improvements in the operation, due to the fact that the heavy lift process involves diverse types of lifting.

V. Conclusions

The operations at the container terminal demand new uses of handling vehicles in order to satisfy productivity as well as customer requirements. Additionally, these vehicles require resources such as people, fuel, and services with the objective of completing the final operation. This study has focused on the fuel management of internal vehicles, although the analysis considered other costs associated with fuel consumption, including running and labor costs.

The research described herein proposes several improvements with the objective of reducing fuel consumption without affecting productivity. These improvements were tested in the field using the vehicles involved in the process; Moreover, these improvements might help the operations cargo department to identify the best resources, positions in the port, and operations, with the intention of reducing costs associated with fuel as well as productivity increases.

One important aspect of this research was that it did not focus on the time taken by the vehicle conducting the operation; the present study has reduced fuel consumption during transportation time via the use of internal vehicles. By implementing four improvements in the port and by probing the internal vehicles in the field, this research concluded the following:

1. At the empty container park, a reduction of 34.76% was achieved, by including fuel, labor, and running costs. This reduction was made by using the new area located next to the quayside.
2. By using the current area and the new access road, the research findings would reduce fuel by 31.68% by including the aforementioned costs. In addition, the results of this study show that this option is suitable only for 20ft containers, or cases in which two semi-trailers are employed.
3. The new process at the empty container park involved a different distribution of the internal vehicles. By using these vehicles, the port has expanded the storage zone by 1.53%, due to the fact that that the process does not require a breaking area.
4. New operation pads have saved up to 15.18% a year (£59,474.61); however, the port company must consider an initial investment of £500,000 in order to build 16 new pads.
5. The study results demonstrated that driving skills effected the most profound improvements, owing to the fact that the research has demonstrated a reduction in total costs of up to 9.81% (£98,032.27) per year without investment. This reduction includes the fuel costs consumed over one year.
6. The heavy lift area evidences three different improvements, all of which include fuel, labor and running costs. Firstly, by changing from the current zone up to the railway zone, the improvements reduced consumption by 8.84%, which corresponds to £1,465.09 a year; secondly, by using the current area and the old access road, the reduction was 20.48% (£3,392.38) per year; finally, by using the

current area and the new access road, the improvements reduced consumption by 57.88% (£9,588.49) per year.

In conclusion, all of the improvements described herein correspond to significant reductions in terms of costs, particularly fuel costs, which are related to both labor and running costs. The implementation of small changes has great potential to improve operations at the Container Terminal; however, the principal challenge is to foster total implementation and sustainability by changing people's behaviors, and ultimately the culture itself.*

* Date of Contribution : May 15, 2012
Date of Acceptance : July 8, 2012

References

BANISTER, D. (2007), *Reducing Energy use in the UK Transport*, BIEE seminar paper to be held at Imperial College, 25th September 2007.

BAZZAZI, M., SAFAEI, N. and JAVADIAN, N. (2009), "A genetic algorithm to solve the storage space allocation problems in a container terminal," *Computers and Industrial Engineering*, Vol. 56, No. 1, pp. 44-52.

BISMARK, S. (2010), Maritime Transport and Port Operations, Global Facilitation Partnership for Transportation and Trade, http://wwwqfptt/org.entitles/TopicProfile.aspx?45124a2-1-56fc-40a0-bf24-21d118c67b8, accessed 13 August 2010.

BRITISH PORT ASSOCIATION (2010), UK Ports Industry - What Ports do, http://www.britishports.org.uk/public/uk_ports_industry, accessed 7 July 2010.

BROYLES, D., BEIMS, J., FRANKO, J. and BERGMAN, M. (2005), Just in time Inventory Management Strategy & Lean Manufacturing, http://www.academicmind.com/unpublishedpapers/business/operationsmanagement/2005-04-00aaf-just-in-time-inventory-management.html, accessed 11 August 2010.

CORDEAU, J. F., GAUDIOSO, M., LAPORTE, G. and MOCCIA, L. (2007), "The service allocation problem at the Gioia Tauro Maritime Terminal," *European Journal of Operational Research*, Vol. 176, No. 2, pp. 263-273.

FREIGHT INDUSTRY TIMES (2010), Port of Felixstowe welcomes first cranes for Felixstowe South, http://freight-online.co.uk/ports/ports/content/6039/port_of_felixstowe_welcomes_first_cranes_for_felixstowe_south, accessed 12 July 2010.

GOODWIN P., DARGAY J. and HANLY M. (2004), "Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review," *Transport Reviews*, Vol. 24, No. 3, pp. 275-292.

HARALAMBIDES, H. (2002), "Competition, Excess Capacity, and the Pricing of Port Infrastructure," *International Journal of Maritime Economics*, Vol. 4, pp. 323-347.

HOUSE OF COMMONS TRANSPORT COMMITTEE (2007), *The Ports Industry in England and Wales: Second Report of Session 2006-07 Volume 1*, The Stationery Office: London.

JAIME, VAN DER EB (2005), The Role of Ports in the Liner industry, http://panamax.co.uk/role%20of%20ports.pdf, accessed 11 August 2010.

KALMAR INDUSTRY (2010), The Common Concerns of Global Ports Operators: Fuel Innovation Handling Solutions, Professional Parking Solutions, http://www.euinfrastructure.com/artide/The-common-concerns-of-global-port-operators-Fuel-innovative-handling-solutions, accessed 13 August 2010.

MARTAGAN, T. G., EKSIOGLU, B., EKSIOGLU, S. D. and GREENWOOD, A. G. (2009), "A Simulation Model of Port Operations during Crisis Conditions," *Proceeding of the 2009 Winter Simulation Conference*, Mississippi State University, pp. 2832-2834.

MURTY, K. G., WAN, Y. W., LIU, J., TSENG, M. M., LEUNG, E., LAI, K. K. and CHIU, W. C. (2005), "Hong Kong International Terminals Gains Elastic Capacity using a Data-intensive Decision-Support System," *Interfaces*, Vol. 35, No. 1, pp. 61-75.

MUSTER T. (2000), *Fuel Savings Potential and Costs Considerations for US CLASS 8 Heavy Duty Trucks through Resistance reductions and Improved Propulsion Technologies until 2020*. Energy Laboratory Publication: Massachusetts.

ONUT, S. and SAGLAM, C. O. (2008), "Modeling and optimization of general cargo port operations through fuzzy minimal spanning tree and fuzzy dynamic programming approaches," International Journal of Innovative Computing, *Information and Control*, Vol. 4, No. 8, pp. 1835-1851.

POITRAS, G., TONGZON, J. and LI, H. (1996), *Measuring Port Efficiency: An application of data envelopment analysis* (Singapore: National University of Singapore).

RENTOKIL INITIAL(2010), *Environmental Good Procedures Efficient Road Transport*, Rentokil Initial plc: West Sussex.

SCHMIDT, F. A., YAZDANI, R. and ROBERT, Y. (2010), "Visualising Layout and Operation of a Container Terminal," *International Journal of Simulation*, Vol. 8, No. 1, pp. 7-15.

SHAMMOON, A. (2009), *Simulation and analysis of port bottlenecks: the case of Male*, Master Theses, Licoln University.

WEINGER, J. (2009), 10 Simple Steps to Save Gas and Improve Gas Mileage, http://www.dailyfueleconomytip.com/driving-habits/10-simple-steps-to-save-gas-and-improve-gas-mileage, accessed 13 June 2012.

WIJLHUIZEN, ERIK. TH.J. and JULIALEI, F. M. (2008), "The Sustainable Container Terminal," 2nd International Conference on Harbours, Air Quality and Climate Change, Rotterdam.

ZHANG C., LIU J., WAN Y. W., MURTY K. G. and LINN R. J. (2003), "Storage space allocation in container terminals," *Transportation Research Part B*, Vol. 37, pp. 883-903.

ZHU, M., FAN, X., CHENG, H. and HE, Q. (2010), "Modeling and Simulation of Automated Container Terminal Operation," *Journal of Computers*, Vol. 5, No. 6, pp. 951-957.