Industrial Management & Data Systems

Simulation based decision support system for optimization: A case of Thai logistics service provider

Mohammad Asif Salam Sami A Khan

IMDS
116,2

Received 17 May 2015
Revised 19 July 2015
25 August 2015
Accepted 17 September 2015

Simulation based decision support system for optimization

A case of Thai logistics service provider

Mohammad Asif Salam and Sami A. Khan
*Faculty of Economics and Business Administration,
King Abdulaziz University, Jeddah, Saudi Arabia*

Abstract

Purpose – The purpose of this paper is to understand and explain how firms use simulation-based decision support systems (DSSs) to optimize container space utilization.

Design/methodology/approach – Using a case study of a logistics company, this research analyzed the application of optimization software through simulation to make efficient loading decisions. The current study attempted to find a method for optimizing and making a loading plan to achieve higher container space utilization using a simulation method.

Findings – A simulation-based DSS and application of an optimization method contributes to the reduction of container shipment volume, and saves logistic costs and its delivery time. This research offers a method for optimizing a loading decision to optimize container space utilization.

Research limitations/implications – The present study is based on a single case study of only one specific type of product, i.e., motorcycle spares parts within a specific industry.

Practical implications – Apart from adding value to the shipment process and improving the efficiency of loading plans, with the use of optimization software, the collaboration between buyers and suppliers can be encouraged to reduce response time and bringing transparency in the pricing process of the shipment.

Originality/value – This research addresses a key concern in the transportation industry: how to reduce the logistics costs and the delivery time. This study demonstrates how a simulation-based tool can be used to reduce freight cost, cycle time, instill waste minimization and improve overall value addition.

Keywords Simulation, Thailand, Case study, Freight transportation, Decision support system, Container logistics

Paper type Case study

1. Introduction

Containerization is a shipment method where commodities are placed in containers. After the initial loading, the commodities *per se* are not re-handled in shipment until they are unloaded at the destination (Vitasek, 2005). Containerization saves transportation costs and increases accessibility via connections with other modes, such as rail and trucking. It also reduces the risk of loss and damage. For some firms, containerized shipments to foreign markets have reduced costs by a margin of 10-20 percent and have improved their service level as well (Coyle *et al.*, 2003). In containerization, container loading is a pivotal function for operating supply chain efficiently and its underperformance results into unnecessary costs and unsatisfactory customer service (Bortfeldt and Wäscher, 2013). Shipments must be consolidated and loaded into containers of varying sizes and costs and then sent along the shipping routes for various destinations, and it creates challenges for shippers in finding an allocation that minimizes the total container transportation and delivery costs (Qin *et al.*, 2014). The emergence of mass customization has also thrown big challenge to the integrated logistic providers, and they are forced to adjust their consolidation polices in

Industrial Management & Data Systems
Vol. 116 No. 2, 2016
pp. 236-254

0263-5577
DOI 10.1108/IMDS-05-2015-0192

order to satisfy their service commitments as well as keeping the cost to a minimum (Tyan *et al.*, 2003).

Containerization of bulk cargo has gradually emerged in recent decades despite the reality that the factors that affect containerization have not been identified (Kawasaki and Matsuda, 2015). A key concern in the container transportation industry is the design of efficient and effective loading schemes for maximizing container space utilization resulting in a reduction of container shipment volume and saving the logistics costs (Zhou-jing and Kevin, 2007). In general, the calculation of carton volume and the loading plan for a container depends on the operator's experience and, in most cases, the optimum loading solutions are not achieved. To achieve an effective and efficient container loading is a complex issue and relying only on an operator's tacit knowledge and experience to achieve good utilization of space has been found to be difficult. This has impact on the cost to a company and its profits. Thus, it is recommended to maximize space utilization by using highly sophisticated optimization techniques (Chua *et al.*, 1998), and there have been numerous simulation-based experiments conducted so far which provide guidance for achieving this result. Wang *et al.* (2015b) studied lean principles using simulation optimization; Jovanoski *et al.* (2013) developed a modeling and simulation method to create vertical hybrid simulation models, whereas, Lam and Ip (2011) used a simulation technique for generating scheduling solutions.

Many researchers have studied the pros and cons of using the simulation technique. Hilletofth and Lättilä (2012) have researched the benefits and barriers of agent-based decision support systems (DSSs) in the supply chain using a simulation method, while the agility of a port system was studied by Pantouvakis and Dimas (2013) with the help of a simulation exercise. By combining agent-based modeling and simulation and system dynamics, Lättilä *et al.* (2010) concluded that it is possible to create more accurate and reliable expert systems. In a study of agent-based DSS of service-related maintenance, Hilletofth *et al.* (2010) find that this approach can improve the understanding of the problem domain and also generates a basis for decision making and structural changes. Wang *et al.* (2014) proposed a mathematical model to deal with trucking problems in yards by using a simulation model, while in an earlier study, Ujvari and Hilmola (2006) looked at the transportation simulation systems based on automated guided vehicles. In that background, using a simulation-based DSS, the present research is concerned with finding a method for optimizing a loading plan to achieve better utilization of container space. This study is an attempt to improve supply chain operations by adding value through waste minimization and achieving optimized loading in a shipping company.

2. Literature review

Logistic management is a key issue today, capturing the essence of integrated logistics planning and management of activities involved internally and externally (Ralston *et al.*, 2015). Logistic service providers are competing vigorously in providing quality services to their customers by minimizing the operational costs and maintaining their profits. Transportation and freight consolidation are major issues for them in the shipment process. Transportation plays an important role in the movement of a product, and its non-availability at a specified time can lead to expensive repercussions, such as lost sales, customer dissatisfaction and production downtime (Lambert and Stock, 1993). Nevertheless, transportation usually represents the most important single element in logistics cost for most firms (Ballou, 2004). In transportation, reduced rates with larger shipment sizes encourage managers to ship in large quantities. Consolidating small shipments into large ones is the primary way to achieve lower transportation costs. This adds to the effective logistic management, and there is significant evidence that the effective implementation of logistic management results into an improvement of a firm's performance (Sweeney *et al.*, 2015).

2.1 The role of transportation in logistics management

An effective transportation system seeks to maximize the value of its services by understanding the service needs of its customers, setting or negotiating prices high enough to cover the delivery costs incurred and then delivering the desired services as efficiently as possible (Wang *et al.*, 2015a). Hence, transportation objectives should be centered on satisfying customers, minimizing costs and making a profit contribution, while maintaining competitiveness (Wisner *et al.*, 2005). Recent efforts have attempted to reduce the shipping times and costs by increasing the various modes' compatibilities and by trying new mode of combinations (Coyle *et al.*, 2003). Caputo *et al.* (2006) argued that the adoption of a DSS can help logistics managers correctly select the carrier and shipping mode while minimizing transportation costs. They are also of the view that the proper choice of a carrier may significantly reduce shipping costs. Even greater savings can be achieved by properly grouping customer orders in order to create optimal shipments (Caputo *et al.*, 2006). Freight consolidation has been studied by very few researchers (Tyan *et al.*, 2003). Hall (1987) studied the problems of freight consolidation by using three strategies of consolidation, i.e., inventory consolidation, vehicle consolidation and terminal consolidation. Structural simulation model was also used by Pooley and Stenger (1992) to study the effects of freight consolidation. Freight consolidation has achieved a significant attention and it helps in enhancing environmental sustainability as well (Mansouri *et al.*, 2015).

2.2 Containerization

A container is a large rectangular box into which a firm places commodities to be shipped. After initial loading, the commodities are not re-handled until they are unloaded at their final destination. Due to the increase in global trade, the demand for the containerization process is growing. Recent studies related to containerization focus on container loading and unloading optimization into the shipping vessels (Zeng *et al.*, 2015), pricing and utilization of reusable containers (Atamer *et al.*, 2013), quay crane scheduling (Bierwirth and Meisel, 2015) or container yard space optimization in the container depot or terminal (Ambrosino and Siri, 2015). Containerization has several advantages. For instance, it can be easily stored and transported resulting in lower warehousing and transportation costs, reduced loading time, shorter transit time and reduced risk of pilferage and damage during the loading and unloading process. On the other hand, containerized shipments have several disadvantages. Not every port is equipped to handle containers, thus limiting the number of shipping routes available. Finding cargo for a container's backhaul may be also difficult. Additionally, carriers at the origin and destination are not always able to take advantage of the speed available in loading and unloading containers, which leads to a decrease in efficiency (Coyle *et al.*, 2003). Maximizing the efficiency of loading space utilization is the main concern in the container loading process (Moura and Oliveira, 2005; Zeng *et al.*, 2015). Miyamoto *et al.* (2007) find that a container loading problem needs a procedure for locating objects that should be loaded into a container.

In general, container loading problems can be classified into two: one is a homogeneity problem where a container consists of identical boxes and the other is where heterogeneous sizes of boxes are used. Most of the algorithms for the container loading problem are very "data dependent," as they work well on a specific distribution of box types (Juraitis *et al.*, 2006). Chen *et al.* (1995) proposed a mixed integer linear programming for the problem of loading multiple containers. Lai *et al.* (1998) proposed a graph-based model for the loading problem with multiple customers' orders where cargos belonging to the same customer were packed together in the container. Martello *et al.* (2000) proposed a branch-and-bound algorithm for loading a single container, which is then used in an exact algorithm for the three-dimensional bin-packing. Additionally, heuristic approaches also present viable alternatives within a reasonable time. Pisinger (2002) classified heuristic approaches into building patterns, namely, wall building, stack building, guillotine cutting and cuboid arrangement. The wall building approach constructs vertical or horizontal layers that reduce the solution space and allows the use of a simple data structure in the implementation of algorithms. Such an approach was introduced by George and Robinson (1980) who suggested a sophisticated constructive heuristic based on vertical layers such that spaces not occupied in a layer can be used in the subsequent layers. Morabito and Arenales (1994) proposed a heuristic model that makes use of guillotine cuts as a strategy to obtain competitive results compared to non-guillotine cuts. In the cuboid arrangement, the container is filled by homogeneous blocks made up of boxes of the same type and with identical orientation. Bortfeldt and Wäscher (2013) also provide a heuristic model that makes use of local arrangements with one or two blocks. In recent times, the use of computer software to optimize loading decisions has been increasing, and shipping companies are using software as DSSs to achieve efficiency in their supply chains.

2.3 Use of optimization software

Simulation optimization method considers the uncertain and stochastic factor in operation process and can deal with complex constraints in scheduling model (Zeng and Yang, 2009). In real life, container loading problems are complex. Providing technological assistance in the form of computers or other equipment improves the ability to serve customers faster and improves the quality of services, as well as having many other benefits (Wisner *et al.*, 2005). Use of optimization software in improving loading and transport is a radical step in this regard, which has had a huge impact in bringing efficiency in the containerization process. Yu and Qi (2013) studied ways to improve the operational efficiency of inbound containers using simulation, whereas, Yun *et al.* (2011) investigated the demand for empty containers and their expected costs using simulation-based optimization. Optimization software slashes the time it takes to work out the best solutions for the cargo by reducing the loading time and improving packaging decisions. The answers arrive in minutes – not hours or days. Loading plans, cutting patterns and packaging designs help to complete the task efficiently and the whole exercise is easy to understand. There are a number of software packages available to optimize the container utilization, including AutoLoadPro, MaxLoad®Pro, CubeMaster and Cargo Optimizer, among others.

3. Research methodology

The present study is a case study providing detailed accounts of experiments undertaken at an export trading company based in Thailand. To avoid the identity of the firm, a pseudonym, Mekong Logistics Service Provider (MLSP), was used. The case study, as a method, was chosen to help us understand and analyze how shipping firms use simulation-based DSSs to optimize their container space utilization. This was an in-depth case study conducted in 2013 based on a simulation experiment. The present research adopted the case study approach and analyzed container space optimization and system improvement in the light of logistics and transportation principles. A case study research aims to gain a deep understanding from the phenomenon under study using a limited number of observations of supply chains or companies (Hilmola *et al.*, 2005). Conducting a case study is a preferred approach when we need to answer "how" and "why" of an experiment and there is little control over the events, and the focus remains on a real-life situation (Yin, 2003). Eisenhardt (1989) also advocates case study approach in the early stages of research on a topic or when a fresh perspective is needed and existing theory seems inadequate for providing the answer. Case studies can be used for all kinds of research, namely, exploratory, descriptive or explanatory (Ghauri and Grønhaug 2002; Yin 2003). Our present research is inductive and based on a single case study, as Ghauri (2004) opines that for an inductive approach and specific explanations we can use the single case design. To optimize the container space, this research analyzed and compared the current and proposed states using improvement metrics. In this experiment, Cargo Optimizer 4.27 was chosen based on its availability and face value.

The study adopted the following five steps of data collection, problem identification, analysis of improvement indicators, implementation and evaluation:

(1) Data Collection: data were collected from a container database, carton database and financial database. The container database covered information regarding various dimensions of containers, e.g., 20 ft, 40 ft, 40 ft High-cube (40 ft HQ), their volume and capacity. The carton database included information regarding size, pack number, maximum number of cartons that can be stacked, their orientation, first-in-last-out and sequence loading information, types of cartons, e.g., boxes or pallets and load positions, etc. The financial database focussed on the transportation costs charged per shipment.

(2) Identifying the problems: the problem analysis was undertaken based on the current situation and future expected improvements planned for this study. In this leg of the experiment, product lists and packing dimensions were prepared, container sizes for loading were identified and product lists of full container loads (FCLs) were inserted into the software. In this exercise, adding more items stopped when the volume size or weight constraints of the given container reached an optimum. Based on the researchers' observations, problems were classified into three main areas, namely: under-utilized container space, higher transportation costs and long order cycle time.

(3) Analysis of the improvement indicators: a comparison of the manual method, which used an Excel spreadsheet *vis a vis* optimization software Cargo Optimizer 4.27, was undertaken to analyze the improvement indicators, i.e., volume utilization, transportation costs per unit and order cycle time.

(4) Implementation: at this stage, three experiments were undertaken. The first two experiments, Experiment 1 and 2 were undertaken using the shipment 1 to judge the suitability of the container size 40 ft and 40 ft HQ. After arriving at the suitability of 40 ft HQ in the above-mentioned two experiments, Experiment 3 was conducted to judge the impact of optimization software on container size 40 ft HQ. This experiment was based on the shipment 2.

(5) Evaluation: this step was conducted to evaluate the suitability of the three experiments undertaken above. It was found that Experiment 3 with shipment 2 was most efficient and relevant.

The simulation experiment in this case study was based on two different types of containers, e.g., 40 ft and 40 ft HQ containers. It is very important to clarify the differences between the two types of containers used in this study. The length and width of both the 40 ft containers and 40 ft HQ containers are the same. As a result, the main difference is their height. The height of the 40 ft container is 2.390 millimeter, while the height of the 40 ft HQ container is 2.697 millimeter. Hence, more goods can be loaded into the 40 ft HQ container. The capacity of the 40 ft container is 67.7 m^3, whereas the capacity of the 40 ft HQ container is 76.3 m^3. If the cargo volume is between 68 and 75 m^3 and the gross weight is not more than 23 mtons, the customer can choose a 40 ft HQ container in order to benefit from the freight costs. Otherwise, the customer has to load the goods into 1×40 ft and 1×20 ft containers. The gross weight of the goods is very important.

3.1 Profile of the company

The present study was conducted at the MLSP Company, Thailand, which is striving hard to sustain itself in a highly competitive Thai market. MLSP is an export trading enterprise established in Thailand in 1997 with a small registered capital of two million Baht having a total capital of 18 million Baht (US\$1 = 30 Baht approx) in assets and employing approximately 170 employees. It has been growing steadily in foreign trade as an intermediary without having its own plant or products. Its major functions are to find required products from domestic manufacturers, consolidate the shipments and export those products to various destinations such as the Dominican Republic, USA, Taiwan, etc. The company is involved in the export of motorcycle spare parts, canned foods, canned coconut milk, herbs and other products depending on customer orders. The value-added activities that the company provides to customers include trade negotiation, product sourcing, consolidating the shipment, sending specification and sample, quotation, export arrangement including documents, transportation and foreign government requirements. The profit of the company comes from commissions which are a markup on each product's value; thus, an increase in more sales volumes increases the profits of the firm. The company transports products in containers by using ocean transportation, usually with a FCL terms.

4. Case findings and discussion

4.1 Improvement indicators

The key improvement indicators for the analysis of the results were as follows:

(1) Volume utilization: the efficiency of container packing can be measured in the percentage of volume utilization (Thapatsuwan *et al.*, 2007). The calculation for volume utilization is as follows:

$$\text{Volume utilization} = \frac{\text{Volume of boxes packed} \times 100\%}{\text{Container volume}}$$

(2) Transportation costs per unit: according to the financial data, transportation costs directly affect container utilization of the company and show the differential cost resulting from applying the new experimental method.

(3) Order cycle time: this can be viewed as the accumulation of time, as an order passes through each step in the order cycle. The order cycle time elements are order transmittal time, order processing time, stock availability, production time and delivery time. However, cycle time reduction is not just about completing a process quickly. Rather, it is concerned with completing the given process effectively as well.

4.2 Data analysis

The collected data for the shipment of MLSP products were analyzed in three phases. Phase 1 of the experiment optimized container utilization based on the results of shipments that used traditional methods of human/manual decisions relying on experience, *vis a vis* the method using Cargo Optimizer 4.27 software. This resulted in comparing the results of the shipment after applying the new method to maximize container space utilization. Subsequently, Phase 2 focussed on reducing the transportation costs by comparing the order cycle time after adoption of the optimization software and improvement achieved by eliminating wasted time in the process. The last phase of the experiment dealt with reducing the total order cycle time after the use of optimization software and analyzing the overall benefits achieved in the process. The details of the experiment are discussed in the following paragraphs.

4.2.1 Phase 1: optimizing container utilization. Table I provides information about the shipment 1 of the motorcycle spare parts which MLSP transports in a shipment with a FCL of a 40 ft HQ container. It also shows the calculations done using an Excel spreadsheet to calculate optimized utilization, while the last two columns provide the data after using the optimization software. The objective was to add products from the customer inquiry until it reached the volume or weight capacity of the container. It showed that the company could not optimize the 40 ft HQ container because shipment 1 used volume utilization of only 63.63 cubic meters or 84.42 percent and weight utilization of only 14,397 kilograms or 45.88 percent, while the volume and weight capacity of 40 ft HQ container was 75.38 cubic meters and 31,380.00 kilograms, respectively. The company could not achieve optimal container utilization using the manual system, as it had to rely on a trial and error approach when loading the containers and usually only 84-87 percent of loading capacity was achieved. To deal with such challenges, optimization software, Cargo Optimizer 4.27 was used to improve and enhance efficiency by optimizing container space utilization. The experiments tested the company shipments and provided alternative solutions. The steps are in accordance with Figure 1:

Remarks: number of cartons = quantity/packing;
Total gross weight (TGW) = number of carton × gross weight (kg);
Cubic meter (CBM) = $H \times W \times L/1{,}000{,}000$; and
Total cubic meter (TCBMS) = number of carton × cubic meter.

Experiment 1: use of optimization software and suggested improvement in shipment 1 using a 40 ft HQ container.

The first part of our experimental case study was to calculate the loading improvement when using a 40 ft HQ container, which is referred to as Experiment 1 in this research. This experiment started with inputting customer, cargo and container information into the database of the shipment. The results showed the underutilization of shipment 1 in both volume and weight capacity, which was 84.42 percent of volume utilization (63.63 cubic meters) and 45.88 percent of weight utilization (14,397 kilograms). The subsequent step of the loading process was based on the automatic

Table I. Motorcycle spare parts used in shipment 1 and the carton volume calculation for shipment 1 (40 ft HQ)

Item	Description and specification	Quantity	Packing	CTN	G.W. (kgs)	Cartons size $H \times W \times L$ (cm)			CBMS	TGW	TCBMS
1	Wheel Rims 1.40 × 18	3,000.00	2.00	1,500.00	3.00	46.00	12.00	47.00	0.03	4,500.00	38.92
2	Grip Nouvo MX	4,000.00	200.00	20.00	31.82	35.00	60.00	46.00	0.10	636.40	1.93
3	Silencer AX100	10,000.00	100.00	100.00	15.00	40.00	57.00	14.00	0.03	1,500.00	3.19
4	Silencer RX-S	2,500.00	50.00	50.00	14.00	43.00	50.00	21.00	0.05	700.00	2.26
5	Break Pedal CG125	1,500.00	50.00	30.00	40.00	33.00	49.00	23.00	0.04	1,200.00	1.12
6	Pedal Gear Change Wave110-S C.P	3,000.00	100.00	30.00	31.00	30.00	41.00	37.00	0.05	930.00	1.37
7	Main Switch AX100	1,500.00	100.00	15.00	17.00	33.00	47.00	24.00	0.04	255.00	0.56
8	Main Switch Crypton Y100	1,000.00	50.00	20.00	6.00	33.00	49.00	23.00	0.04	120.00	0.74
9	Holder Break Lever YMH RS (RX-S)	1,400.00	200.00	7.00	10.00	29.00	48.00	22.00	0.03	70.00	0.21
10	Holder Clutch Yamaha RS (RX-S)	2,000.00	200.00	10.00	10.00	29.00	48.00	22.00	0.03	100.00	0.31
11	Side Stand HD C50-C70-C700	1,000.00	100.00	10.00	22.00	25.00	40.00	25.00	0.03	220.00	0.25
12	Side Stand Suzuki A100	2,000.00	100.00	20.00	15.00	25.00	40.00	25.00	0.03	300.00	0.50
13	Side Stand RX100, RX-S (black)	1,500.00	50.00	30.00	18.50	25.00	25.00	25.00	0.02	555.00	0.47
14	Muffler Yamaha RX-S	700.00	2.00	350.00	6.50	11.00	24.00	90.00	0.02	2,275.00	8.32
15	Head Lamp Unit Crypton Diamond Eye	1,000.00	50.00	20.00	11.00	52.00	72.00	30.00	0.11	220.00	2.25
16	Front Footrest Y100	3,000.00	125.00	24.00	34.00	30.00	37.00	47.00	0.05	816.00	1.25
	Total	39,100.00		2,236.00						14,397.40	63.63

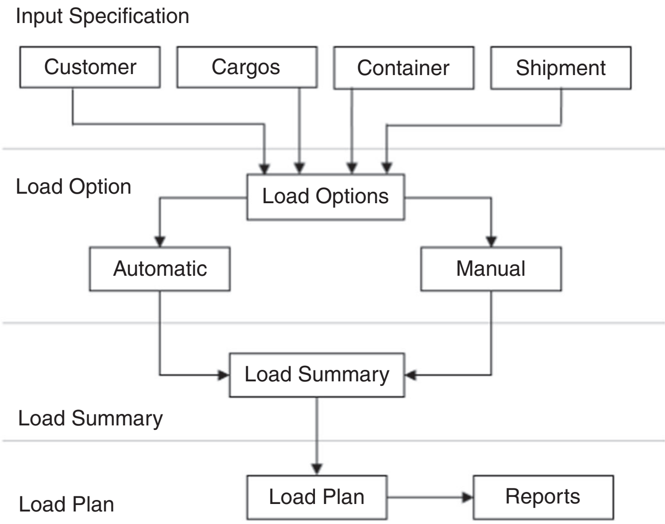

Figure 1.
Calculation steps of loading flow of Cargo Optimizer 4.27

calculation done by the chosen software. The load summary indicated load statistics as amount of used container space and the number of loaded and left cartons. In this shipment, all 2,236 cartons were loaded into a 40 ft HQ container and the software provided a loading plan that showed step by step loading of cartons into the container by using animation and a load report which suggested the best loading and provided data to expedite the optimum loading decisions.

Experiment 2: use of optimization software and suggested improvement in shipment 1 using a 40 ft container.

In this research, the improvement after using the software while shipping into a 40 ft container is referred to as Experiment 2. In this leg of the experiment, Cargo Optimizer 4.27 software was used with a 40 ft container instead of a 40 ft HQ container and results were compared for container utilization. The results showed mixed improvement over Experiment 1. It utilized almost the full capacity when a 40 ft container was used. The percentage of volume utilization was found to be 94.18 percent (or 63.63 cubic meters out of 67.57 cubic meters) but the weight utilization was achieved to the extent of 45.27 percent (or 14,397.40 kilograms out of 31,800 kilograms) only. For this experiment, 100 percent loading means that all 16 items in 2,236 cartons of shipment 1 were possible to load into a 40 ft container. The animation helped to see the possible loading scenario before the actual human loading took place and the loading plan reports showed the results of the loading process with the position of cartons arranged in a container.

Experiment 3: use of optimization software and suggested improvement in shipment 2 using a 40 ft HQ container.

Experiment 3 of this experiment dealt with the use of the optimization software for the current customer order in a 40 ft HQ container, which is referred to in this research as shipment 2 (see Table II). The use of software resulted in a load summary of a total of 55,900 pieces being loaded into 2,424 cartons, which were subsequently loaded into a 40 ft HQ container. The results of past manual calculations for the same shipment was between 84 and 87 percent for volume capacity utilization, which marked an

Table II. Motorcycle spare parts used in shipment 2 and the carton volume calculation for shipment 1 (40 ft HQ)

Item	Description and specification	Quantity	Unit	Packing	CTN	G.W. (kgs)	Cartons size $W \times L \times H$ (cm)		
1	Wheel Rim 1.20 × 17	2,500.00	Pcs	2.00	1,250.00	3.00	46.00	12.00	47.00
2	Wheel Rim 1.40 × 18	1,000.00	Pcs	2.00	500.00	16.00	46.00	12.00	47.00
3	Brake Pedal Yamaha Y80	1,500.00	Pcs	100.00	15.00	31.00	58.00	80.00	20.00
4	Brake Pedal Honda C700	1,500.00	Pcs	100.00	15.00	31.00	58.00	80.00	20.00
5	Brake Pedal Honda WAVE110	1,000.00	Pcs	100.00	10.00	31.00	58.00	80.00	20.00
6	Head Lamp Honda C70	2,000.00	Pcs	50.00	40.00	13.00	52.00	72.00	37.00
7	Muffler HRC E84 (blue)	200.00	Pcs	10.00	20.00	21.00	36.00	105.00	30.00
8	Muffler HRC E84 (red)	200.00	Pcs	10.00	20.00	21.00	36.00	105.00	30.00
9	Tail Lamp Assy HD CG125	1,000.00	Pcs	50.00	20.00	12.00	33.00	62.00	53.00
10	Sprocket 35T HD CG125	2,500.00	Pcs	50.00	50.00	21.70	31.75	16.50	21.00
11	Sprocket 36T HD CG125	2,500.00	Pcs	50.00	50.00	23.94	31.75	16.50	21.00
12	Sprocket 15T HD CG125	3,000.00	Pcs	200.00	15.00	25.02	31.75	16.50	21.00
13	Sprocket 16T HD CG125	3,000.00	Pcs	200.00	15.00	28.68	31.75	16.50	21.00
14	Sprocket 15T YMH RXZ	3,000.00	Pcs	200.00	15.00	25.24	31.75	16.50	21.00
15	Sprocket 37T SZK	2,500.00	Pcs	50.00	50.00	30.02	31.75	16.50	21.00
16	Sprocket 39T SZK	2,500.00	Pcs	50.00	50.00	32.70	31.75	16.50	21.00
17	Sprocket 40T SZK	2,500.00	Pcs	50.00	50.00	35.64	31.75	28.90	21.00
18	Kick Starter Honda WAVE 110	2,500.00	Pcs	50.00	50.00	23.00	25.00	43.00	17.00
19	Disk Brake Pad VR150	3,000.00	Pairs	100.00	30.00	12.00	31.00	42.00	13.00
20	Disk Brake Pad Akira-RR	3,000.00	Pairs	100.00	30.00	12.00	31.00	42.00	13.00
21	Disk Brake Pad Nova	4,000.00	Pairs	100.00	40.00	12.00	31.00	42.00	13.00
22	Disk Brake Pad Akira	4,000.00	Pairs	100.00	40.00	12.00	31.00	42.00	13.00
23	Disk Brake Pad Tiara	3,000.00	Pairs	100.00	30.00	12.00	31.00	42.00	13.00
24	Front Winker Lamp Assy Crypton R	2,000.00	Pcs	200.00	10.00	16.00	46.00	47.00	30.00
25	Front Winker Lamp Assy Crypton L	2,000.00	Pcs	200.00	10.00	16.00	46.00	47.00	30.00
	Total	38,900.00	Pcs		2,425.00				
		17,000.00	Pairs						

improvement of up to 91.61 percent (96.06 cubic meters) of volume utilization after the use of optimization software. This also resulted in 63.68 percent (19,984.10 kilograms) of weight utilization, which was much higher than the earlier two experiments.

4.2.2 Phase 2: reducing transportation costs. The company improved its operating strategies for transport optimization in people, process and technology and gained benefits after using the optimization software. Total transportation costs of shipment 1 showed improvement with the use of optimization software (refer to Table IV). In traditional method, the transportation cost of shipment was resulting from an under-utilized container loading. Employees wasted time in trial loading and unloading all products into the container for two days. The reasons were that each motorcycle spare parts shipment contained a variety of products and different sizes of packaging and were difficult to load. There was no fixed loading plan to guide staff arranging cartons into a container. Staff skills in loading were based on their own experience which was time consuming. The company had to use many staff members for one shipment. The total transportation expenses came to 23,425 Baht per shipment in this method. The main transportation cost used to come from variable cost of rent for a loading yard for two days (i.e. 2,000 Baht) and the labor cost was 7,000 Baht. Using optimization software helped in arranging cartons into a container, and employees loaded cartons by following the automatic loading plan report. This reduced loading time from two days to one day. In addition to minimizing the loading time, this method also reduced the transportation costs. The company reduced its rental of a loading yard by 1,000 Baht and reduced the labor costs by 3,000 Baht, the cost of supervisor by 1,000 per day, and the number of loading staff was reduced from five to four resulting in saving 500 Baht per day.

4.2.3 Phase 3: to reduce order cycle time. The customer order cycle time of shipment contains all the time-related events that make up the total time required for a customer to receive an order. The order cycle time consists of the following elements: order transmittal time, order processing time, stock availability, production time and delivery time. For any shipment, the order transmittal time begins with the customer sending enquiries by e-mail or fax to the company. After receiving them, the company sources suppliers, check order availability, its prices, credit terms and packing lists with suppliers and thereafter sends a quotation and specification details to the customer. In the traditional shipping method without using any optimization software, the company used to calculate carton volumes in a spreadsheet until there is a FCL which was usually found to be in the range of 84-87 percent of container volume utilization. After that, the company issues a pro forma invoice to the customer and waits for a purchase order. In consolidating an order from a customer, the firm takes about 18 days. Subsequently, after receiving a purchase order, the company has to wait for the arrival of T/T deposit (Telex or telegraphic transfer) from the customer and only then does the company issue the final purchase order to suppliers.

In the traditional system, the next step is to plan a loading schedule for suppliers and inform them of the time planned for the shipment loading, reserve the booking with a shipping line and obtain shipping documents, such as invoices, packing lists, bills of lading (B/L) and custom formality documents, etc. The total time taken for this order processing was about seven days. For stock availability and production time, normally, customer products are made to order. Manufacturers do not keep stock, so the company has to wait for production processes with a lead time of about 30-45 days. Delivery time comes next and, after finishing production, the ready products are packed into cartons and the company appoints all suppliers to deliver products to the loading yard. On a loading day, the staff uses their own experience by trial loading and it used to take two days. The mode of transportation for shipment in this case was sea freight and the transport lead time from port of origin to customer destination took about 45 days. After loading, the company collects T/T balance from the customer and prepares payment to suppliers. B/L and export documents are also required to be sent to the customer. Thus, total delivery time came about 47 days, the total customer order cycle time of traditional system is shown in Figure 2.

Hence, the order cycle time or customer order process flow of shipment without using any optimization software was found to be 102 days. This is described in Figure 3.

After using the optimization software, there was a huge improvement in the order cycle time. The customer order cycle time clocked for shipment was 13 days. It included the order's transmittal time elapsed in the communication from the point when the customer sends an inquiry to the point when the company orders consolidation to a FCL 40 ft HQ container by using optimization software. It also included the time elapsed till the company receives a purchase order. The next segment is order processing time, which includes time elapsed in awaiting the arrival of T/T deposit and issuance of a purchase order to suppliers and time wasted waiting for the suppliers' purchase order after their final consent. The plan loading schedule is then sent to suppliers who load the shipment, reserve a booking with a shipping line and prepare shipping documents, such as invoices, packing lists, B/L, custom formality documents, etc. The total time elapsed in order processing is about six days. For stock availability and production time, there was no stock and the company had

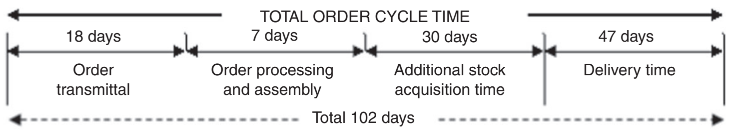

Figure 2. Customer order cycle time of shipment without using optimization software

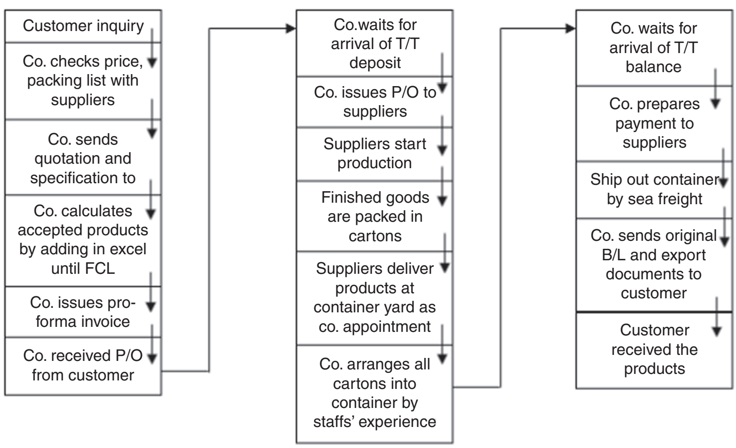

Figure 3. Customer order process of shipment without using optimization software

to wait for production lead time of about 30 days. The next important issue is the delivery time. After finishing the production, all suppliers deliver the products to the loading yard and loading is done with a load plan report. It takes only one day. The company delivers shipment by sea freight and the transport lead time to customer destination takes around 45 days. After loading, the company collects the T/T balance from the customers and prepares payment to the suppliers. B/L and export documents are also sent to the customer. So, the total delivery time taken is about 46 days. The total customer order cycle time of shipment is 95 days, as shown in Figure 4.

4.3 Data comparison

This section compares the results of container utilization between the traditional operation method mainly based on human decision and the method using optimization software. The key evaluations of testing validity were volume utilization, transportation costs per unit and accumulated order cycle time process.

4.3.1 Volume utilization. Based on the results of the experiments, shown in Table III, the traditional operation cannot fully utilize the container space in both shipments 1 and 2.

The earlier decision on cargo loading capacity was based on human experience. The addition of more volume may have the risk of unloading all cartons of the customer order into a container. After applying optimization software, the results showed that shipments 1 and 2 were utilizing container space properly and volume utilization increased from 84-87 to 90 percent or more. Automated calculation of optimal quantities and automated loading plan reports indicate clearly the position of each carton, which matches volume with the best size of container. This was demonstrated when shipment 1 was actually loaded in a 40 ft container with greater volume utilization of 94.18 percent.

4.3.2 Reduced transportation cost per unit. In the traditional method of transportation without using any optimization software, the transportation costs per

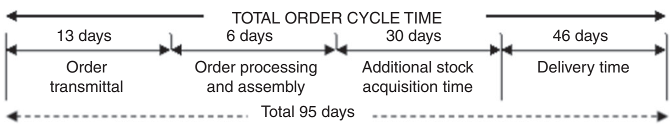

Figure 4. Customer order cycle time of shipment after using optimization software

Table III. Volume utilization of shipments 1 and 2

% Volume utilization	Traditional operation	Loading plan	Loading time	Optimization software	Loading plan	Loading time
Shipment 1 (40 ft HQ)	84.42% (63.63 CB. M)	Human decision	2 days	84.42% (63.63 CB. M)	Automate plan report	1 day
Shipment 1 (40 ft)	~84.87% (~56.58 CB. M)	Human decision	2 days	94.18% (63.63 CB. M)	Automate plan report	1 day
Shipment 2 (40 ft HQ)	~84.87% (~63.66 CB.M)	Human decision	2 days	91.61% (69.05 CB. M)	Automate plan report	1 day

unit of shipment in 40 ft HQ container was 0.59 Baht/unit calculated by dividing total transportation costs of 23,425 Baht by total quantity i.e., 39,100 units. After using the optimization software, the transportation cost per unit of shipment 2 in one container of 40 ft HQ containers was found to be 0.33 Baht/unit (total transportation costs 18,425 Baht divided by the total quantity of 55,900 units). This information shows that use of optimization software reduced transportation costs per unit from 0.59 Baht/unit to 0.33 Baht/unit in this experiment. In addition, the traditional method of shipment used to take two days to achieve complete loading, whereas, with the use of optimization software, shipment 2 was loaded within one day with fewer staff and less rent for the loading yard. It reduced the transportation costs from 23,425 Baht to 18,425 Baht (see Table IV). The company saved 5,000 Baht per shipment for an average order of 8-12 shipments per year, and thus saved transportation expenses by 40,000 Baht-60,000 Baht per year for the firm.

4.3.3 Order cycle time reduction. Table V summarizes the cumulative cycle time of the traditional operation of all sub-processes (i.e. order transmittal, order processing, production time and delivery time) for shipment without using optimization software, which was 102 days. After using the software, the total order cycle time clocked was 95 days with an improvement of seven days. With the use of the software, the order transmittal was reduced from 18 to 13 days with an improvement of five days. Order processing time decreased by one day through improvement in sharing information

Description	Loading time 1 day	 2 days
Export document fees		
B/L fee	Baht 4,400.00	Baht 4,400.00
Export formality charges	Baht 2,400.00	Baht 2,400.00
C/O and C/F	Baht 330.00	Baht 330.00
Customs documentation fees	Baht 200.00	Baht 200.00
Port gate charges	Baht 1,095.00	Baht 1,095.00
Trailer	Baht 6,000.00	Baht 6,000.00
Rent loading yard	Baht 1,000.00	Baht 2,000.00
Labor cost		
Supervisor 1 person	Baht 1,000.00	Baht 2,000.00
Staff @ 8,500/day	Baht 2,000.00	Baht 5,000.00
Total transportation cost	Baht 18,425.00	Baht 23,425.00

Note: Expenses for one container/shipment of motorcycle spare parts

Table IV. Transportation cost per shipment based on the loading time

Activities	Total order cycle time Before	 After	 Improvement
Order transmittal	18 days	13 days	5 days
Order processing	7 days	6 days	1 day
Production time	30 days	30 days	0 day
Delivery time	47 days	46 days	1 day
Total order cycle	102 days	95 days	7 days

Note: Time before and after improvement

Table V. Total customer order cycle time before and after the introduction of optimization Software with suppliers. The delivery time also showed a reduction of one day loading activity, with the company being able to eliminate extra rework from its employees.

The present case study was concerned with container loading problems arising out of traditional and manual calculations based on the tacit knowledge and experience of loading staff, which led to a waste of container space and escalation of loading costs. Use of optimization software was able to generate optimized use of container space and volume utilization, use of appropriate container size, reduction in loading time and the resultant savings in loading expenditures, thereby making the whole experience of loading efficient and effective. It aided in bringing customers and suppliers satisfaction, as well, and streamlined transactions with the suppliers and customers and ultimately cut down the total time elapsed in final loading. The case study was successful in conducting experiments involving comparisons of shipments using a traditional manual operation based on human decisions *vis a vis* use of optimization software. The improvement results showed that many more companies can optimize their container utilization by using the automated system to bring efficiency in their system and to cut down the costs involved.

5. Concluding remarks

5.1 Conclusions and implications

The study was successful in conducting experiments involving comparisons of shipments using the traditional manual operation based on human decisions and using software and applying logistics and supply chain strategies to eliminate waste in each process. It was quite evident in this study that use of optimization software was able to generate better use of container space, volume utilization, use of appropriate container size and reduction in loading time. It led to savings on loading expenditures and making the whole process of loading more efficient and effective. It aided in streamlining transactions with suppliers and customers and ultimately cut down the total time elapsed in the final loading. The findings of the study suggest that many companies can optimize their container utilization by using the automated system to ensure efficiency and cut costs. The study goes well in line with the earlier studies of Tyan *et al.* (2003), Bortfeldt and Wäscher (2013), Kawasaki and Matsuda (2015) and Qin *et al.* (2014).

Container operators and logistics service providers face the challenge of ensuring cheaper, faster and better services in the shipping industry. There is a need for research that can shed light on handling maximum possible loads, with large call sizes within the shortest time possible at competitive rates. In addition, there is a need to replicate this simulation-based optimization process with other non-uniform products in other industries. Lack of collaboration between the shipping company and the suppliers in this study was evident which is a cause for concern. There is a need to standardize packaging as much as possible in order to increase loaded volumes and to utilize space efficiently. This will also facilitate an efficient loading plan by packing the cargo as specified to avoid mistakes and reduce cost. There is a strong need to share information among buyers, suppliers and shipping companies to minimize response time and its variability. Shipping companies should encourage customers to send their order plans in advance to reduce order cycle time and cut the costs of services.

The present study resulted in better volume utilization of containers and in cutting transportation costs, as a result of improved loading decisions with the use of optimization software. Shipping companies should also train their staff to fully exploit the benefits of the software utilized and reward them adequately so as to reinforce this kind of behavior. Use of optimization software by most shipping companies may reduce transportation requirements, which will lead to better usage of shipping facilities and minimize the impact on the environment. Usage of such tools by shipping companies will definitely contribute toward lower carbon emissions and environmental impact (Mansouri *et al.*, 2015). This can also improve the image of shipping companies in the larger societal context by creating a win-win situation for all stakeholders.

5.2 Limitations and further research

One of the major limitations of this experiment was that we investigated only one specific type of product, e.g., motorcycle spares parts within a specific industry. The packaging and loading process of these parts is quite uniform and may not have many variations. Therefore, the findings of this research may not be generalizable to other products. Due to the paucity of time, other optimization software was not evaluated using SWOT analysis to benchmark the best optimization software to be used in this experiment. Also, the different scenarios in this study were limited, as the study was conducted involving only two different containers types (40 ft and 40 ft HQ). So, future studies should conduct a sensitivity analysis with different shipments to add new insights. Cargo Optimizer 4.27 used in this study is a powerful optimization software but it has its own limitations in handling mixed loading. Future research should focus on the innovative container space optimization technologies for capacity utilization, and developing new models for creating customer value by using efficient loading systems. It will help in bringing operational efficiency for logistics service providers, shipping lines@ and port/terminal operators.

References

Ambrosino, D. and Siri, S. (2015), “Comparison of solution approaches for the train load planning problem in seaport terminals”, *Transportation Research Part E: Logistics and Transportation Review*, Vol. 79, pp. 65-82.

Atamer, B., Bakal, İ.S. and Bayındır, Z.P. (2013), “Optimal pricing and production decisions in utilizing reusable containers”, *International Journal of Production Economics*, Vol. 143 No. 2, pp. 222-232.

Ballou, R.H. (2004), *Business Logistics/Supply Chain Management: Planning, Organizing, and Controlling the Supply Chain*, Pearson Education, Inc, NJ.

Bierwirth, C. and Meisel, F. (2015), “A follow-up survey of berth allocation and quay crane scheduling problems in container terminals”, *European Journal of Operational Research*, Vol. 244 No. 3, pp. 675-689.

Bortfeldt, A. and Wäscher, G. (2013), “Constraints in container loading – a state-of-the-art review”, *European Journal of Operational Research*, Vol. 229 No. 1, pp. 1-20.

Caputo, A.C., Fratocchi, L. and Pelagagge, P.M. (2006), “A genetic approach for freight transportation planning”, *Industrial Management & Data Systems*, Vol. 106 No. 5, pp. 719-738.

Chen, C.S., Lee, S.M. and Shen, Q.S. (1995), “An analytical model for the container loading problem”, *European Journal of Operational Research*, Vol. 80 No. 1, pp. 68-76.

Chua, C.K., Narayanan, V. and Loh, J. (1998), “Constraint-based spatial representation technique for the container packing problem”, *Integrated Manufacturing Systems, MCB University Press*, Vol. 9 No. 1, pp. 23-33.

Coyle, J.J., Bardi, E.J. and Langley, C.J. (2003), *The Management of Business Logistics: A Supply Chain Perspective*, South-Western.

Eisenhardt, K.M. (1989), "Building theories from case study research", *Academy of Management Review*, Vol. 14 No. 4, pp. 532-550.

George, J.A. and Robinson, D.F. (1980), "A heuristic for packing boxes into a container", *Computers and Operations Research*, Vol. 7 No. 3, pp. 147-156.

Ghauri, P. (2004), "Designing and conducting case studies in international business research", in Marschan-Piekkari, R. and Welch, C. (Eds), *Handbook of Qualitative Research Methods for International Business*, Edward Elgar, Cheltenham, pp. 109-124.

Ghauri, P. and Grønhaug, K. (2002), *Research Methods in Business Studies: A Practical Guide*, Financial Times and Prentice Hall, Harlow.

Hall, R.W. (1987), "Consolidation strategy: inventory, vehicles and terminals", *Journal of Business Logistics*, Vol. 8 No. 2, pp. 57-73.

Hilletofth, P. and Lättilä, L. (2012), "Agent based decision support in the supply chain context", *Industrial Management & Data Systems*, Vol. 112 No. 8, pp. 1217-1235.

Hilletofth, P., Aslam, T. and Hilmola, O.-P. (2010), "Multi-agent based supply chain management: case study of requisites", *International Journal of Networking and Virtual Organisations*, Vol. 7 Nos 2/3, pp. 184-206.

Hilmola, O.P., Hejazi, A. and Ojala, L. (2005), "Supply chain management research using case studies: a literature analysis", *International Journal of Integrated Supply Management*, Vol. 1 No. 3, pp. 294-311.

Jovanoski, B., Minovski, R.N., Lichtenegger, G. and Voessner, S. (2013), "Managing strategy and production through hybrid simulation", *Industrial Management & Data Systems*, Vol. 113 No. 8, pp. 1110-1132.

Juraitis, M., Stonys, T., Starinskas, A., Jankauskas, D. and Rubliauskas, D. (2006), "A randomized heuristic for the container loading problem: future investigations", *Information Technology and Control*, Vol. 35 No. 1, pp. 7-12.

Kawasaki, T. and Matsuda, T. (2015), "Containerization of bulk trades: a case study of US-Asia wood pulp transport", *Maritime Economics and Logistics*, Vol. 17 No. 2, pp. 179-197.

Lai, K.K., Xue, J. and Xu, B. (1998), "Container packing in a multi-customer delivering operation", *Computers & Industrial Engineering*, Vol. 35 Nos 1/2, pp. 323-326.

Lam, C.Y. and Ip, W.H. (2011), "Constraint priority scheduling using an agent-based approach", *Industrial Management & Data Systems*, Vol. 111 No. 2, pp. 246-263.

Lambert, D.M. and Stock, J.R. (1993), *Strategic Logistics Management*, Richard D. Irwin, Inc, Miami, FL.

Lättilä, L., Hilletofth, P. and Lin, B. (2010), "Hybrid simulation models: when, why, how?", *Expert Systems with Applications*, Vol. 37 No. 12, pp. 7419-8914.

Mansouri, S.A., Lee, H. and Aluko, O. (2015), "Multi-objective decision support to enhance environmental sustainability in maritime shipping: a review and future directions", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 78, pp. 3-18.

Martello, S., Pisinger, D. and Vigo, D. (2000), "The three dimensional bin packing problem", *Operations Research*, Vol. 48 No. 2, pp. 256-267.

Miyamoto, S., Endo, Y., Hanazawa, K. and Hamasuna, Y. (2007), "Metaheuristic algorithms for container loading problems: framework and knowledge utilization", *Journal of Advanced Computational Intelligence and Intelligent Informatics*, Vol. 11 No. 1, pp. 51-60.

Morabito, R. and Arenales, M. (1994), "An AND/OR-graph approach to the container packing problem", *International Transactions in Operational Research*, Vol. 1 No. 1, pp. 59-73.

Moura, A. and Oliveira, J.F. (2005), "A GRASP approach to the container-loading problem", *Intelligent Systems, IEEE*, Vol. 20 No. 4, pp. 50-57.

Pantouvakis, A. and Dimas, A. (2013), "The role of corporate agility and perceived price on the service quality – customer satisfaction link: some preliminary evidence from the port industry", *International Journal of Shipping and Transport Logistics*, Vol. 5 Nos 4/5, pp. 412-431.

Pisinger, D. (2002), "Heuristics for the container loading problem", *European Journal of Operational Research*, Vol. 141 No. 2, pp. 143-153.

Pooley, J. and Stenger, A.J. (1992), "Modeling and evaluating shipment consolidation in a logistics system", *Journal of Business Logistics*, Vol. 13 No. 2, pp. 153-174.

Qin, H., Zhang, Z., Qi, Z. and Lim, A. (2014), "The freight consolidation and containerization problem", *European Journal of Operational Research*, Vol. 234 No. 1, pp. 37-48.

Ralston, P.M., Blackhurst, J., Cantor, D.E. and Crum, M.R. (2015), "A structure-conduct-performance perspective of how strategic supply chain integration affects firm performance", *Journal of Supply Chain Management*, Vol. 51 No. 2, pp. 47-64.

Sweeney, E., Grant, D.B. and Mangan, D.J. (2015), "The implementation of supply chain management theory in practice: an empirical investigation", *Supply Chain Management: An International Journal*, Vol. 20 No. 1, pp. 56-70.

Thapatsuwan, P., Chainate, W. and Pongcharoen, P. (2007), "Improving packing efficiency for shipping container", *Proceedings of the 24th South East Asia Regional Computer Conferences, Bangkok, November 18-19*.

Tyan, J.C., Wang, F.K. and Du, T.C. (2003), "An evaluation of freight consolidation policies in global third-party logistics", *Omega*, Vol. 31 No. 1, pp. 55-62.

Ujvari, S. and Hilmola, O.P. (2006), "Advanced manufacturing simulation: minor system details can be major issues in the real world", *Industrial Management & Data Systems*, Vol. 106 No. 8, pp. 1166-1186.

Vitasek, K. (2005), "Supply chain and logistics terms and glossary", Supply Chain Visions, Chicago, IL.

Wang, S., Liu, Z. and Bell, M.G. (2015a), "Profit-based maritime container assignment models for liner shipping networks", *Transportation Research Part B: Methodological*, Vol. 72 No. 4, pp. 59-76.

Wang, T.K., Yang, T., Yang, C.Y. and Chan, F.T.S. (2015b), "Lean principles and simulation optimization for emergency department layout design", *Industrial Management & Data Systems*, Vol. 115 No. 4, pp. 678-699.

Wang, Z.X., Felix, T.S., Chan, S.H. and Chung, B.N. (2014), "A decision support method for internal truck employment", *Industrial Management & Data Systems*, Vol. 114 No. 9, pp. 1378-1395.

Wisner, J.D., Leong, G.K. and Tan, K.C. (2005), *Principles of Supply Chain Management: A Balanced Approach*, South-Western, OH.

Yin, R.K. (2003), *Case Study Research – Design and Methods*, Sage, London.

Yu, M. and Qi, X. (2013), "Storage space allocation models for inbound containers in an automatic container terminal", *European Journal of Operational Research*, Vol. 226 No. 1, pp. 32-45.

Yun, W.Y., Lee, Y.M. and Choi, Y.S. (2011), "Optimal inventory control of empty containers in inland transportation system", *International Journal of Production Economics*, Vol. 133 No. 1, pp. 451-457.

Zeng, Q. and Yang, Z. (2009), "Integrating simulation and optimization to schedule loading operations in container terminals", *Computers & Operations Research*, Vol. 36 No. 6, pp. 1935-1944.

Zeng, Q., Diabat, A. and Zhang, Q. (2015), "A simulation optimization approach for solving the dual-cycling problem in container terminals", *Maritime Policy & Management*, Vol. 42 No. 8, pp. 806-826.

Zhou-Jing, W. and Kevin, L. (2007), "Layer-layout-based heuristics for loading homogeneous items into a single container", *Journal of Zhejiang University Science A*, Vol. 8 No. 12, pp. 1944-1952.

Further reading

Bortfeldt, A., Gehring, H. and Mack, D. (2003), "A parallel tabular search algorithm for solving the container loading problem", *Parallel Computing*, Vol. 29 No. 5, pp. 641-662.

Corresponding author

Associate Professor Mohammad Asif Salam can be contacted at: mbamas@yahoo.com