國立交通大學

交通運輸研究所

博士論文

No.058

近洋貨櫃航商艙位配置
及空櫃調度之最適化研究

Optimization of Containership Slot Allocation and Empty Container Reposition for a Short-Sea Container Carrier

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博士論文
No.058

A Dissertation
Submitted to Institute of Traffic and Transportation
College of Management
National Chiao Tung University
in Partial Fulfillment of the Requirements
for the Degree of
Doctor of Philosophy
in
Management

May 2009

Hsinchu, Taiwan, Republic of China

中華民國九十八年五月

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摘 要

貨櫃航商主要經營海上定期航線，藉由運送貨物以賺取運費收入，其航線泊靠港口遍佈世界各地，在貨物承攬部份主要與各地之貨務運輸代理商合作，透過其承攬貨物。實務上，貨櫃航商通常重視“船舶滿載”，忽略貨物流向及運費收入管理，而貨務運輸代理商收入主要來自運費中之佣金，因此他們通常會爭取多裝載貨物以增加佣金收入，在市場繁榮時，各地之貨務運輸代理商常常會因艙位問題而引起衝突，最常發生情形為在某一航線上，先泊靠港口之代理商會超裝貨物在貨櫃船上，導致後續泊靠港口之代理商面臨船上無艙位可裝載之情況。在國際貿易中，貨物通常從出口導向國家運送至進口導向國家，此一貨物流向不平衡現象為全球性且無法避免，貨櫃航商因此面臨部份港口累積大量空櫃(積櫃港)，部份港口卻面臨缺乏空櫃以裝載客戶待運送之貨物(缺櫃口)，因此貨櫃航商須負擔大量之空櫃調度費用，在實務之空櫃調度，貨櫃航商通常安排從積櫃港一次調度大量的空櫃或將空櫃運送至較遠地區之缺櫃港，而這些空櫃將佔用貨櫃船上的艙位，其結果將造成貨櫃船上減少運送重櫃而賺取運費收入之機會；貨櫃航運業是一個競爭性的服務業，為了增加公司的競爭優勢，貨櫃航商須對其運費收入及支出費用進行謹慎管理與控制。

過去國內外有部份學者提出艙位配置及空櫃管理的相關研究，在艙位配置相關研究中缺乏以近洋航線多港口泊靠及納入空櫃調度成本之研究，在空櫃管理中缺乏以貨櫃航商經營之海上運輸網絡進行公司整體空櫃調度之研究；因此本研究以亞洲區間之貨櫃航商為研究標的，近洋航線主要特性為：航線航程較短、泊靠港口較多且每個港口裝載及卸載頻繁，並分為艙位配置及空櫃管理二部份加以探

討。第一部份，本研究提議以收益管理之概念建立重櫃艙位配置計畫，並將空櫃調度之期望成本納入目標式，以反應貨物流向不平衡之成本，其模式透過線性規劃求得貨櫃航商在單一航線上之單一航次利潤最大化，其限制條件包含船舶艙位容量、船舶重量及各港口之貨櫃需求。本模式應用國內某航商在一近洋航線為案例進行應用與分析，其模式結果與實際航行裝載情形比較，本模式之結果不僅可獲得較佳收益，並可作為貨櫃航商在管理各地貨務運輸代理商之指導方針，以避免因艙位問題而引起貨物運輸代理商間之衝突。

第二部份，本研究提出將貨櫃航商經營之海上運輸網絡分為數個地理區域，空櫃配送則在單一地理區域內進行，此舉可避免實務上因長途運送空櫃而佔用貨櫃船上之艙位；在模式建構上分為上、下二層問題，上層問題先考量各個港口在某一段間內貨櫃移動情形，包括進口貨櫃、出口貨櫃、空櫃搬入及空櫃搬出等因素，以區分各港口之特性(積櫃港/缺櫃港)及數量(供應量/需求量)；下層問題則考量到以不同運送模式(自有艙位/租賃艙位/內陸拖運)之成本差異建構最佳空櫃配送計畫，其模式透過線性規劃之運輸問題求算總體空櫃運送成本最小，將積櫃港之空櫃運用至缺櫃港，本模式應用國內某航商整體貨櫃流向資料為案例進行應用與分析，模式結果可做為貨櫃管理部門在安排空櫃調度之參考，並建議將其空櫃安排分數個航次裝載至航線剩餘之艙位(空艙位)，並進行進一步之分析，可獲得各港口之空櫃調度所面臨之問題，短期可透過改變空櫃安全存量、租用艙位、額外派遣船泊或暫時改變其他航線航程來解決部份港口空櫃調度不易之情形，長期則可考量調整公司整體海上運輸網絡。

關鍵字: 收益管理、艙位配置、空櫃配送、貨櫃航商

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ABSTRACT

Container carriers gain freight revenue by delivering containers from one port to another and depend on shipping agencies to provide cargo. Since a fully loaded carrier brings immediate revenue that is higher than that of a partially loaded carrier, cargo flow and freight revenue management are often ignored. To improve their own revenue, which is supplemented by commissions from ocean freight, shipping agencies typically compete for additional slots on containerships. In booming markets, arguments over slot allocation between shipping agencies occur frequently. These disputes, when coupled with the mismanagement of freight revenue on the part of containerships, often result in a loss of revenue for both shipping agencies and carriers. Container carriers tend to accumulate a large number of unnecessary empty containers at particular ports while other ports face a shortage of empty containers. In practice, carriers often reposition a considerable number of empty containers to others ports with shortage, during a single voyage. However, the operational expenses are substantial when an accumulation of this sort occurs. Empty containers also occupy slots on containerships with the result that carriers are unable to take aboard loaded containers yielding freight revenue. In order to increase their competitive edge, container carriers need to manage revenue and control expenditures.

Several studies have been conducted on slot allocation and empty container management. A few of these studies have sought to maximize profits on short-sea, multiple-port service routes by considering the cost of empty container repositioning. Little attention has been paid to the management of such repositioning within the sea transportation network. This study, which focuses on short-sea service intra-Asian routes, focuses on both aspects of repositioning. The main characteristics of intra-Asian service routes include: voyage distance is short, there are multiple-port calls, and loading and unloading is frequent at each port. These observations are factored into this study which is divided into two parts. The first part incorporates the concept of revenue management with expected cost of empty container repositioning, by offsetting cargo imbalance. Here an optimal model has been formulated via linear programming to maximize operational profit, subject to the constraints of vessel capacity, vessel deadweight, and container demand. A Taiwan container carrier has been used as a case study. The analytical results show that by implementing the proposed model, containerships can increase profits and shipping agencies might avoid friction in a booming market.

The second part of this study proposes to partition the sea transportation network into several geographical regions and distribute empty containers within a single region, in order to reduce the number of occupied slots over a long distance. There are two challenges to this proposal. The first challenge, which is termed the "upper-problem," lies in identifying and estimating empty container stock for each port. The second challenge or "lower-problem" concerns incorporating modes of transportation into the model. The empty container reposition model that is deemed optimal has been formulated via linear programming with a view to overcoming the transportation problem and minimizing the total cost of transferences within a single region. Here again, the research uses data obtained from a Taiwan container carrier. When this data is applied for analysis, the results show that the allocation of empty containers can be optimized by repositioning them over the course of several voyages where they can occupy unsold slots. With regard to port characteristics, this study proposes the following strategies to solve empty container problems: charter slots, launching a containership for extra service, or introducing a temporary change in the service route. These are all short-term solutions. In the long-term, sea ports might need to restructure their sea transportation network.

Keywords: Revenue Management, Slot Allocation, Empty Container Reposition, Container Carrier

誌　謝

畢業了…，真的畢業了嗎?連自己都有點詫異，有好長一段時間覺得自己走在一條看不到盡頭的路上，不管是快步走、慢步走或是原地踏步，都沒有選擇的只能繼續走下去。六年前一次偶然的機遇，進入了交大交研所，那時還是一位職場上的單身女性，期待將工作與學術結合，而現在已為人妻、為人母；在這條漫長且艱辛的路程，感謝身旁諸多的長輩、老師、長官、同學、同事及好友的協助與鼓勵，才能順利完成學業。

首先，感謝恩師馮正民教授在論文研究概念與邏輯思維之指導，並給予學生在學業、工作及家庭間無限的包容與體諒，老師的待人處事及教學態度，都是學生一生的學習楷模，僅此致上最深之謝意；研究所修業期間，謝謝黃承傳老師、黃台生老師、汪進財老師、許鉅秉老師、邱裕鈞老師、毛治國老師及游伯龍老師給予之教誨與指導，讓學生在課業上收穫良多；謝謝所辦洪瑛瓔小姐及何玉鳳小姐，洪姐除了協助學校的事務外，更觀心我們的生活，不時的為我們打氣，何小姐總是扮演我們和老師之間最好的橋樑，讓我們與老師隨時都有最好的溝通與聯繫。論文口試時，承蒙陳武正院長、吳榮貴教授、梁金樹教授、黃承傳教授及邱裕鈞老師不吝指正，所提供寶貴的意見與建議，讓本論文更加完整，在此表達感謝。

在職期間，感謝周宜強董事長、王以湘總經理、張正忠總經理、李勇協理及正利航業的同仁在工作上給予之協助與包容，讓我能有機會以在職的方式回到學校，繼續學業，尤其周宜強老師從學生在碩士班、職場工作、博士班進修、論文議題的啟發到近期的創業，一路以來的協助與支持，感恩之情，莫能言喻。

研究所期間，戴輝煌學長、鍾政祺學長不斷地鼓勵，論文初期構建時丁士展學長更是耐心與我討論，協助修正；資格考的同學們，不會忘了博二的那一年暑假，大家挑燈夜戰，全力為資格考準備的時光，同學慧娟、世昌、國洲及昭弘等彼此互相打氣，都是在交大不可磨滅的記憶；而在新竹準備投稿期間，謝謝韻嵐、志華、彥曲、靜芳的陪伴，在枯燥的寫作過程中增添歡樂，有你們真好！

最後要感謝的是身邊所有愛我的家人，沒有您們的支持，沒有今天的我，外子城印在漫長的求學路程，一路的陪伴與支持，公公、婆婆無怨的協助照顧稚子宇翔，讓我無後顧之憂於學業與工作，翔翔的童言童語總是我在辛苦一天後最好的撫慰，居住在台中的雙親對於我從小到大在求學、工作及生活的支持與關心。

最後，僅以此論文獻給我摯愛的家人以及所有關心我、教導我的師長與好友。

張嘉惠　謹誌
July, 2009. 於新竹

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P	set of calling port in a service route, $P = \{1,2,3,\ldots,n\}$
K	set of container specifications, $K = \{1:20'DC,\ 2:40'DC,\ 3:40'HQ\}$ container carriers provide different specification of container for fitting customer demand, it includes $20'\times8'\times8'6''$ dry container, $40'\times8'\times8'6''$ dry container, $40'\times8'\times9'6''$ high cube, $45'\times8'\times9'6''$ high cube, $20'\times8'\times8'6''$ open top, $40'\times8'\times8'6''$ open top, $20'\times8'\times8'6''$ flat rack, $40'\times8'\times8'6''$ flat rack, $20'\times8'\times8'6''$ reefer, and $420'\times8'\times9'6''$ 40’ reefer high cube. The flat rack container and open top container are designed to load over-width, over-length, or over-height cargo which effects stowage plan on containership. Three major types of containers $20'\times8'\times8'6''$ dry container (20’DC), $40'\times8'\times8'6''$ dry container (40’DC), and $40'\times8'\times9'6''$ high cube (40’HQ) which were considered.
H	set of port within sea transportation network, $H = \{TYO, NGO, \ldots, KEL, \ldots, SUB\}$
F	number of port group within sea transportation network
M	set of transportation mode to reposition empty container. $M = \left\{ \begin{array}{l} 1: owned\ slot\ on\ vessel\ within\ sea\ transportation\ network, \\ 2: charted\ slot\ \ from\ other\ carriers\ within\ sea\ transportation\ network, \\ 3: charted\ slot\ \ from\ other\ carriers\ without\ sea\ transportation\ network, \\ 4: inland\ drayage\ by\ truck \end{array} \right\}$
i	index of loading port in a service route, $i \in P$
j	index of unloading port in a service route, $j \in P$
k	index of container specification, $k \in K$
n	The number of calling ports in a service route
h	index of port with sea transportation network, $h \in H$
t	index of time period
f	index of port group within sea transportation network, $f \in F$
α	index of loading port within sea transportation network, $\alpha \in H$
β	index of unloading port within sea transportation network, $\beta \in H$

$$T_{z+1} = \{(z \bmod n)+1,\ [(z+1) \bmod n]+1,\ \ldots,[(z+n-1) \bmod n]+1\}$$

The sequence of calling ports on the service route

$$T_{z+1}(l) = [(z+l-1) \bmod n]+1$$

z	the first calling in sequence of calling ports on the service route, $z \in P$
l	the number in the sequence of calling port in the service route, $1 \le l \le n$
FR_{ij}^{k}	Freight revenue including ocean freight and surcharge of $k \in K$ type container delivered from port $i \in P$ to port $j \in P$ (unit：USD)
VC_{ij}^{k}	Variable cost of $k \in K$ type container delivered from port $i \in P$ to port $j \in P$, including handling charges at both ports, commissions, container rental (depreciation) and repair, truck fee and depot stowage costs (unit：USD)
OP_{ij}^{k}	Operational profit of $k \in K$ type container delivered from port $i \in P$ to port $j \in P$ (unit：USD)

$$OP_{ij}^{k} = FR_{ij}^{k} - VC_{ij}^{k} - EC_{i}^{k} - EC_{j}^{k}$$

EC_{i}^{k}	Expected cost of empty container reposition of $k \in K$ type at loading port $i \in P$ (unit：USD)

$$EC_{i}^{k} = CS_{i}^{k} \cdot HE_{i}^{k} \cdot POR_{i}^{k}$$

CS_{i}^{k}	Empty container stock of $k \in K$ type in loading port $i \in P$

$$CS_{i}^{k} = \begin{cases} -1, & surplus, \quad save\ \text{cost}\ of\ empty\ container\ reposition\ out \\ 0, & balance, \quad non-reposition\ empty\ container\ in\ or\ out \\ +1, & shortage, \quad spend\ \text{cost}\ of\ empty\ conatiner\ reposition\ in \end{cases}$$

HE_{i}^{k}	Handling cost of empty container of $k \in K$ type at loading port $i \in P$ (unit：USD)
POR_{i}^{k}	Probability of repositioning empty container of $k \in K$ type at loading port $i \in P$
EC_{j}^{k}	Expected cost of empty container reposition of $k \in K$ type at discharging port $j \in P$ (unit：SD)

$$EC_{j}^{k} = CS_{j}^{k} \cdot HE_{j}^{k} \cdot POR_{j}^{k}$$

CS_j^k	Empty container stock of $k \in K$ type at discharging port $j \in P$ $CS_j^k = \begin{cases} +1, & surplus, \quad spend\ \cos t\ of\ empty\ container\ reposition\ out \\ 0, & balance, \quad non-reposition\ empty\ container\ in\ or\ out \\ -1, & shortage, \quad save\ \cos t\ of\ empty\ conatiner\ reposition\ in \end{cases}$
HE_j^k	Handling cost of empty container of $k \in K$ type at discharging port $j \in P$ (unit：USD)
POR_j^k	Probability of repositioning empty container of $k \in K$ type at discharging port $j \in P$
OC_i	The operational capacity on containership when containership leaved from port $i \in P$ (unit：TEU, twenty-foot equivalent units)
DW_i	The operational deadweight tonnage on containership when containership leaved from port $i \in P$ (unit：ton)
DU_{ij}^k	The maximum full container demand for $k \in K$ type from port $i \in P$ to port $j \in P$
ω_{ij}^k	The average weight of $k \in K$ type from port $i \in P$ to port $j \in P$ (unit：ton)
D_i^{ω}	The maximum of deadweight tonnage for all loaded containers at loading port $i \in P$ (unit：ton)
λ^k	Transferring coefficient of TEU by $k \in K$ type. 20’DC is referred to as “Twenty-Foot-Container” which equals to one Twenty-Foot Equivalent Unit (1 TEU). 40’DC and 40’HQ are referred to as “Forty-Foot-Container (FEU)” which equals to two Twenty-Foot Equivalent Unit (2 TEU).
Q_{ht}^k	quantity of empty container stock of $k \in K$ type in t period at port $h \in H$
SS_h^k	quantity of safety stock of $k \in K$ type at port $h \in H$
IB_{ht}^k	quantity of inbound container of $k \in K$ type in t period at port $h \in H$
OB_{ht}^k	quantity of outbound container of $k \in K$ type in t period at port $h \in H$
RI_{ht}^k	quantity of repositioned-into empty container of $k \in K$ type in t period at port $h \in H$

RO_{ht}^{k}	quantity of repositioned-out empty container of $k \in K$ type in t period at port $h \in H$
S_{ht}^{k}	supply number of $k \in K$ type empty container at port $h \in H$
D_{ht}^{k}	demand number of $k \in K$ type empty container at port $h \in H$
G^{s}	set of ports having a surplus of empty containers within sea transportation network
G_{f}^{s}	set of ports having a surplus of empty containers within $f \in F$ group
G^{d}	set of ports having a shortage of empty containers with sea transportation network
G_{f}^{d}	set of ports having a shortage of empty containers within $f \in F$ group
$\rho_{\alpha\beta}^{m}$	=1, if transportation mode $m \in M$, repositioning empty containers from port $\alpha \in G^{s}$ to port $\beta \in G^{d}$, was selected =0, otherwise
$C_{\alpha\beta}^{mk}$	cost of repositioning an empty container of $k \in K$ type from port $\alpha \in G^{s}$ to port $\beta \in G^{d}$ by transportation mode $m \in M$
$\delta_{\alpha\beta}$	=1, if it had direct sailing from port $\alpha \in G^{s}$ to port $\beta \in G^{d}$ within sea transportation network =0, otherwise
S_{α}^{k}	supply number of $k \in K$ type empty containers at port $\alpha \in G^{s}$
D_{β}^{k}	demand number of $k \in K$ type empty containers at port $\beta \in G^{d}$

CHAPTER 1 INTRODUCTION

1.1 Research Background

Container shipping has been the fastest growing sector of the maritime industries in the last twenty years. Containerized cargo volumes have grown at an average annual rate of 9.1% since 1980 and by an even stronger 11.2% since 2000. In 2004, an estimated 928 million tons (excluding box weights) of containerized cargo was transported by sea in international and domestic trades. Container traffic is now estimated to account for more than 70% of international seaborne trade according to cargo value. Intra-Asian trade (excluding the Mid-East, Indian subcontinent and Australasia) accounts for one fifth of total global trade. With China acting as a regional resource centre, there seems little doubt that intra-Asian trade will continue to grow at a robust pace in the short to mid-term (Drewry Shipping, 2008).

In international trade, a global phenomenon is that cargo is delivered from export oriented areas to import oriented areas. The imbalance of international trade typically results in cargo imbalance and an empty container transference cost. The empty container incidence has exceeded 20% since 1998. The costs associated with repositioning these empty containers are considerable as they include an allowance for terminal handling, the costs of rest wage, administration, container storage, ship’s time, equipment per diem and repair. For instance, mainland China is the world factory and exports many made-in-China goods all over the world. A serious trade imbalance has arisen between mainland China and some other regions, particularly the United States and Europe. The phenomenon of import-export imbalances also occurs in the Middle-East. Container activity in the Middle-East has grown consistently and at an alarming rate since the end of 2002, and the high oil revenues earned by the region are reflected in increased imports for both public sector projects and private sector consumption. Without question, the Middle-East has been the most imbalanced region.

In 2004, Drewry Shipping Consultants estimated the cost of empty container repositioning at US$14.9 billion. This figure did not include the costs of overland repositioning or inland(intra-zonal) imbalance costs, which are necessarily speculative, but were estimated at another US$7.7 billion. This brought the total empty container cost, direct and indirect, to an estimated US$22.6 billion. For trade route analysis, the main lines are usually shipping services between two continents or regions, such as Trans-Pacific Service, Trans-Atlantic Service, Asia-Europe Service, and Asia-Australia Service. Drewry Shipping Consultants (2006) forecast that in 2010 the eastbound trade would be 17.2 million TEUs and westbound trade 6.9 million TEUs, resulting in a cargo imbalance of 10.3 million TEUs. Given an estimated US$250 per TEU for empty container handling cost at port, this present study forecasts that the total cost of empty container repositioning will increase from US$1.98 billion in 2006 to US$2.58 billion in 2010.

Facing a market-driven and competitive environment, Asian container carriers must provide services with frequent sailing, shorter shipping times and direct delivery. As most service routes are designed to call at multiple ports and frequent loading and unloading cargo is performed at each port, containership slot allocation is becoming increasingly complex. While container carriers have done moderately well in restraining empty incidence to reduce cost, they need to devote more energy to better match cargo flows and for sophisticated revenue management systems. The logistics challenge for container carriers is to better manage and control their containers.

1.2 Research Motivations and Objectives

Containership slot allocation involves two stakeholders: the container carrier and the shipping agency. Container carriers gain freight revenue by delivering containers from one port to another and by cooperating with shipping agencies which provide cargo at each port. Typically, container carriers aim to fully load their containers in order to earn high freight revenue; consequently cargo flow and freight revenue management are often ignored. Shipping agencies gain a commission from ocean freighters by providing cargo and finding additional cargo to load. Arguments over slot allocation between shipping agencies frequently occur in booming markets. For instance, a shipping agency at the first port of call on a service route that involves several port calls, might load additional cargo onto a containership resulting in a shortage of slots for shipping agencies at subsequent ports. These shipping agencies lose commission and typically complain to headquarter, placing the blame on container carriers. In some cases, container carriers take strict action to unload all cargo that has been loaded at previous ports, and when this occurs they bear double the handling expenses at a port. The alternative is to take a loss when freight revenue at subsequent ports is higher than at the first port. Since spaces or slots are the most perishable inventory; when a containership leaves port, there is typically no unsold space/slot revenue right. Container carriers need to find a way of managing their revenue from shipping agencies to maximize profits via slot allocation.

Owing to imbalances in international trade, container carriers accumulate a large number of unnecessary empty containers in the import-dominant ports, and they acquire a short of empty containers in export-dominant ports. The core problem faced by container carriers is determining how to deliver empty containers to the ports that need them, without losing revenue. In practice, container carriers often make an arrangement to reposition a great quantity of empty containers in a single voyage. These empty containers occupy slots on containerships with the result that container carriers are unable to take aboard loaded containers which yield fright revenue. Song et al. (2005) pointed out that the cost of transferring an empty container is 27% of the total world fleet running cost. Since liner shipping is a competitive service industry, container carriers are always seeking to decrease their shipping costs in order to increase their competitiveness. No significant gains will be made until an efficient method for empty container transference is found.

A review shows that some research has been conducted on the subject of slot allocation and empty container management, but few studies have sought to maximize profit through slot allocation, and minimize the cost of empty container transference in short-haul, multiple-port network conditions, such as those affecting the Asian liner shipping industry. The purpose of this study is to provide optimal and quantitative models that can function as a decision-support tools to enhance management performance for a short-sea container carrier.

1.3 Research Scope

By Drewry's estimates, intra-Asian trade (excluding the Mid-East, Indian subcontinent and Australasia) amounted to 28.6 million TEUs in 2007, accounting for one fifth of total global trade. These figures obviously exclude any business moving within its confines on a feeder basis which are bound for markets such as Europe, the US and South America. This volume is forecasted to reach 50.7 million TEUs by 2013. There is no doubt that intra-Asian trade will continue to grow at a robust pace in the short to mid-term.

Within the intra-Asian operating arena, niche, regional and global container carriers co-exist among operating ships with diverse commercial strategies, including ships as small as 150 TEUs and those as large as 4,000 TEUs or more. A couple of clear trends have emerged in recent years. Regional container carriers have expanded into the long-haul markets and larger containerships have been deployed on the core

China/ASEAN axis. Both developments have arisen as a result of a number of global container carriers launching more of their own intra-Asian services, primarily for the purpose of meeting their feeder requirements. China remains the growth engine for the region, and the environment is changing as China is beginning to import more raw materials from its neighbors. With raw materials and semi-finished products moving from South East Asia to China, transit times are becoming more important for shippers. Intra-Asian trade involves a complex combination of regional local business and feeder traffic, and two often become mixed.

This study, which focuses on intra-Asian trade, has chosen one Taiwan container carriers (refer to T Line) as a case study. T Line is a regional carrier in the intra-Asian trade route with a strategic alliance to global container carriers and their service coverage.   This service coverage includes: Japan, Korea, China, Taiwan, Hong Kong, Philippines, Vietnam, Thailand, Malaysia, Singapore, and Indonesia (as seen in Figure 1.1 and Table 1.1). T Line provides intra-Asian services to its own customers and also to global container carriers as a feeder.

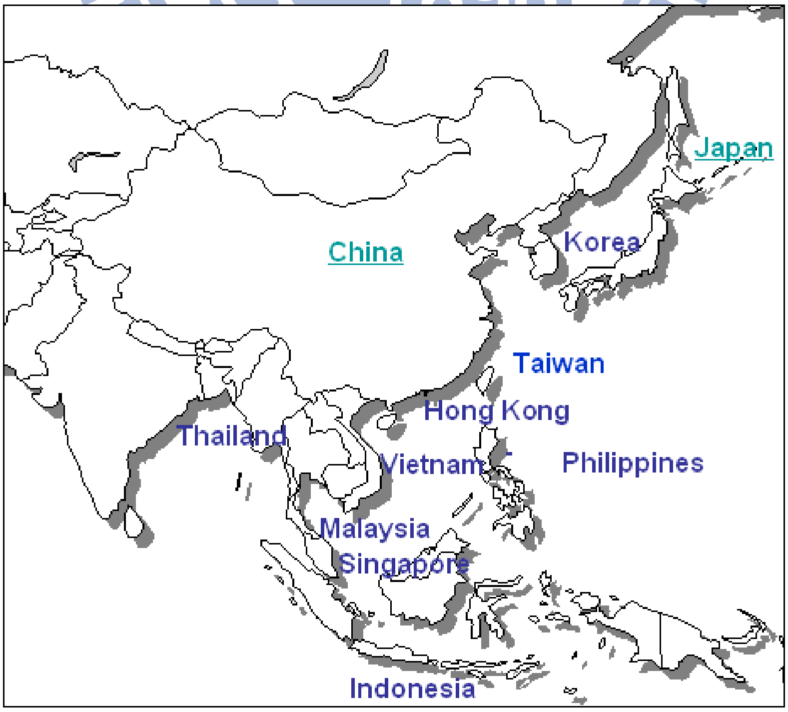

Figure 1.1 The map of research scope

Table 1.1 List of region and port for research scope

Region	Port Name (Port Code)
Japan	Tokyo(TYO), Yokohama(YOK), Nagoya(NGO), Kobe(UKB), Osaka(OSA), Moji(MOJ), Hakata(HKT), Oita(OIT)
Korea	Pusan(PUS) , Inchon(ICN) and Kwangyang(KAN)
North China	Dalian(DLC), Xingang(XGG), Qingdao(TAO), and Lianyungang(LYG). Middel China includes ports of Shanghai(SHA), Ningbo(NGB)
South China	Fozhou(FOC), Quanzhou(QZJ), Chiwan(CWN), Shekou(SHK), Xiamen(XMN)
Taiwan	Keelung(KEL), Taichung(TXG), Kaohsiung(KHH)
Philippines	Manila(MNL)
Vietnam	Ho Chi Min(SGN)
Thailand	Bangkok(BKK), Laem Chabang(LCH)
Indonesia	Jakarta(JKT), Surabaya(SUB)
Malaysia	Port Kelang(PKG), Pasir Gudang(PGU)

1.4 Research Method

The research for this study included a literature review of the container shipping market, revenue management, containership slot allocation, empty container management, and related researches on container shipping. Information obtained from these areas was incorporated into the present study, which consists of two parts: the formulation of an optimal model of slot allocation, and the development of an optimal model of empty container reposition.

1.4.1 An optimal model of containership slot allocation

The present study was incorporates the concept of revenue management to formulate an optimal model of slot allocation via linear programming. In the past, because of the imbalance of cargo flow, container carriers have paid a substantial amount for the repositioning of empty containers. To reduce these costs, the present study proposes to determine the probability of transference empty containers in order to estimate the expected costs. The objective is to maximize the operational profit (OP), which takes into consideration the expected cost of empty container repositioning, not including freight revenue, which is subject to constraints of containership capacity, containership deadweight, and container demand..

1.4.2 An optimal model of empty container reposition

This study addresses empty container repositioning by considering safety stock management and geographical regions. The proposed method has the potential to avoid the drawback associated with the current practice of collecting a large number of empty containers at one port and distributing these throughout one voyage. As a result, these empty containers come to occupy previously allocated slots. The present study proposes to partition the sea transportation network into several geographical regions and to empty containers within a single region. There are two challenges to this proposal: the first challenge or “upper-problem” lies in identifying and estimating empty container stock; the second challenge or “lower-problem” pertains to modes of transportation included in the model. The lower-problem will be solved via linear programming; different strategies will be proposed to resolve the upper-problem.

1.5 Research Framework

This study is organized as follows: Chapter 1 contains introductory material, including an overview of the research, motivation of the study, its objective, methodologies and approach. Chapter 2 contains a review of the container shipping market and related researches on revenue management, slot allocation, empty container management, routing, cost, and strategy alliance. Chapter 3 outlines the problems which pertain to: revenue management and slot allocation, service routes and cargo types, container movement at terminal, the cost of empty container repositioning, obtaining sufficient operational profit, and safety stock management for empty containers. Chapter 4 formulates an optimal slot allocation model and uses a case study to demonstrate the application of the model. Chapter 5 formulates an optimal empty container distribution model and clarifies the application with the same case study. The final chapter (Chapter 6) summaries the findings and proposes recommendations for future research.

The framework and organization of this study are shown in Figure 1.2. The research processes and steps can be stated as follows:

1. Motivation

Illustrate the overview of this study in terms of background, purpose, objectives, and scope.

2. Literature Review

This study comprehensively reviewed the existing literature on the abovementioned topics pertaining to the shipping industry in order to understand important factors when positioning an intra-Asian containership in the global container shipping market and when applying revenue management to container shipping. Few previous studies of slot allocation have sought to maximize profit in short-sea, multiple-port service routes; also, little attention has been paid to the reposition of empty containers by container carriers within the sea transportation network.

3. Problem Description

To better understand the key problems facing the shipping industry, this study describes the present characteristics of slot allocation and empty container reposition.

4. Model Formulation

Optimal models of slot allocation and empty container reposition are formulated based on the analysis found in steps 2 and 3.

5. Case Study

To demonstrate the application and the results of the proposed model, this study uses as a case study a container carrier with a long history of use in intra-Asian trade.

6. Strategy Analysis

Through further iteration and analysis, this study provides a potential strategy for container carriers to maximize operational profits and minimize expenditures.

7. Conclusions and Recommendations

Several conclusions and recommendations are offered.

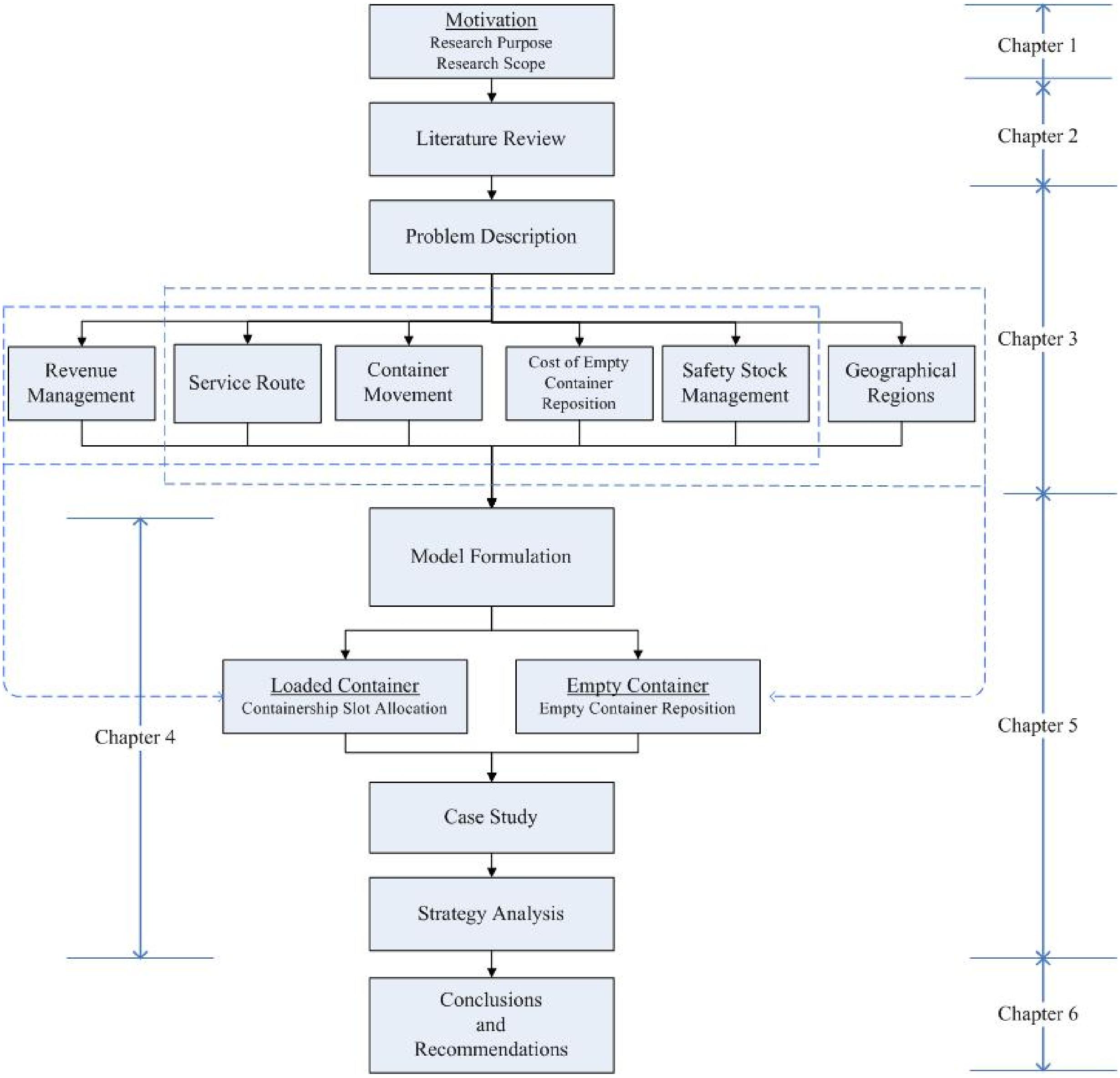

Figure 1.2 Research Flow Chart

CHAPTER 2 LITERATURE REVIEW

This chapter is devoted as a literature review that covers several topics. Section 2.1 reviews the container shipping market; Section 2.2 revenue management related issues; Section 2.3 containership slot allocation and related research; Section 2.4 empty container management; and Section 2.5 other research in container shipping. Section 2.6 concludes this study with a summary of the findings.

2.1 Container Shipping Market Review

2.1.1 Container traffic activity

Container shipping has been the fastest growing sector of the maritime industries in the last twenty years; containerized cargo volumes have grown at an average annual rate of 9.1% per annum (pa) since 1980, and by an even stronger 11.2% pa since 2000. Clarkson Research pointed out that global container trade was estimated at 502 million TEUs in 2008, a 7% increase over 2006.

The strong rate of container traffic growth has been sustained not only by the growth of output and consumption, but also by the powerful economics forces of globalization, whereby production has shifted away from high cost OECD nations to low wage countries. These countries are located predominantly in Asia (where China has become increasingly dominant, especially since the end of 2001 with its accession to WTO), but also in the Indian subcontinent and Latin America (as seen in Table 2.1). As manufacturing and assembly activity has been relocated away from the main consumption areas in North America, Europe and Japan, the shipping demand has naturally increased, while the net reduction in the cost of delivered goods has led to low inflation that has added a further stimulus to consumption (Drewry Shipping, 2005).

Table 2.1 Drivers demand growth in container shipping

Types of growth	Drivers	Results
Organic	Economic activity, trade liberalization, reduced import tariffs, globalization (FDI) and outsourcing	Increased container trade
Substitution	Conversion of break-bulk cargo to containers	Increased container trade and reduced break-bulk trade
Induced	Carriers scheduling strategies; port development; economies of scale	Transshipment activity producing increased port throughputs and additional ship capacity demand
Accidental	Regional variations in export and import activity causing imbalances in directional containerized trade flows	Empty container movements and increased port throughputs

Source: Drewry Shipping Consultants Ltd (2005)

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The effect of the global economic slowdown early in 2009 has brought about downward revisions to the Clarkson Research container trade projections. Throughout the year 2008, the total global box trade was estimated to have experienced only 7.04% growth. Even more significant cuts have been made to the total global box trade growth projection for 2009, which now stands at 6.57%, a reflection of the degree of uncertainty felt over the state of the global economy in the coming year (as seen in Table2.2).

Over 50% share of container trade occurs in Asia. It is now estimated 55% for the year 2008 and a projected 56% in 2009 (as seen in Figure 2.1). With growth rates, China continues to be the main driving force behind world container trade expansion (as seen in Figure 2.2).

Table 2.2 Forecast container volumes and growth by region (million TEUs)

Year	2006		2007		2008		2009		2010	
Regions	Volumes	(%)	Volumes	(%)	Volumes	(%)	Volumes	(%)	Volumes	(%)
N America	45	10.69	47	10.02	46	9.16	46	8.60	47	8.17
N Europe	54	12.83	60	12.79	63	12.55	63	11.78	65	11.30
Mediterranean	27	6.41	30	6.40	30	5.98	30	5.61	31	5.39
China (incl. HK)	108	25.65	127	27.08	142	28.29	163	30.47	184	32.00
Asia excl. China	115	27.32	126	26.87	136	27.09	144	26.92	153	26.61
Other	72	17.10	79	16.84	85	16.93	89	16.64	95	16.52
TOTAL	421	100.00	469	100.00	502	100.00	535	100.00	575	100.00

Source: Clarkson Research services (Jan-2009)

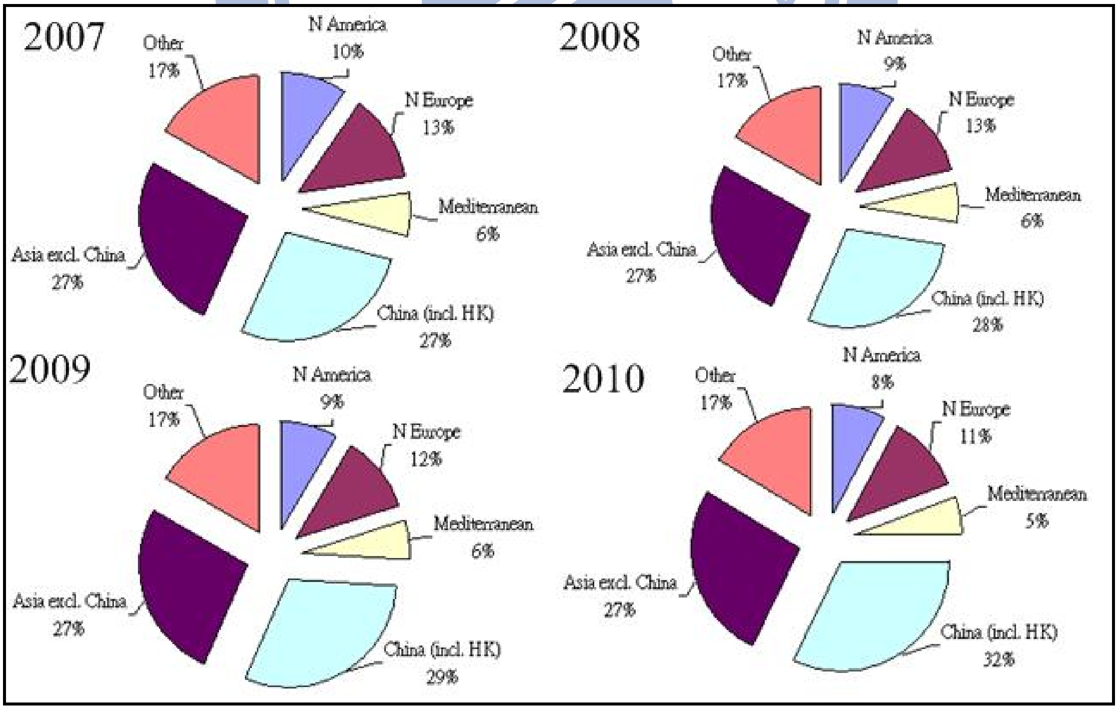

Figure 2.1 Share of container trade by region 2007-2010

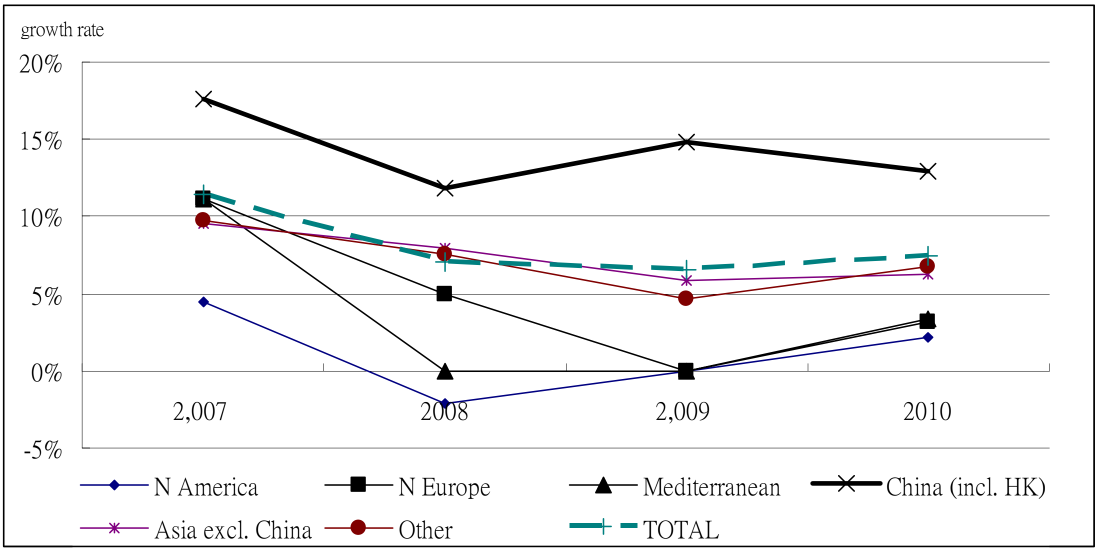

Figure 2.2 Trend of container growth by region 2007-2010

2.1.2 Container trade by route

Containerized trade is carried across three major sea lanes: the East-West axis, North-South axis, and intra-Regional trade routes. The East-West axis includes the transpacific linking Asia and North America, the transatlantic located between Europe and North America, and the Asia-Europe lane. East-West trade is estimated to have generated almost 44% of global container traffic volumes in 2004; 39 % was attributable to intra-regional trades and 17% to the north-south trade (as seen in Figure 2.3).

By Drewry's estimates, intra-Asian trade (excluding the Middle-East, Indian subcontinent and Australasia) amounted to 28.6 million TEUs in 2007, accounting for one fifth of total global trade. This volume is forecasted to reach 50.7 million TEUs by 2013.

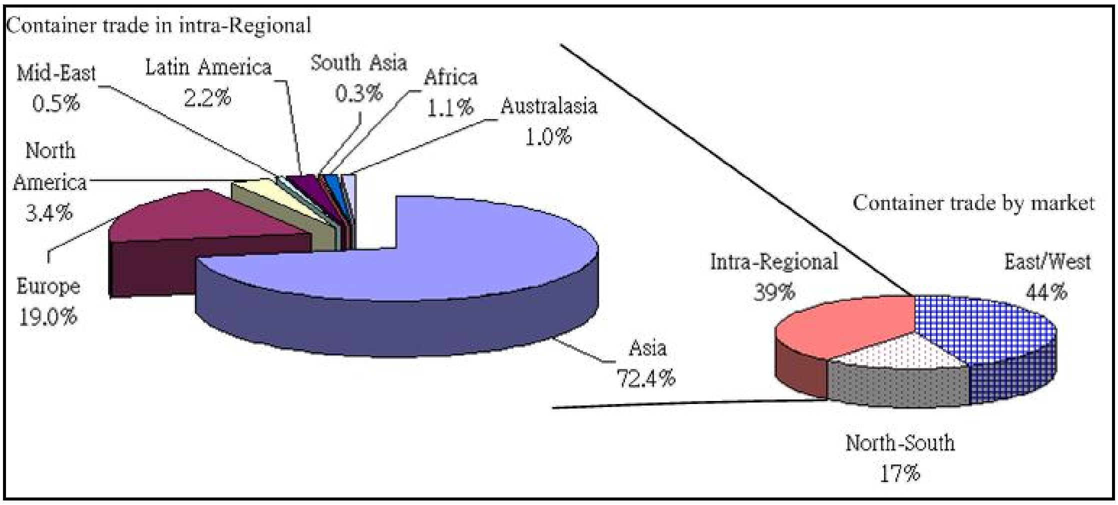

Figure 2.3 Share of container trade route by market

2.1.3 Empty container volume

Drewry Shipping Consultants estimated that by 2004 there were 37.2 million TEUs of seaborne empty container movements, which generated some 74.3 million TEUs of port handling. The costs associated with the repositioning of empty equipment were considerable, as they include an allowance for terminal handling, the costs of rest wage, administration, container storage, ship's time, equipment per diem and repair. It was estimated that this cost was about US$14.9 billion. In addition, there were overland repositioning and inland (intra-zonal) imbalance costs which, while necessarily speculative, were estimated at another US$7.7 billion. This brought the total empty container cost (direct and indirect) to an estimated US$22.6 billion (Drewry Shipping, 2005).

The empty container incidence has exceeded 20% over since 1998, when the Asian currency crisis caused some structural fault lines to develop in directional trade balances, fault lines that show no signs of working themselves out of the system, judging on the performance of the two main Asian export trades to Europe and North American. Against the backdrop of rising trade imbalances on those two key routes, carriers have done well in somehow managing to restrain the global empty incidence over the last couple of years. This possibly points to more balanced flows in intra-regional trades, especially intra-Asian areas. While carriers are devoting considerable energy and investment to better matching equipment flows and sophisticated yield management systems, there is an over-riding structural problem pertaining to the increasing deep-sea trade imbalances; this is setting the agenda for the foreseeable future (Drewry Shipping, 2005).

In view of these observations, carriers would do well to hold the empty incidence at the current levels of just under 21%. Each percentage point results in an increase or decrease in the global empty container incidence, which is estimated at US$650 million pa(2004). By the year 2010, the increased volume of world container activity will have pushed this figure up to around US$1 billion pa.

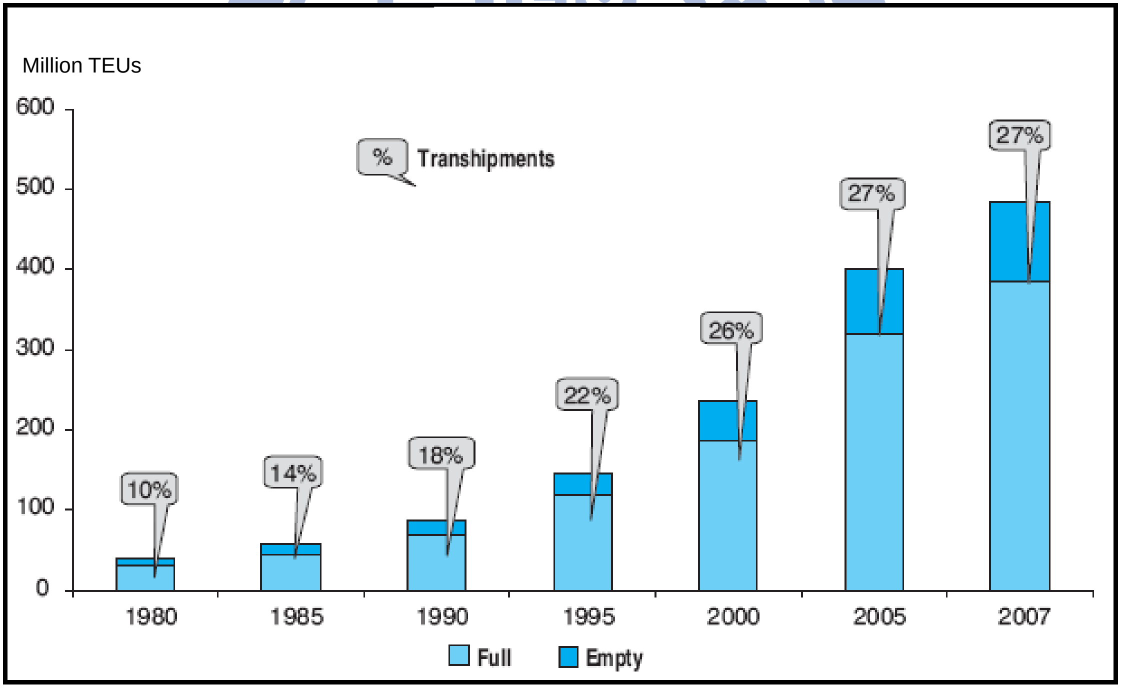

Figure 2.4 Container traffic by full and empty, 1980-2007

Source:United nations conference on trade and development, Review of Maritime Transport 2008

2.2 Revenue Management

Revenue management (also known as yield management) is used to determine optimal inventory allocation and scheduling strategies as well as to set prices for perishable assets in order to maximize revenue within the planning horizon. Revenue management is rooted in the airline industry where revenue management systems have been applied for over 40 years (Lai and Ng, 2005). Revenue management is a broad term that refers to the various ways a service provider can secure increased revenues from a relatively fixed capacity. Revenue management has been successfully applied to airlines, car rental firms, cruise lines, restaurants, hotels, etc. Berman (2005) indicated that yield management pricing can be successfully applied to service industries with demand characteristics, reservations, cost characteristics, and capacity limits (as shown in Table 2.3). In general, these industries include markets that can be segmented, services that are traditionally booked via a reservation system, and services characterized by a low marginal cost and a relatively fixed capacity.

There is a wealth of literature on revenue management for airlines, hotels, restaurants, etc. For liner shipping, quantitative tools for solving revenue management problems are relatively limited. Ting and Tzeng (2002, 2004) presented revenue management systems that would increase profits using slot allocation in long-haul services for liner shipping. However, their work did not address the issue of how to maximize profit in short-haul, multiple-port network conditions.

Since container carriers share very close characteristics with airlines, it would appear possible to directly transfer successful airline revenue management tools to liner shipping. This means that liner shipping has a high potential for the application of revenue management techniques.

For example:

(1) Both vessel-slots and air-seats are perishable and can not be stored for future sale

(2) Capacity is usually fixed and cost of instant expansion is very high

(3) Advance booking is allowed and thus cancellations, no-shows and overbooking problems exist.

Table 2.3 Ideal applications of yield management pricing

Demand characteristics
♦ Significant variation in demand by time of day, season, day of week (weekend vs. weekday)
♦ Demand that is capable of being segmented.
♦ Significant differences in price elasticity by marker segment.
Existence of reservations
♦ Demand is somewhat predictable.
♦ Service is reserved by consumers in different time periods (ranging from well in advance to just before the service expires).
♦ Uncertainty of actual usage despite reservations creates possibility of unsold seats. Service providers can protect against no-shows through overbooking.
Cost characteristics
♦ Low costs of marginal sales in comparison to marginal revenues.
♦ High fixed costs.
Capacity limits
♦ Capacity is relatively fixed. The fixed number of output units needs to be allocated among customers.
♦ Service providers have excess capacity at certain times and excess demand at other times. When demand peaks, many services face binding capacity constraints that prevent serving additional customers. Care rental agencies have a limited number of cars; hotels have a limited number of rooms, etc. Yield management is meat to redress that difference between the demand level of the moment and much longer-term fixed capacities.
♦ Capacity is perishable. It cannot be stored. Revenues from unsold tee times, restaurant seats, hotel rooms, and airline seats are lost forever.

Source:Berman (2005)

2.3 Containership Slot Allocation

Container carriers use containerships as the main vehicles to carry containers from one port to another on their sea transportation network. In general, the containerships carry containers loaded with imported cargo (loaded container) and empty containers transferred from previous ports. After the containership arrives at a terminal, some of the loaded containers and empty containers are unloaded. Empty containers are dispatched to depots to meet the demand of shippers. Loaded containers are transported to their destination and then unloaded to a local consignee. Empty containers, which previously contained loaded cargo, are returned to depots and reused by container carriers to meet surplus demands, or else stored at deports for future use. If they are stored, then costs pertaining to container storage and rest wage begin to accrue. Also, container utility and the turn-over rate of containers decreases. As a result, container carriers hardly generate reasonable profits and even run deficits.

Quantitative tools to solve the problem of slot allocation for container shipping are relatively limited. Fagerholt and Christiansen (2000) developed a hypothetical bulk ship scheduling problem mimics existing problems pertaining to multi-ship pickup and delivery problem with a time window (m-PDPTW) and a multi-allocation problem. Their work suggested a set partitioning approach consisting of two phases. In the first phase, feasible schedules for each ship were generated. These schedules included the optimal allocation of cargoes to the ships' nominal compartments. The second phases included the solution to a set partitioning problem in which the proposed schedules, generated in Phase One, were represented by columns. The solution of the set-partitioning problem was to allocate one schedule for each ship, with cargoes serviced by spot carriers, thus minimizing transportation costs. However, the solution focused on the problems faced by bulk ships which have a different operational procedure than that of containerships. Bulk ships follow the available cargo, much like a taxi service. Container carriers operate according to a published itinerary and they run a schedule similar to that of a bus line.

Ting and Tzeng (2001, 2004) formulated an optimal slot allocation model with revenue management systems. The objective of the proposed model was to maximize the total freight contribution, due to high variable costs, instead of focusing on freight revenue. The model also considered the possibility of the continuing worsening of trade imbalances, and it responded to this possibility by locating repositioning costs in the objective function. Ting and Tzeng (2002) used fuzzy multi-objective programming techniques to deal with two conflicting objectives: the carrier's freight contribution and the agents' degree of satisfaction; they did not seek to maximize profit in short-haul, multiple-port service routes for container carriers. This present research extends the concept of Ting and Tzeng (2001, 2002 & 2004) by utilizing revenue management to arrive at a slot allocation scheme for multi-port intra-Asian service routes.

2.4 Empty Container Management

In the literature on empty container management, Shintani et al. (2007) presented a design of container liner shipping service networks that focused on empty container repositioning. The objective was to maximize the company's profit and minimized the cost of empty container traffic; however, it did not address techniques for empty container repositioning. Choong et al. (2002) addressed the effect of the planning horizon length on empty container management for inter-modal transportation networks. That analysis proposed an integrated program that sought to minimize total costs related to moving empty containers. The objective was the same as that of the present study, but it presumed a different operational procedure that focused on empty container management of inter-model container-on-barge. Li et al. (2004) stated the obvious; it is essential for any unnecessary empty containers to be repositioned from surplus locations to shortage locations. That paper addressed the question of how many empty containers at a given port are unnecessary; however, it did not consider the transportation problem, nor did it propose an overall empty container repositioning plan.

Table 2.4 Literatures on slot allocation for loaded containers

Authors	Year	Main issues and results
K Fagerholt M Christiansen	2000	♦ Present a bulk ship scheduling problem that was a combined multi-ship pickup and delivery problem with time windows and multi-allocation problem. ♦ The model generated a number of feasible candidate schedules for each ship and these schedules included the optimal allocation of cargoes to the ships' nominal compartments.
Shin-Chan Ting Gwo-Hshiung Tzeng	2001	♦ Propose liner shipping revenue management to formulate an optimal slot allocation model. ♦ Suggest the objective was to maximize total freight contribution, but not freight revenue, because of high variable costs and repositioning costs.
Shin-Chan Ting Gwo-Hshiung Tzeng	2002	♦ Formulate optimal slot allocation through fuzzy multi-objective programming. The objective of the slot allocation model is to maximize the total freight contribution and agents' degree of satisfaction..
Shin-Chan Ting Gwo-Hshiung Tzeng	2004	♦ The results indicated the optimal slot allocation can be a guideline for distributing space to every calling port to achieve the most expected contribution. ♦ An Asia-Europe service route of a liner company in Taiwan was used as a case study. ♦ For implementation, this work still needed to integrate with related databases and pricing, as well as container inventory and dynamic slot control.

Chou (2006) tried to draw up a model for solving the empty container allocation problem with a mathematic programming method. The objective of that paper was to minimize the cost of empty containers on service routes by conducting a case study referring to the data of long-haul service. Li et al. (2007) proposed heuristic methods to solve the problem of empty container allocation between multi-ports. The work calculated simulation costs and average expected costs, but it did not consider empty container flow between multi-ports. Shen and Khoong (1995) presented a decision support system to solve a large-scale planning problem concerning the multi-period distribution of empty containers. They noted that ports were partitioned into geographical regions and each region had a group of ports with one main port. Through trade activities, any port might be a demand port (i.e., a port demanding more empty containers to ship out the outbound cargo), or a supply port (i.e., a port having a surplus of empty containers for global liner shipping companies). Shen and Khoong focused on the business aspects of shipping and prescribed the placement of empty containers in a distribution planning proposal. Only one type of container was considered in that proposal and technical aspects were not discussed. .

In this present study, the concept proposed from Shen and Khoong(1995) has been extend to include the various partitions in the sea transportation network as implied by different geographical regions.

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Table 2.5 Literatures on empty container management

Authors	Year	Main issues and results
W.S. Shen, C.M. Khoong	1995	♦ Partition ports into geographical regions and each region had a group of ports with on main port. ♦ This paper took a business process perspective, and did not discuss technical aspects to work out this model in practice.

Table 2.5 (cont’d) Literatures on empty container management

Authors	Year	Main issues and results
Sook Tying Choong, Michael H. Cole, Erhan Kutanoglu	2002	♦ Proposed an integer program that sought to minimize total costs related to moving empty containers.
Jing-An Li, Ke Liu, Stephen C.H. Leung, Kin Keung Lai	2004	♦ Formulate one port containerization problem as an inventory problem. ♦ Multi-port problem including how to allocate all empty containers between ports with the minimum expected cost did not be discussed.
Hossein Jula, Anastasios Chassiakos Petros Ioannou	2006	♦ Model the dynamic empty container reuse analytically, and develop an optimization technique to minimize the number and cost of truck trips. ♦ The results found the model would reduce the traffic and congestion around the ports, but this work do not discuss empty container distribution problem.
Chien-Chang Chou	2006	♦ Formulate a model for solving empty container allocation problem in the shipping company by mathematic programming method. ♦ Take into account of empty container safety inventory and maximum inventory at each port.
Koichi Shintani Akio Imai Etsuko Nishimura Stratos Papadimitriou	2007	♦ The results indicated design of the container shipping network without consideration of the empty container traffic eventually becomes very costly due to less efficient empty container distribution.

Table 2.5 (cont'd) Literatures on empty container management

Authors	Year	Main issues and results
Jing-An Li, Stephen C.H. Leung, Yue Wu, Ke Liu	2007	◆ Design a heuristic algorithm to show how to allocate the empty containers to reduce the average cost. ◆ The result found the optimal policy for only one port may not be used successfully in the multi-port case.
Shao-Wei Lam, Loo-Hay lee, Loon-Ching Tany	2007	◆ Formulate the dynamic container allocation problem as a dynamic stochastic program with the decision policy optimal in the infinite horizon average cost sense. ◆ Simplistic two-ports two-voyages model was extended to a more realistic multiple-ports multiple-voyages model, improvements of the average cost optimal solution was not as significant.
Hwan Chang, Hossein Jula, Anastasios Chassiakos, Petros Ioannou	2008	◆ Address empty containers can be directly distributed among customers without necessarily passing through container terminals. ◆ This proposed process could change the port distribution mechanism in current practices.

2.5 Other Related Researches on Container Shipping

A wealth of literature is available on the subjects of routing, cost, and strategic alliance. The problem of routing was studied by Fagerholt(1999 and 2004); Lu and Hsu (2001); Lu(2002 and 2003); Chen and Chiu(2002); Lai and Lo(2004); and Hsu and Hsieh(2007). Bergantino and Veenstra (2002) investigated an application of network theory to line shipping. They pointed out that the rationale behind the strategies of the operators was to extend market coverage globally. Researches on maritime hub-and-spoke networks were studied by Hsieh and Chang(2001) and Hsu and Hsieh(2007).

Song et al. (2005); and Ting and Tzeng (2003) focused on aspects of cost in liner shipping. Song et al. (2005) indicated that the cost of repositioning empties was 27% of the total world fleet running cost. Cullinane and Khanna (1999 and 2000) studied economies of scale in large containerships, and indicated optimal containership size with respect to different operational scenarios.

Table 2.6 Literature on routing and network

Authors	**Year**	**Topic**
Kjetil Fagerholt	1999	Optimal fleet design in a ship routing problem
Hua-An Lu Yu-Chang Hsu	2001	Route selection and fleet deployment for a container liner
Shang-Hsing Hsieh Fei-Ru Chang	2001	Applications of the hub-and-spoke network model in routing liner ships
Hua-An Lu	2002	Route planning for container liner
Chuen-Yih Chen Ming-Chi Chiu	2002	A network design model for the containership routing problem
Angela S Bergantino Albert W Veenstra	2002	Interconnection and co-ordination: an application of network theory to liner shipping

Table 2.6(cont'd) Literature on routing and network

Authors	Year	Topic
Hau-An Lu	2003	Modeling ship's routing and container positioning for transoceanic liner
M.F. Lai Hong K. Lo	2004	Ferry service network design: optimal fleet size, routing, and scheduling
Kjetil Fagerholt	2004	Designing optimal routes in a liner shipping problem
Chaug-Ing Hsu Yu-Ping Hsieh	2007	Routing, ship size, and sailing frequency decision-making for a maritime hub-and-spoke container network

Table 2.7 Literature on cost and economies of scale

Authors	Year	Topic
Kevin Cullinane Mahim Khanna	1999	Economies of scale in large container ships
Kevin Cullinane Mahim Khanna	2000	Economies of scale in large containerships: optimal size and geographical implications
Shin-Chan Ting Gwo-Hshiung Tzeng	2003	Ship scheduling and cost analysis for route planning in liner shipping
Dongping Song Jie Zhang Jonathan Carter Tony Field James Marshall John Polak Kimberly Schumacher Proshun Sinha-Ray John Woods	2005	On cost-efficiency of the global container shipping network

The problem of strategic alliance was studied by Ryoo and Thanopoulou(1999); Midoro and Pitto(2000); Song and Panayides(2002); Slack et al.(2002); Shyr et al.(2003); Ding and Liang(2004); and Chou(2007). These studies indicated that the pressure was high for forms of co-operation that could reduce costs, share the risk of over-committing capital, and market coverage, thus ultimately increasing market control through the combined activities of what would have been individual competitors (Ryoo and Thanopoulou, 1999). Cooperative game theory was applied by Song and Panayides(2002) and Shyr et al. (2003) to analyze co-operation among members of liner shipping strategic alliances. Ding and Liang(2005) presented a fuzzy MCDM to select partners of strategic alliances for line shipping.

Table 2.8 Literature on strategic alliance

Authors	**Year**	**Topic**
D. K. Ryoo H. A. Thanopoulou	1999	Liner alliances in the globalization era: a strategic tool for Asia container carrier
Renato Midoro Alessandro Pitto	2000	A critical evaluation of strategic alliances in liner shipping
Dong-Wook Song Photis M. Panayides	2002	A conceptual application of cooperative game theory to liner shipping strategic alliances
Brian Slack Claude Comtois Robert McCalla	2002	Strategic alliances in the container shipping industry: a global perspective
Feng-Yeu Shyr Carlton-M.H. Chen Chuan-Feng Hwu	2003	An evaluation of various strategic alliances among container carriers-a cooperative game approach
Ji-Feng Ding Gin-Shun Liang	2005	Using fuzzy MCDM to select partners of strategic alliances for liner shipping

2.6 Summary

Container shipping has been the fastest growing sector of the maritime industries in the last twenty years, with over 50% of container trade occurring in Asia. East-West trade is estimated to have generated almost 44% of the global container traffic volume in 2004; 39.1% is attributed to intra-regional trade and 17.2% to north-south trade. By Drewry's estimates, intra-Asian trade (excluding the Middle-East, Indian subcontinent and Australasia) amounted to 28.6 million TEUs in 2007, accounting for one fifth of total global trade. This volume is forecast to reach 50.7 million TEU by 2013. The empty container incidence has exceeded 20% since 1998. Even so, container carriers have done well to restrain empty incidence by devoting considerable energy and investment to better matching of equipment flows and to sophisticated revenue management systems.

Revenue management has been successfully applied to airlines, car rental firms, cruise lines, restaurants and hotels, etc. In the airline industry, revenue management has been introduced to successfully solve problems related to perish ability, fixed capacity, variable cost, demand and market segmentation, advance sales and bookings, stochastic demand, and historical sales data. It has also been used to assist forecasting capabilities. Container shipping has a high potential for the application of revenue management techniques, as container carriers share very close characteristics with airlines. It would appear possible to directly transfer successful airline revenue management tools to container shipping.

As mentioned above, there is a substantial amount of literatures on the subject of routing, cost, and strategic alliance, but few studies on slot allocation have sought to maximize profit in short-sea, addressed multiple-port service routes, or considered the cost of empty container repositioning on these routes. This study focuses on a container carrier providing service in the intra-Asian area. It addresses the optimization of slot allocation and empty container reposition. In part one, we aimed to find a way to optimize slot allocation within a specific shipping service route in order to maximize operational profits for container carriers and provide a guideline for shipping agencies soliciting cargo. In part two, we sought to minimize the total transportation cost of empty container repositioning within the sea transportation network in order to provide a guideline for empty container distribution that can be implemented by the container management department.

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CHAPTER 3 DESCRIPTION OF PROBLEM

This chapter describes transportation characteristics of container carriers consisting of loaded containers and empty containers, and introduces the problems associated with both. The chapter is organized as follow: Section 3.1 presents the relationship between revenue management and containership slot allocation. Section 3.2 describes service routes and the cargo types of containerships. Section 3.3 provides an illustration of container movement at container terminals. Section 3.4 considers the cost of empty container reposition. Section 3.5 presents safety stock management for loaded containers and empty containers. The expected cost of empty container reposition is presented in this section. This cost is taken into consideration in the model proposed for containership slot allocation. Section 3.6 provides an illustration of the various geographical regions within the sea transportation network. A summary of this chapter is given in the last section.

3.1 Revenue Management and Containership Slot Allocation

Container carriers would improve freight revenue on a port-pair under the restriction of fixed containership capacity, through better management and allocation of ship slots. For example, a containership sails on a service route between ports A, B, C and port D; its capacity was 100 TEUs. Figure 3.1 shows freight revenue per port-pair in various scenarios. In scenario 1, the carrier directly loads 100 TEUs from port A to port D and gains total freight revenue of US$215,000. The shipping agencies at port B and port C do not have any slots. Such a situation often creates friction among shipping agencies. Although, the containership is fully loaded, market activity at ports B and port C decrease and demand is not served. In scenario 2, the carrier loads 100 TEUs from port A to port B; 100 TEUs from port B to port C; and 100 TEUs from port C to port D. The carrier fully utilizes slots on each port-pair and maximizes total loaded cargo and total freight revenue. However, a carrier takes risk of varying cargo demand and do not expand market coverage. If cargo demand in a certain port-pair, such as port B to port C is less than containership capacity, the unsold space revenue is lost. Scenario 3 is what the case in practice. The carrier transports 20 TEUs from port A to port B; 50 TEUs to port C; 30 TEUs to port D; 10 TEUs form port B to port C; 10 TEUs to port D; and 60 TEUs from port C to port D. Shipping agencies in each port solicits cargo that must be transported to diverse destinations, creates wide market coverage, and reduces risk associating with variable market demand. Therefore, slots need to be allocated among shipping agents in a revenue maximizing manner via revenue management.

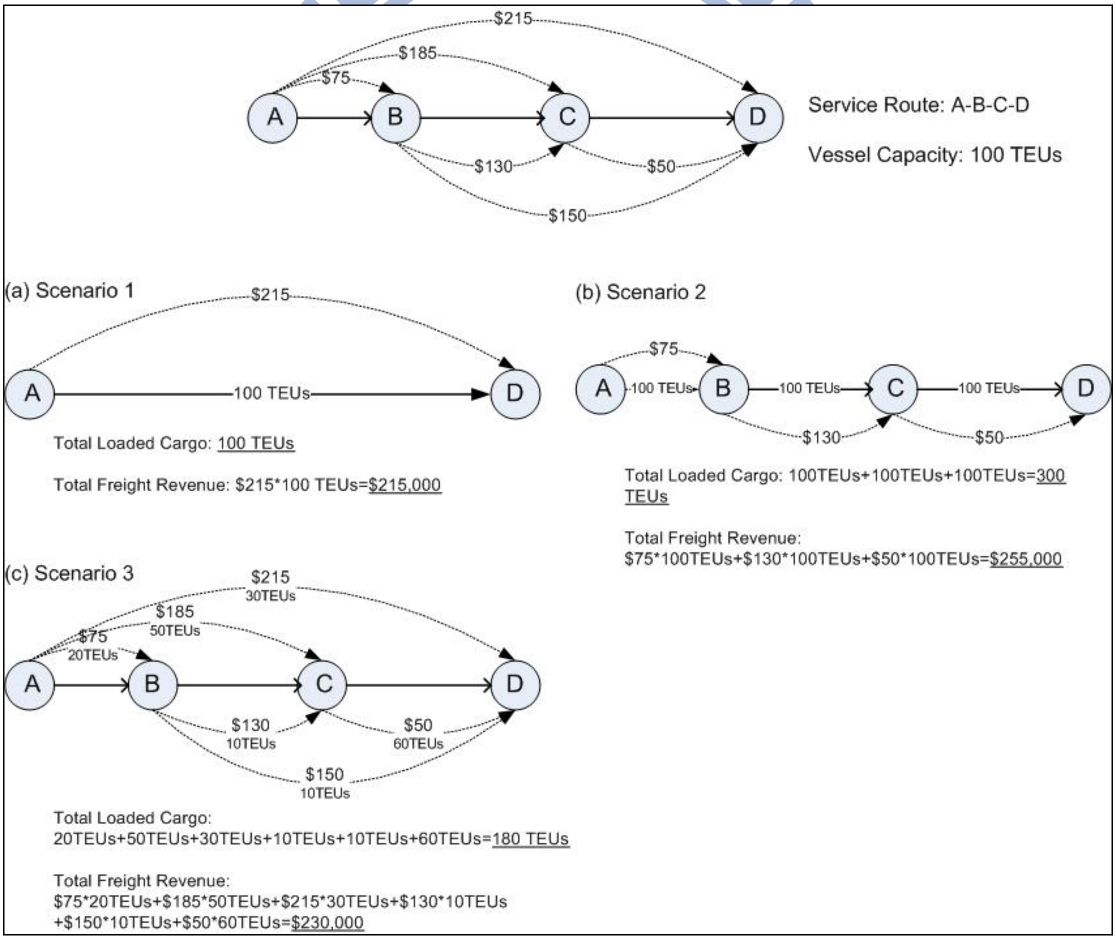
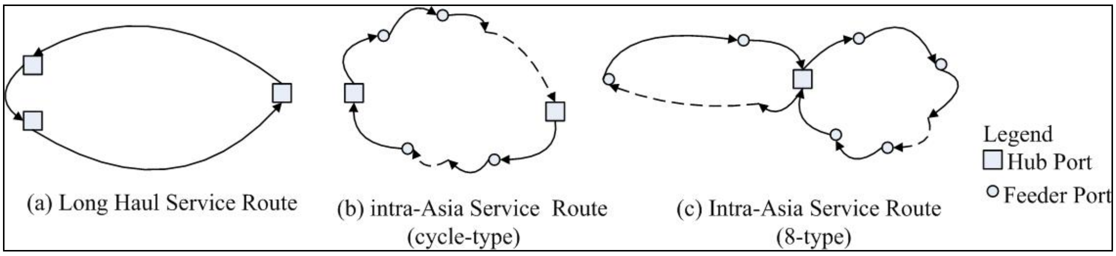


Figure 3.1 The concept of containership slot allocation with revenue management

3.2 Service Routes and Cargo Types on Containership

Container shipping industry is operating in a fiercely competitive, market-driven environment. Most container carriers strive to increase the number of service routes, improve service frequency and provide direct delivery. Long-haul and intra-Asian services differ both in terms of service routes and containership planning. As a rule, large mother ships are used on long-haul service routes to provide services among hub ports, while smaller ships are deployed in feeder lines to provide regional distribution. Most ports in Asia berth only mid-sized containership and thus intra-Asian services are feeder lines collecting or delivering cargo for long-haul service routes (as shown in Figure 3.2). In intra-Asia services, container carriers must collect and deliver cargo by calling at an increased number of ports (multiple-port service), providing convenient and direct services to improve service quality and competitiveness. For instance, a multiple-port service is designed to call at five ports. At each port, some of cargo is unloaded from the containership before it starts to load local cargo. Thus, the containership’s cargo is divided into three types on containership: loaded cargo, unloaded cargo and remain-on-board (ROB) cargo. When the containership arrived at port 2, the loaded cargo was $X_{21}+X_{23}+X_{24}+X_{25}$, the unloaded cargo was $X_{12}+X_{32}+X_{42}+X_{52}$, and ROB cargo was $X_{13}+X_{14}+X_{15}+X_{43}+X_{53}+X_{54}$ (as shown in Figure 3.3).


(a) Long Haul Service Route

(b) intra-Asia Service Route (cycle-type)

(c) Intra-Asia Service Route (8-type)

Figure 3.2 Types of service route for long haul service and intra-Asia service

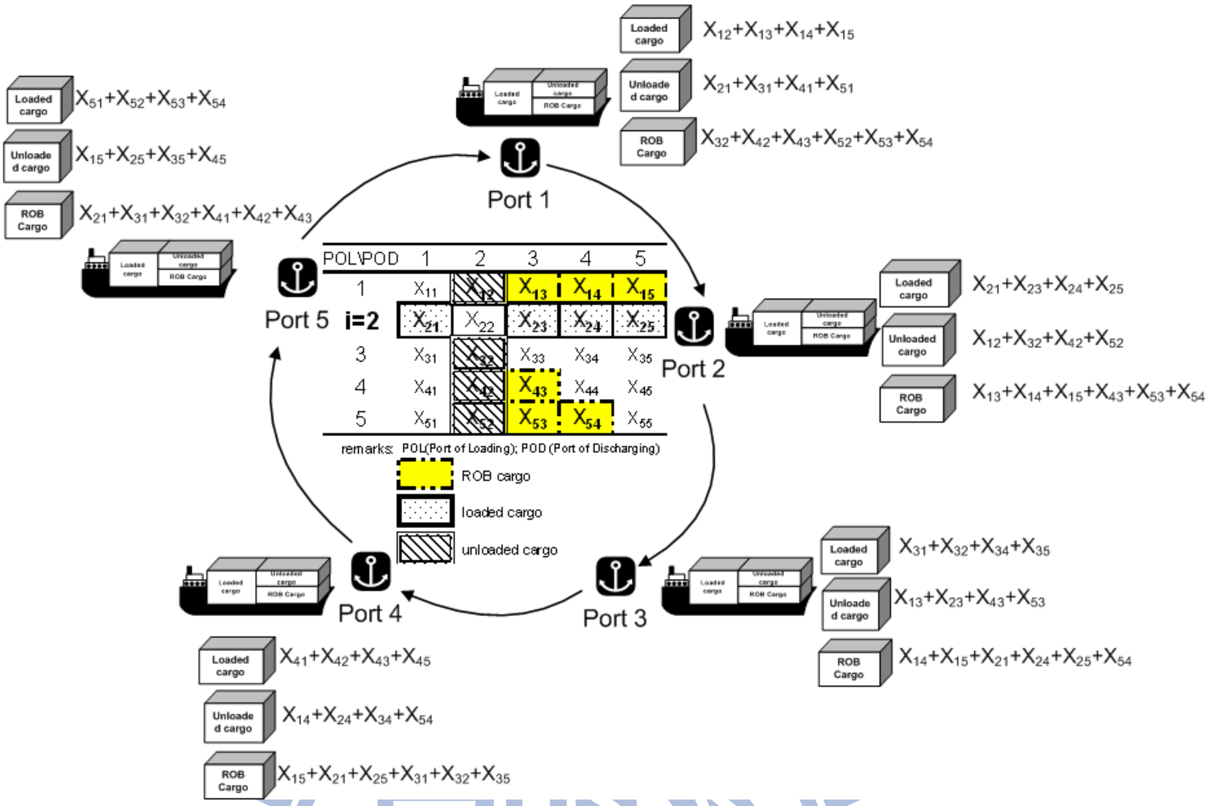


Figure 3.3 Types of loaded cargo, unloaded cargo and ROB cargo on containership

3.3 Container Movement at Terminal

Container carriers use containerships as the main mode of transport to carry containers from one port to another over its sea transportation network. Usually, the containerships carry containers loaded with imported goods and empty containers transferred from previous ports. After the containership arrives at the terminal, the loaded containers are unloaded from the containership. At the same time, container carriers conduct processing of repositioning surplus empty containers from supply ports to demand ports. Figure 3.4 shows the different movements involved in container transportation. For an inbound container movement, a loaded container is dispatched from a container terminal to a local consignee 『I/B (1) movement』 and empty container is taken back to the container depot 『I/B (2) movement』. For an outbound container movement, an empty container is dispatched from the container depot to a local shipper 『O/B (1) movement』 who takes the loaded container to the container terminal 『O/B (2) movement』. When a port had a surplus of empty containers, the container carrier repositions out empty containers to ports that is short of them 『R/O movement』. When a port is short of empty containers, the container carrier repositions in empty containers from ports that has a surplus 『R/I movement』.

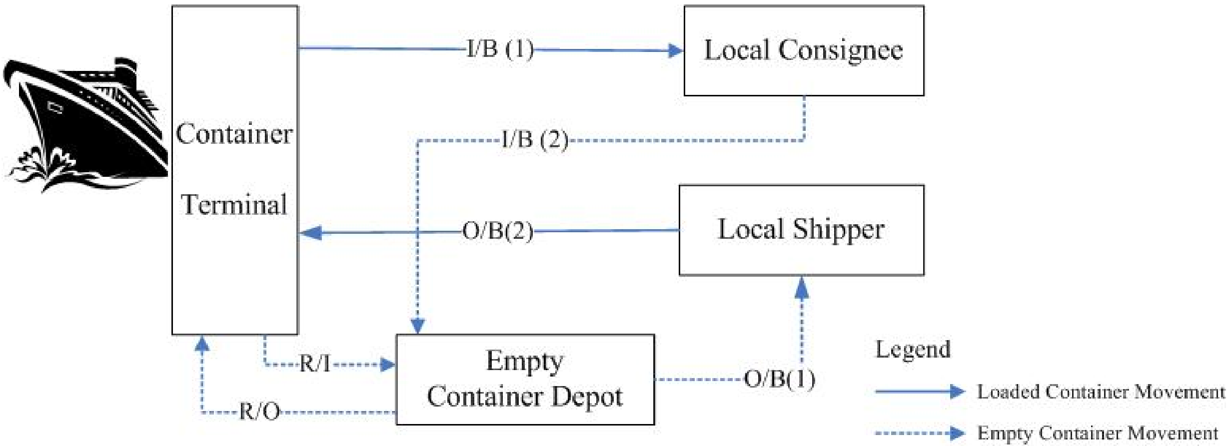


Figure 3.4 Container movements at terminal

3.4 Empty Container Transference Costs and Operational Profits

Due to an imbalance in international trade activity, container carriers need to distribute empty containers to the ports that need them. The cost of empty container is 27% of the total world fleet running cost (Song et al., 2005), which is costly for container carriers. Figure 3.5 illustrates the cost of empty container repositioning and the operational profits for various conditions of empty container stock: the container delivered from port A to port B produced higher freight revenue than that from port C to port D. Typically, container carriers seek to deliver many containers from port A to port B to increase freight revenue. However, the results are changeable owing to various conditions of empty container stock at the time of loading and unloading. We propose "Operational Profit (OP)" to reflect profit for each port-pair shipment.

Freight Revenue unit:$/port-pair

－）**Variable Cost (Loading Port + Unloading Port)**

－）**Cost of Empty Container Reposition (Loading Port + Unloading Port)**

Operation Profit

In condition 1, port A had a shortage of empty containers. Before delivering its shipment, the container carrier should reposition empty containers and pay the cost of (US$56). After finishing delivery, the container carrier should transfer out empty containers from port B (US$52), which had a surplus. Using this strategy, the operational profit from port A to port B can be calculated as follows:

$$\text{Operational Profit}: \ \text{US\$}124 = \text{US\$}380 - US\$86 - US\$62 - US\$56 - US\$52$$

In condition 2, port C had a surplus of empty containers and port D had a shortage of empty containers. Normally, the container carrier would reposition empty containers from port C (US$52) and reposition into empty containers to port D (US$40). However, if the container carrier would first deliver its shipments, the cost of empty container reposition could be eliminated or reduced. Containers delivered from port C to port D created freight revenue of US$250; by eliminating the cost of empty container repositioning, which would otherwise by US$92, the container carrier might create an operational profit of US$194.

$$\text{Operational Profit}: \ US\$194 = US\$250 - US\$68 - US\$80 - \left(-US\$52\right) - \left(-US\$40\right)$$

It follows that the container carrier should allocate more slots from port C to port D than from port A to port B in order to increase operational profits (as seen in Table 3.1).

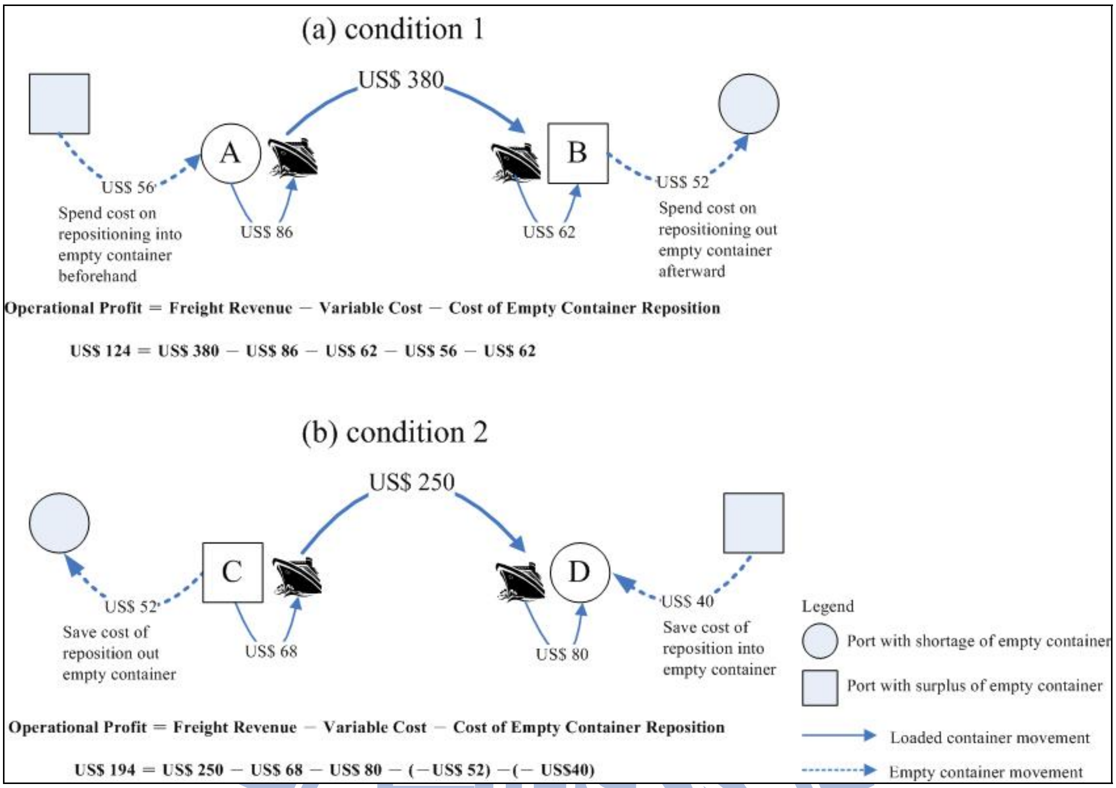


Figure 3.5 Concept of operational profit with empty container reposition

Table 3.1 Comparing condition 1 with condition 2 in freight revenue and operational profits

	Condition 1		Condition 2
Scenario	Shortage(A) ⇩ Surplus(B)		Surplus(C) ⇩ Shortage(D)
Freight Revenue	US$380	>	US$250
Operational Profit	US$124	<	US$194

3.5 Safety Stock Management for Empty Containers

Container carriers accumulate a large number of empty containers in import-oriented ports and export-oriented ports often face a shortage of empty containers. The cost of dispatching empty containers can be substantial. Since the demands for containers are variable, it is not surprising that some ports may require more containers than are currently available, while other ports may store surplus empty containers. In practice, any port might be a demand port or a supply port, depending on current conditions. To reduce expenditure and increase responsiveness to shippers' demands, container carriers should apply safety stock management to control empty containers at each empty container depot. Safety stock produces an added inventory that smoothes delivery and demand variations coupled with timing and quantity deviations is one (beside others) buffering technique.

The safety stock management of empty containers, shown in Figure 3.6, can be briefly described as follows: The amount of empty container Q_t is variable because of the interaction of outbound(O/B) containers, inbound(I/B) containers, repositioned-in(R/I) empty containers and repositioned-out(R/O) empty containers.

$$Q_t = IB_t - OB_t + RI_t - RO_t$$

Container carriers regularly surveyed empty container stock at each depot to conduct plans for empty container reposition. For example, in first time period of T, the number of empty containers was greater than safety stock $[Q_1 > S]$ which meant that this port could be a supply point for container carriers to reposition idle empty containers $[Q_1^S]$. However, in this case study there were limits on the number of slots allocated to empty containers on the containership. The proposed solution was to apportion the empty containers into several voyages for repositioning. The containership occasionally still accumulated a great quantity of empty containers that idled at the depot (as shown in the second time period of 2T and the third time period of 3T). Also, the number of empty containers at this port decreased to less than safety stock $[Q_4 < S]$ and this port now had a shortage of empty containers, which meant it had become a demand point. The proposed solution was to reposition empty containers $[Q_4^D]$ to meet demands (as shown in the forth time period of 4T). Again, this was done throughout several voyages. In the final count, the number of empty containers was probably still less than safety stock (as shown in the fifth time period of 5T and the sixth time period of 6T).

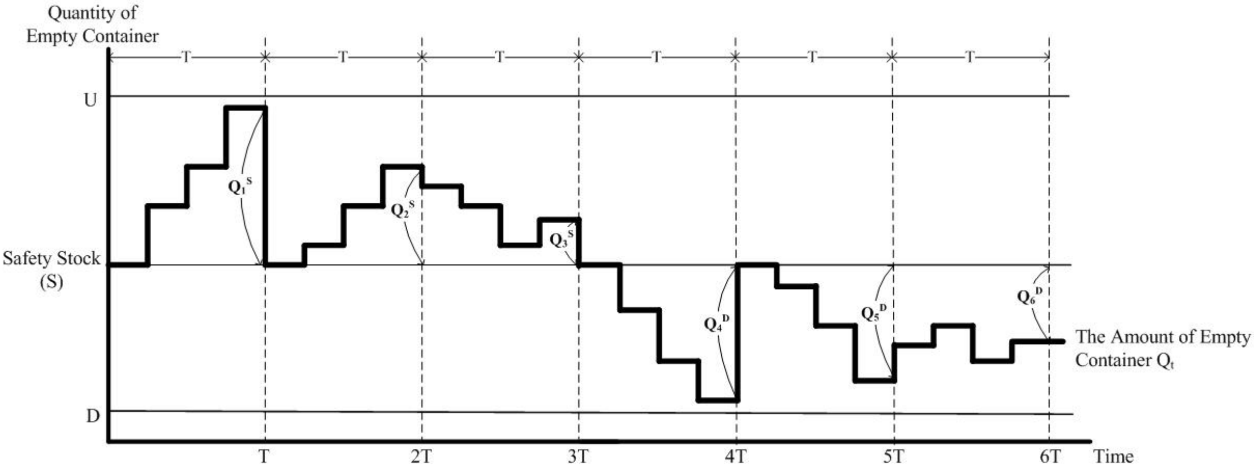


Figure 3.6 Safety stock management of empty container

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When the number of idle empty containers was greater than the safety stock of empty containers $[Q_t > S]$, container carriers repositioned out empty containers; when the number of idle empty containers was less than the safety stock of empty containers $[Q_t < S]$, they repositioned in empty containers to meet demands. When the number of idle empty containers was equal to the safety stock of empty containers $[Q_t = S]$, they did nothing. When accumulating a large number of idle empty containers, container carriers were made to pay substantial storage expenses. The process of repositioning out empty containers was conducted rapidly. In the event that the containership lacked a large number of empty containers, they quickly repositioned in empty containers to meet demands. The probability of repositioning empty containers depends on the gap between the number of empty containers and the amount of safety stock $[(Q_t \& S)]$ (as seen in Figure 3.7). We proposed the probability and the expected cost of empty container repositioning as follows.

$$POR = \begin{cases} = 1,\ if\ \ Q_t = U\ \ or\ Q_t = D \\ < 1,\ if\ \ S < Q_t < U\ \ or\ \ D < Q_t < S \\ = 0,\ otherwise \end{cases}$$

$$EC = HE \times POR$$

where,

EC : *the expected cost of empty container reposition*

HE : *handling cost of empty container at port*

POR : *probability of repositioning empty container*

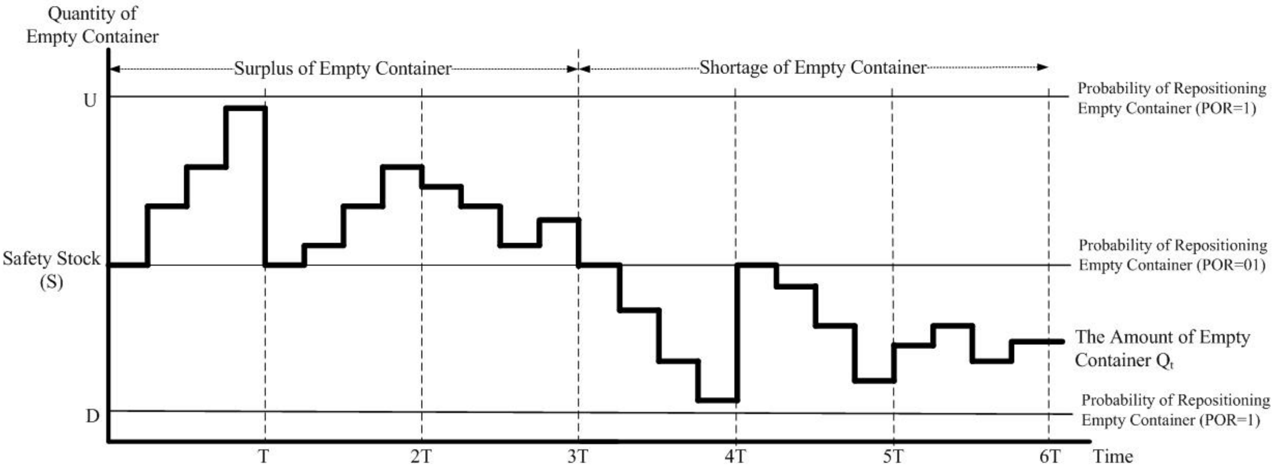

Figure 3.7 Empty container stock and probability of empty container reposition

3.6 Geographical Regions with the Sea Transportation Network

Container carriers deliver cargo to customers by designing a service route with fixed schedules and weekly service. They conduct a plan of empty container reposition via unsold slots on containerships and make arrangements through direct delivery without transshipping to reduce costs. When empty containers occupy slots on a containership over a long distance, containership lose the opportunity to take aboard loaded containers which generate freight revenue. An intra-Asian service route was designed to sail between Japan, Taiwan, Hong Kong, and Thailand calling at Tokyo (TYO) port, Yokohama (YOK) port, Nagoya (NGO) port, Osaka (OSA) port, Kobe (UKB) port, Keelung (KEL) port, Taichung (TXG) port, Kaohsiung (KHH) port, Hong Kong (HKG) port, Bangkok (BKK) port and Laem Chabang (LCH) port, and then return to Tokyo (TYO) port for a round voyage (as seen in Figure 3.8). If an empty container was repositioned from TYO port to LCH port, the container carrier lost the opportunity to take aboard a loaded container for several sailing legs (i.e. TYO/KEL, KHH/HKG and HKG/BKK). To resolve this problem, it was proposed that containerships partition the service route into three geographical regions and distribute empty containers within a single region (as seen in Figure 3.9).

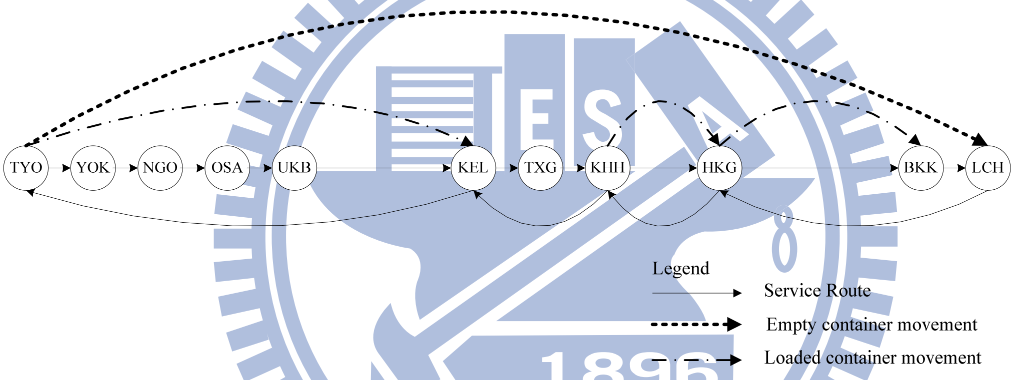

Figure 3.8 Service route and container movement

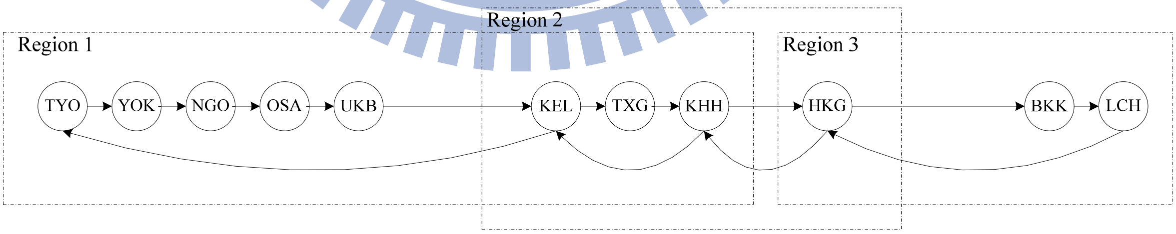

Figure 3.9 Geographical regions of service route

As explained in Figure 3.10, the sea transportation network is composed of all service routes and partitioned into several geographical regions.

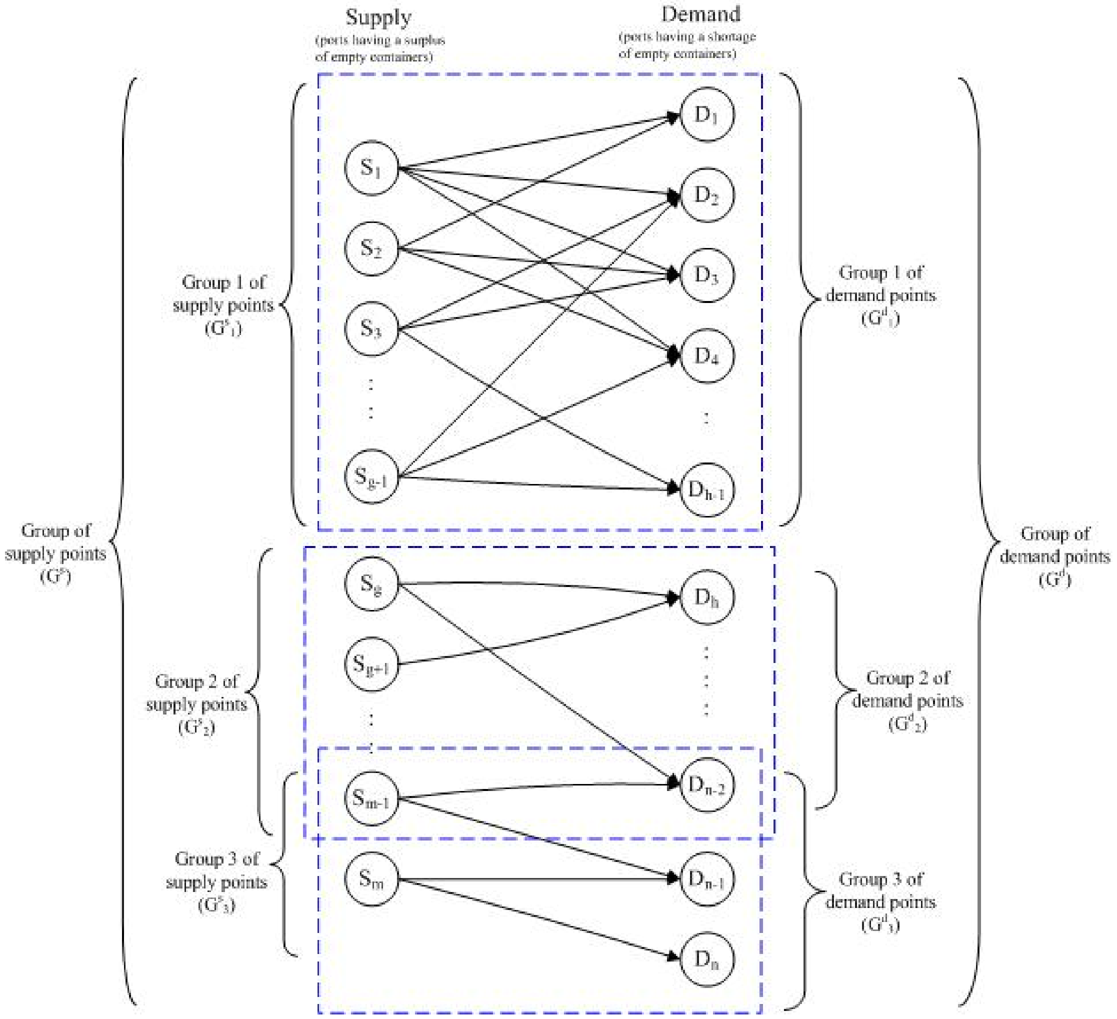

Figure 3.10 Geographical regions with sea transportation network

3.7 Summary

This summary is divided into two parts. The first part outlines the plan for containership slot allocation for a loaded container; the second part outlines the paln for empty container reposition.

3.7.1 The plan for containership slot allocation

Factors affecting the plan for slot allocation are summarized below (see Figure 3.11).

1) Freight revenue: Containership carriers deliver cargo to get freight revenue which is provided from different port-pairs depending on the market situation. For example, the region between Hong Kong and Taiwan is very competitive because many carriers run service routes. The freight revenue is very low for this port-pair.

2) Cost: Costs are both fixed and variable. Fixed costs are not influenced by the amount of cargo on a containership, and they included port charges, bunker fee, containership costs, and administration fees. Variable costs include the handling fee at terminal, commissions, container rental and depreciation, and drayage.

3) Service route: Designing the service route plan is the main difficulty, as it must take into consideration the various calling ports, sailing times, and containership capacities for container carriers. Slot allocation should depend on characteristics of the service route.

4) Safety stock of empty containers: The number of empty containers and the amount of safety stock affect empty container reposition. Unless there is a plan for the management of empty containers, container carriers might not obtain a reasonable profit and they might even run a deficit due to the high cost of empty container repositioning.

5) Capacity: Containership capacity and containership deadweight should influence the scheme of slot allocation. Strategic alliance with other partners affects containership capacity.

6) Container movement: I/B and O/B cargo depend on the global economy and regional economy. I/B cargo are the most important, but also the most uncertain.

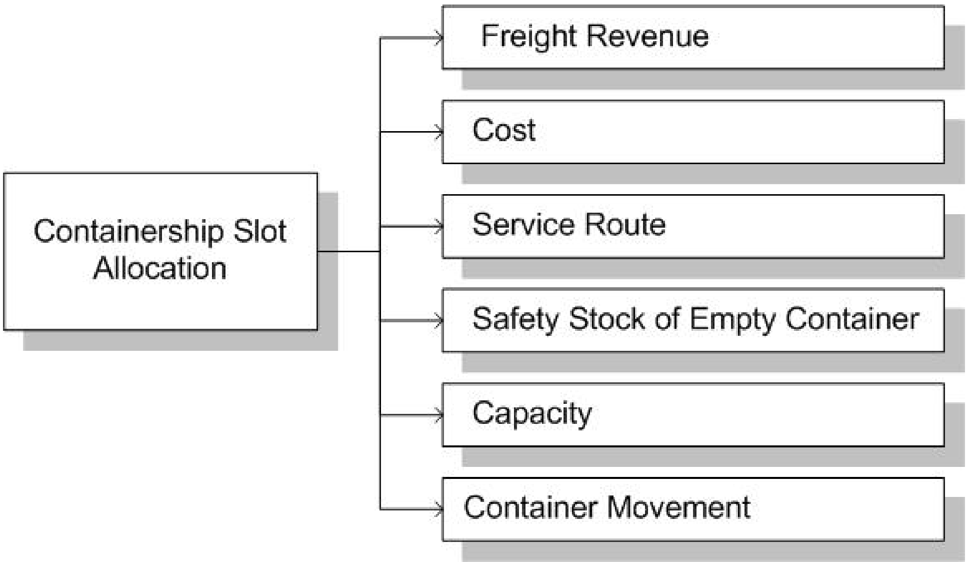

Figure 3.11 Influence factors for containership slot allocation

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3.7.2 The plan for empty container reposition

Factors affecting the plan for empty container reposition are summarized below (see Figure 3.12).

1) Container movement: The difference between I/B and O/B containers results in empty container reposition at each port.

2) Safety stock of empty containers: Container carriers store empty containers to meet customer demand and they attempt to minimize safety stock of empty containers at each port. Safety stock affects the amount of R/I empty containers and R/O empty containers.

3) Service routes: All the service routes form a sea transportation network to make channels for empty container reposition.

4) Geographical region: To avoid the occurrence of empty containers occupying slots for a long-distance, thereby costing the containership freight revenue, the sea transportation network is partitioned into several geographical regions. Empty containers are repositioned within a single region.

5) Cost: Handling costs at port are major and indispensable expenditure. The cost of transportation is divided into three kinds: the cost of owned slot, the cost of charted slot, and the cost of inland drayage by truck.

6) Slot on containership: Empty containers are allocated on unsold slot. If the slot is not available, either the plan for repositioning empty containers is suspended or container carrier charter slots are from other carriers.

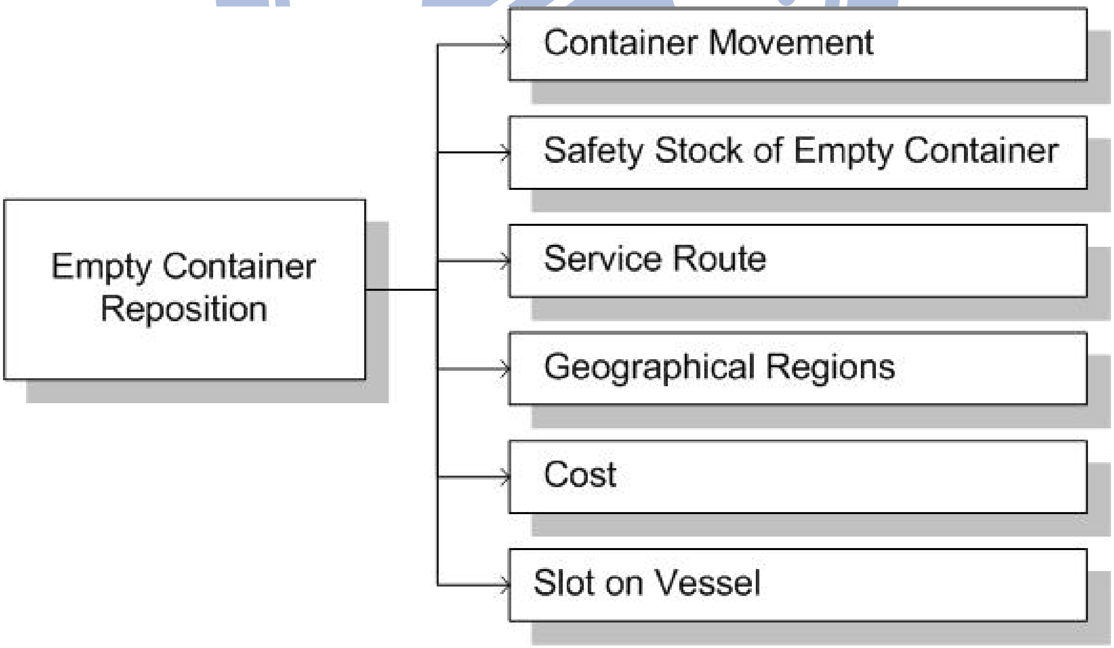

Figure 3.12 Influence factors of empty container reposition

CHAPTER 4 THE PLAN FOR CONTIANERSHIP SLOT ALLOCATION

This study uses revenue management modeling as a decision-support tool in forming the containership slot allocation plan for a loaded container. The proposed model, which incorporates the expected cost of empty container reposition, was formulated through mathematical programming to maximize operational profit, subject to the constraints of containership capacity, containership deadweight, and container demand (as seen in Figure 4.1). The proposed model uses a Taiwan shipping company as a case study and a strategy has been developed by means of computational analysis.

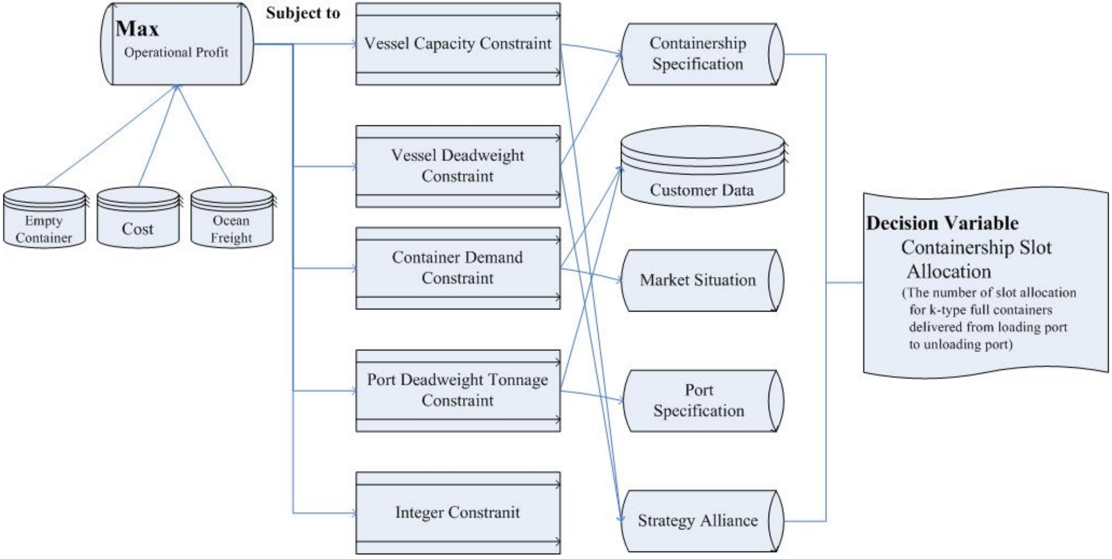

Figure 4.1 A concept chart for containership slot allocation

4.1 Assumptions

The following assumptions are made in this research：

(1) The freight of various port-pairs was given. Container carriers charge ocean freight and surcharges including currency adjustment factor (CAF), fuel adjustment factor (FAF), terminal handling charge in loading port (L/THC), terminal handling charge in unloading port (D/THC) and document fee from shippers. Occasionally, container carriers offer all-in tariffs (including surcharges). Tariffs are determined based on quantity of containers, container specification, and customer classification. In this study, freight revenue is estimated as average freight revenue and surcharge for each port-pair (Appendix A).

(2) The variable cost of various port-pairs was given. The fixed cost includes port charges, bunker costs, containership cost and administration. As fixed cost is not affected by variations in shipment, only variable cost is factored into the model (see Appendix B).

(3) The maximum and minimum container demands at various port-pairs are given. Demand uncertainty is a function of market size; competition; and the ability of shipping agencies in seeking cargo (see Appendix C).

(4) Strategic alliances have grown in significance in recent decades, in an effort to increase market coverage, decrease overheads, share the cost of capital equipment and improve market control (Ryoo et al., 1999). Containership capacity is therefore shared with partners and the container carrier gets operational capacity through joint service, slot-exchange and slot-charters. In this study, operational containership capacity and deadweight tonnage are given.

(5) Safety stock of empty containers, empty container stock, and probability of reposition empty container are given.

(6) From a miscellany of different container types and sizes used by container shipping industry, only 20'×8'×8'6" dry container (20’DC), 40'×8'×8'6" dry container (40’DC), and 40'×8'×9'6" (40’HQ) are considered in this proposed model.

4.2 Model Formulation

$$\text{Maximize } Z = \sum_{i\in P}\sum_{j\in P}\sum_{k\in K}\left[\left(FR_{ij}^{k} - VC_{ij}^{k} - EC_{i}^{k} - EC_{j}^{k}\right)\cdot X_{ij}^{k}\right] \tag{1}$$

Subject to

$$\sum_{j\in P}\sum_{k\in K}\lambda^{k}\left(X_{ij}^{k}\right) - \sum_{j\in P}\sum_{k\in K}\lambda^{k}\left(X_{ji}^{k}\right) + \sum_{3\le r\le n}\ \sum_{2\le o<r}\ \sum_{k\in K}\lambda^{k}\left(X_{T_{m(r)}T_{m(o)}}^{k}\right) \le OC_{i} \quad \forall i\in P \tag{2}$$

$$\sum_{j\in P}\sum_{k\in K}\omega^{k}\left(X_{ij}^{k}\right) - \sum_{j\in P}\sum_{k\in K}\omega^{k}\left(X_{ji}^{k}\right) + \sum_{3\le r\le n}\ \sum_{2\le o<r}\ \sum_{k\in K}\omega^{k}\left(X_{T_{m(r)}T_{m(o)}}^{k}\right) \le DW_{i} \quad \forall i\in P \tag{3}$$

$$X_{ij}^{k} \le DU_{ij}^{k} \quad \forall i, j\in P, k\in K \tag{4}$$

$$\sum_{j\in P}\sum_{k\in K}\omega_{ij}^{k}\left(X_{ij}^{k}\right) \le D_{i}^{\omega} \quad \forall i\in P \tag{5}$$

$$X_{ij}^{k} \in \text{integer} \quad \forall i, j\in P, k\in K \tag{6}$$

Where,

P	set of calling port in a service route, $P = \{1,2,3,\ldots,n\}$
K	set of container specifications, $K = \{1:20'DC,\ 2:40'DC,\ 3:40'HQ\}$
i	index of loading port in a service route, $i\in P$
j	index of unloading port in a service route, $j\in P$
k	index of container specification, $k\in K$
n	The number of calling ports in a service route

$$T_{z+1} = \{(z \mod n)+1,\ [(z+1) \mod n]+1,\ \ldots, [(z+n-1) \mod n]+1\}$$

The sequence of calling ports on the service route

$$T_{z+1}(l) = [(z+l-1) \mod n]+1$$

z the first calling in sequence of calling ports on the service route, $z \in P$

l the number in the sequence of calling port in the service route, $1 \le l \le n$

FR_{ij}^{k} Freight revenue including ocean freight and surcharge of $k \in K$ type container delivered from port $i \in P$ to port $j \in P$ (unit：USD)

VC_{ij}^{k} Variable cost of $k \in K$ type container delivered from port $i \in P$ to port $j \in P$, including handling charges at both ports, commissions, container rental (depreciation) and repair, truck fee and depot stowage costs (unit：USD)

OP_{ij}^{k} Operational profit of $k \in K$ type container delivered from port $i \in P$ to port $j \in P$ (unit：USD)

$$OP_{ij}^{k} = FR_{ij}^{k} - VC_{ij}^{k} - EC_{i}^{k} - EC_{j}^{k} \tag{7}$$

EC_{i}^{k} Expected cost of empty container reposition of $k \in K$ type at loading port $i \in P$ (unit：USD)

$$EC_{i}^{k} = CS_{i}^{k} \cdot HE_{i}^{k} \cdot POR_{i}^{k} \tag{8}$$

CS_{i}^{k} Empty container stock of $k \in K$ type in loading port $i \in P$

$$CS_{i}^{k} = \begin{cases} -1, & surplus, \quad save \ \text{cost} \ of \ empty \ container \ reposition \ out \\ 0, & balance, \quad non-reposition \ empty \ container \ in \ or \ out \\ +1, & shortage, \quad spend \ \text{cost} \ of \ empty \ conatiner \ reposition \ in \end{cases}$$

HE_{i}^{k} Handling cost of empty container of $k \in K$ type at loading port $i \in P$ (unit：USD)

POR_{i}^{k} Probability of repositioning empty container of $k \in K$ type at loading port $i \in P$

EC_j^k	Expected cost of empty container reposition of $k \in K$ type at unloading port $j \in P$ (unit：SD)

$$EC_j^k = CS_j^k \cdot HE_j^k \cdot POR_j^k \tag{9}$$

CS_j^k	Empty container stock of $k \in K$ type at unloading port $j \in P$

$$CS_j^k = \begin{cases} +1, & surplus, \quad spend \ \ \text{cost} \ of \ empty \ container \ reposition \ out \\ 0, & balance, \quad non-reposition \ empty \ container \ in \ or \ out \\ -1, & shortage, \quad save \ \ \text{cost} \ of \ empty \ conatiner \ reposition \ in \end{cases}$$

HE_j^k	Handling cost of empty container of $k \in K$ type at discharging port $j \in P$ (unit：USD)
POR_j^k	Probability of repositioning empty container of $k \in K$ type at discharging port $j \in P$
OC_i	The operational capacity on containership when containership leaved from port $i \in P$ (unit：TEU, twenty-foot equivalent units)
DW_i	The operational deadweight tonnage on containership when containership leaved from port $i \in P$ (unit：ton)
DU_{ij}^k	The maximum loaded container demand for $k \in K$ type from port $i \in P$ to port $j \in P$
ω_{ij}^k	The average weight of $k \in K$ type from port $i \in P$ to port $j \in P$ (unit：ton)
D_i^{ω}	The maximum of deadweight tonnage for all loaded containers at loading port $i \in P$ (unit：ton)
λ^k	Transferring coefficient of TEU by $k \in K$ type. 20’DC is referred to as “Twenty-Foot-Container” which equals to one Twenty-Foot Equivalent Unit (1 TEU). 40’DC and 40’HQ are referred to as “Forty-Foot-Container (FEU)” which equals to two Twenty-Foot Equivalent Unit (2 TEU).

The decision variable is X_{ij}^k (the number of slot allocation for $k \in K$ type loaded containers delivered from the loading port $i \in P$ to the unloading port $j \in P$).

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The objective function (1) sleeks to maximize operational profit. Constraint (2) of containership capacity requires that total allocated slot of loaded containers do not exceed containership operational capacity. Constraint (3) of containership deadweight requires that total weight of loaded containers do not exceed operational deadweight tonnage. Constraint (4) of container demand requires that slots allocated to various port-pairs be within the min-max boundaries of loaded container demand. Constraint (5) represents the total deadweight tonnage of loaded slots which could not exceed the upper bound deadweight tonnage in the loading port. Constraint (6) defines the decision variable to be integers.

4.3 Case Study

To discuss the analytical results of the proposed model and its application, this research uses one of Taiwan's shipping companies (T Line), which has a long history of operation on the intra-Asian service routes.

4.3.1 Background and relevant data

T Line runs one service route, named CHI (China-Hong Kong-Indonesia) service, calling at Qingdao (TAO), Shanghai(SHA), Hong Kong(HKG), Manila(MNL), Jakarta(JKT), Surabaya(SUB), Manila, and Hong Kong again, and then returns to Qingdao for a roundtrip (as shown in Figure 4.1). Four full-container containerships were deployed on this service route to provide weekly service. The containership capacity was 1,100 TEU and 15,400 tons deadweight. To decrease overhead and share the cost of capital equipment, T Line cooperated with other container carriers in launching the CHI service through joint service, slot exchange and slot charter. T Line had an operational capacity of 350 TEUs and 4,900 tons on a containership. The container management department regularly recorded empty container stock of O/B containers and I/B containers, and then classified them into five types: S(surplus), SS(serious surplus), A(balance), D(shortage), and DD(serious shortage). If an SS was record, it meant that a large number of empty containers had accumulated at depot, requiring immediate repositioning out. The study supposed: $POR_i^k = 1 \ or \ POR_j^k = 1$. If S was recorded, preparation was made for repositioning empty containers out or in. The study then supposed: $POR_i^k = 0.5 \ or \ POR_j^k = 0.5$. If A was recorded, this meant that the amount of empty containers was equal to the safety stock. The study then supposed: $POR_i^k = 0 \ or \ POR_j^k = 0$. The record of empty container stock at each port is displayed in Table 5.1. Although this proposed model included a deadweight constraint, we analyzed the operational capacity of slot allocation without it, as the container deadweight data was unavailable.

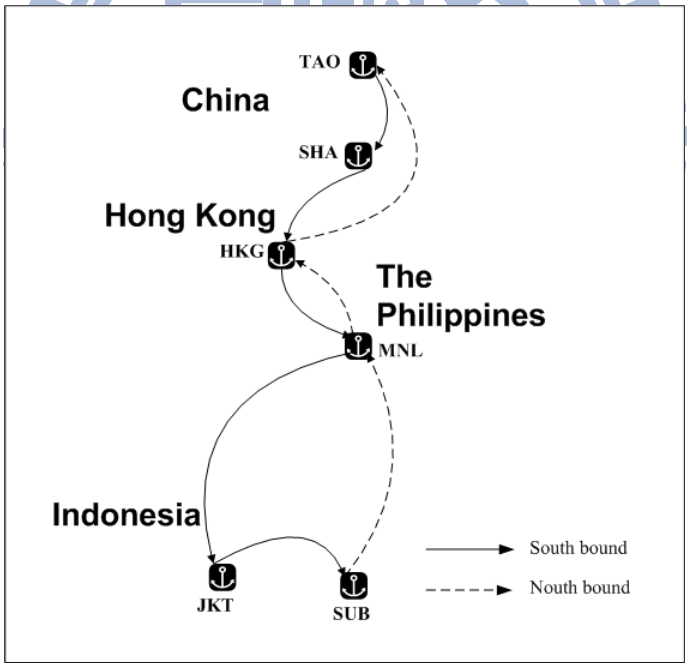


Figure 4.2 Service route of CHI service

Table 4.1 Record of empty container stock

Item	Port	TAO	SHA	HKG	MNN	MNS	JKT	SUB
20'DC	Stock	D	D	A	S	S	SS	D
	Probability	50%	50%	0%	50%	50%	100%	50%
	Handling Cost (USD)	44	56	52	52	52	53	53
	EC_i^k	22.0	28.0	0.0	(26.0)	(26.0)	(53.0)	26.5
	EC_j^k	(22.0)	(28.0)	0.0	26.0	26.0	53.0	(26.5)
40'DC	Stock	DD	DD	A	SS	SS	S	DD
	Probability	100%	100%	0%	100%	100%	50%	100%
	Handling Cost (USD)	64	83	77	66	66	79	79
	EC_i^k	64.0	83.0	0.0	(66.0)	(66.0)	(39.5)	79.0
	EC_j^k	(64.0)	(83.0)	0.0	66.0	66.0	39.5	(79.0)
40'HD	Stock	D	DD	D	S	S	S	D
	Probability	100%	100%	50%	50%	50%	50%	50%
	Handling Cost (USD)	64	83	77	66	66	79	79
	EC_i^k	64.0	83.0	0.0	(66.0)	(66.0)	(39.5)	39.5
	EC_j^k	(64.0)	(83.0)	0.0	66.0	66.0	39.5	(39.5)

Notes: S: Surplus　SS: Serious Surplus
D:Shortage　DD: Serious Shortage
A: Balance

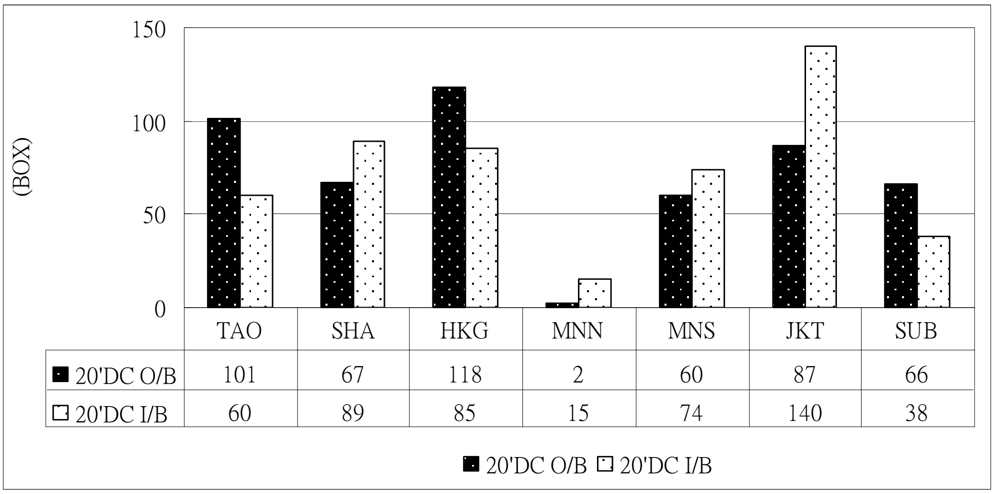
4.3.2 Computational results

Table 4.2 presents an optimal plan of slot allocation solution using the WinQSB 2.0 software. For instance, the shipping agency at TAO has a slot allocation for 21 TEU and 19 FEU to HKG; 23 TEU to MNN; 18 TEU and 6 FEU to MNS; 42 TEU and 5 FEU to JKT; 14 TEU and 4 FEU to SUB. Total O/B cargos from TAO are 118 TEU and 34 FEU (186 TEUs). Total I/B cargos to TAO port are 63 TEU and 53 FEU (169 TEUs). Total loaded cargos are 1,025 TEUs and load factor (L/F) is 2.93 (1,025 TEUs / 350 TEUs) for a roundtrip.

Table 4.2 An optimal plan of containership slot allocation for CHI service

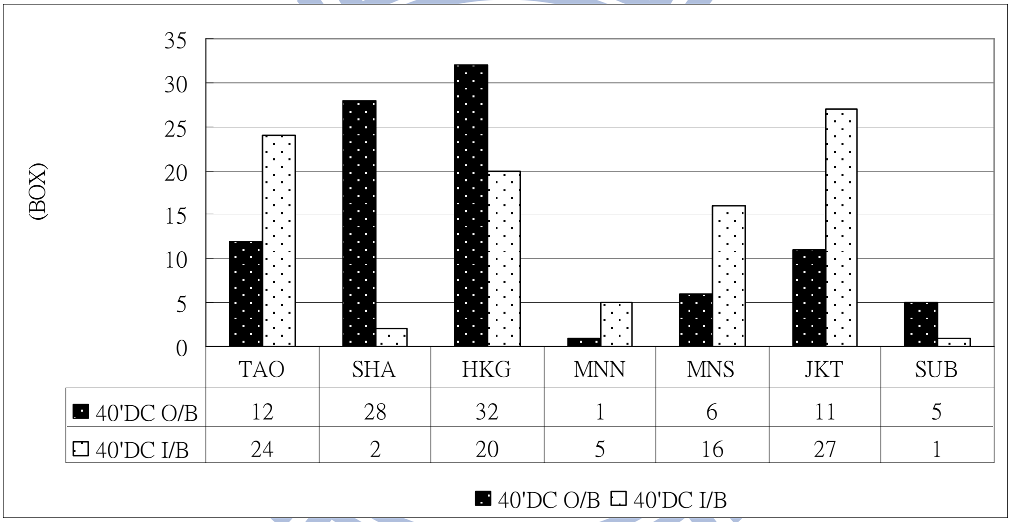
POL	POD	TAO	SHA	HKG	MNN	MNS	JKT	SUB	MNS	HKG	TOTAL	
											(BOX)	(TEU)
TAO	20'DC			21	6	18	42	14			101	169
	40'DC			7	0	3	1	1			12	
	40'HQ			12	0	3	4	3			22	
SHA	20'DC			0	9	20	32	6			67	181
	40'DC			0	2	4	22	0			28	
	40'HQ			11	2	7	9	0			29	
HKG	20'DC				0	1	36	10			47	81
	40'DC				3	3	1	0			7	
	40'HQ				0	0	8	2			10	
MNN	20'DC						2	0			2	4
	40'DC						1	0			1	
	40'HQ						0	0			0	
MNS	20'DC						28	8			36	46
	40'DC						2	0			2	
	40'HQ						2	1			3	
JKT	20'DC	0	56						17	14	87	181
	40'DC	0	0						6	5	11	
	40'HQ	0	1						32	3	36	
SUB	20'DC	4	16						18	28	66	122
	40'DC	0	1						0	4	5	
	40'HQ	0	2						6	15	23	
MNS	20'DC	0	2							22	24	48
	40'DC	0	0							4	4	
	40'HQ	0	2							6	8	
HKG	20'DC	56	15								71	175
	40'DC	24	1								25	
	40'HQ	25	2								27	
TOTAL	20'DC	60	89	21	15	39	140	38	35	64	501	L/F=2.88
	40'DC	24	2	7	5	10	27	1	6	13	95	
	40'HQ	25	7	23	2	10	23	6	38	24	158	
	(TEU)	158	107	81	29	79	240	52	123	138	1,007	

Figure 4.2, 4.3 and 4.4 illustrate an imbalance between O/B cargo and I/B cargo for 20’DC, 40’DC, 40’HQ. I/B cargo are greater than O/B cargo at MNL (MNN+MNS) port, an import-oriented port, and as a consequence a large number of empty containers accumulated. In contrast, SUB port often faces a shortage of empty containers, because O/B cargo is exported to other regions. Additionally, there is a huge imbalance for 40’DC at SHA port. T line repositions a large number of empty containers of 40’DC into SHA port resulting in a high cost of empty container repositioning.



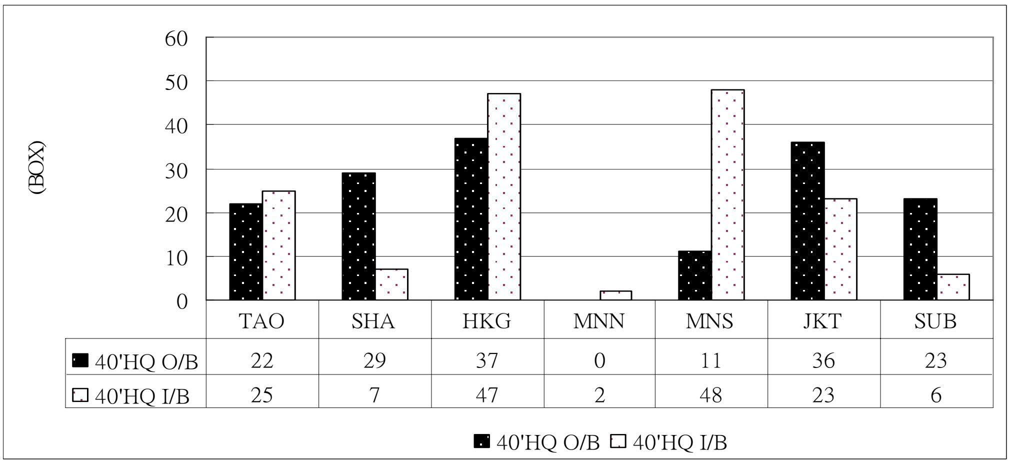
	TAO	SHA	HKG	MNN	MNS	JKT	SUB
■ 20'DC O/B	101	67	118	2	60	87	66
☐ 20'DC I/B	60	89	85	15	74	140	38

Figure 4.3 Imbalance between O/B cargo and I/B cargo for 20’DC



	TAO	SHA	HKG	MNN	MNS	JKT	SUB
■ 40'DC O/B	12	28	32	1	6	11	5
☐ 40'DC I/B	24	2	20	5	16	27	1

Figure 4.4 Imbalance between O/B cargo and I/B cargo for 40’DC



	TAO	SHA	HKG	MNN	MNS	JKT	SUB
■ 40'HQ O/B	22	29	37	0	11	36	23
☐ 40'HQ I/B	25	7	47	2	48	23	6

Figure 4.5 Imbalance between O/B cargo and I/B cargo for 40’HQ

Table 4.3 compares the experimental and actual results. Two voyages were randomly selected in order to calculate actual slot on containerships in the CHI service. The total number of “model” loaded containers (1,007 TEUs) was greater than the actual number in voyage 1 (738 TEUs) and voyage 2 (980 TEUs) (see Appendix D and E). Model operation profit (US$251,052) was also higher than actual profit on voyage 1 (US$171,521) and voyages 2 (US$216,762). The ration of empty container reposition, 57.6% drawn from the proposed model, was less than actual slots of voyage 2 (78.16%).

Table 4.3 Comparing optimal containership slot allocation with actuality

Item / Type		Opeational capacity (TEU)	Total loaded container (TEU)	Load facctor (L/F)	$FR_{ij}^{k} - VC_{ij}^{k}$ (USD)	Exptected cost of empty container reposition $EC_{i}^{k} + EC_{j}^{k}$ (USD)	Operational profit (USD)	Number of empty container reposition (TEU)	Ratio of empty container reposition (%)
Optimal slot allocation		350	1,007	2.93	264,933	13,881	251,052	580	57.60%
Actual slot	Voyage 1	350	738	2.11	184,727	13,206	171,521	376	50.95%
	Voyage 2	350	980	2.80	235,150	18,388	216,762	766	78.16%

Notes: 1) Load Factor (L/F): Total loaded container / Operational capacity

2) Ratio of empty container reposition: the number of empty container reposition / Total loaded container

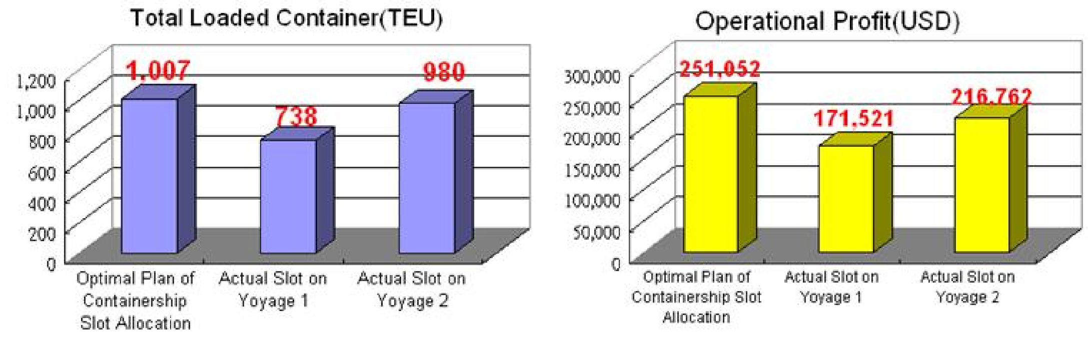


Figure 4.6 Comparing optimal containership slot allocation with actuality in total loaded container and operational profit

4.4 Strategy Analysis

It was proposed that the T Line develop both short-term and long-term strategies to improve their management of slot allocation (as seen in Figure 4.8).

4.4.1 The short-term strategy

Further analysis compared the actual number of slots on a containership with that of the proposed model, and the actual number of slots at the point of departure from each port (as seen in Figure 4.7). A containership received many slots when it departed from SHA port on voyage 2. Total loaded cargo on the containership exceeded operational capacity (350 TEUs), indicating that containers which were loaded at the TAO and SHA occupied too many slots. As a result, the shipping agency at HKG did not have enough space to load its own containers. Such a situation often creates friction among shipping agencies at the TAO, SHA and HKG.

T Line needs to take action to solve this problem.

One such action is to unload cargo loaded at TAO or SHA to provide space to the shipping agency at HKG. Consequently, T Line will be made to bear the additional costs of discharging and of a second loading. Also, by doing so, it might jeopardize its reputation with customers whose cargo was discharged.

An alternative action would be to charter slots from alliance partners.

In the other situation pertaining to voyage 1, the containership was not fully loaded and freight revenue was lost from unsold slots. Also, there were dramatic swings in both voyages (voyage 1 and voyage2) that did not occur in the proposed model.

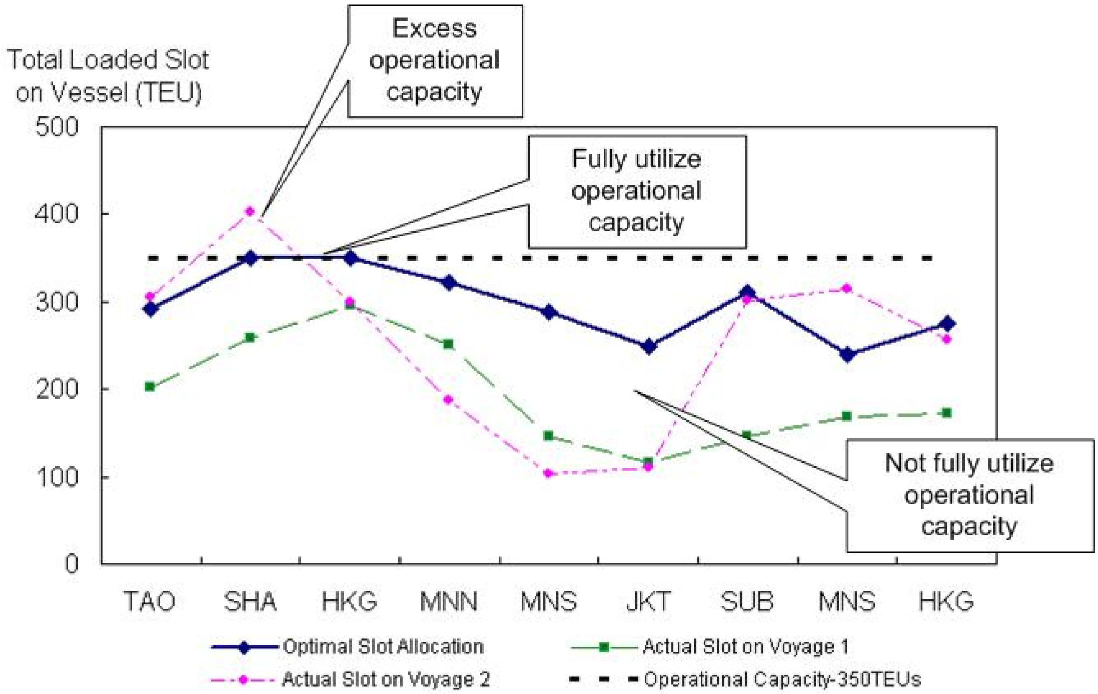


Figure 4.7 Comparing total slots on containership with optimal containership slot allocation and actual slots on yoage1 and voyage 2

4.4.2 The long-term strategy

According to model results, a loaded containership departed from SHA and HKG at T Line's 350 TEU operational capacities. At subsequent ports the containership was not fully loaded. Based on analyzed parameter data, cargo demand was less than maximum cargo demand (DU_{ij}^{k}) at some ports.

Strategies to solve this problem:

The first strategy would be to request shipping agencies at MNL, JKT, SUB and HKG to increase their marketing effort and solicit additional cargo to achieve full operational capacity.

A second strategy would be to adjust its alliance strategy in order to reduce operational capacity, overhead and risk through slot-exchange or slot-charter with other carriers.

Given this second strategy, freight revenue would be reduced for shipping agencies at TAO, SHA, and HKG because of the reduced slot allocation. However this adjustment strategy has the potential to increase the utilization rate and load factor, and achieve increased performance. For example, if the operational capacity was reduced to 300 TEUs, the containership would be fully loaded after departing from SHA, HKG, MNN and SUB. If the operational capacity was reduced to 250 TEUs, then the containership would be fully loaded with cargo for the roundtrip voyage (as seen in Figure 4.9) .

In order to recover market activity at TAO and SHA, a new service route might be designed for short distance.

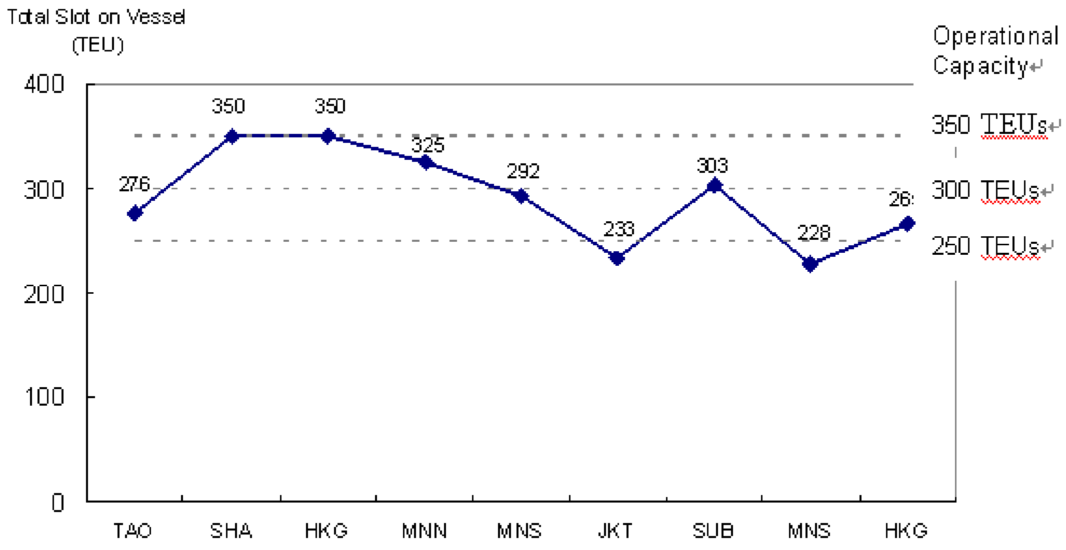


Figure 4.8 Total loaded cargos on containership vs. operational capacity

4.4.3 Summary

Container carriers face problems of excess operational capacity, meaning capacity that is not fully utilized. Figure 4.8 illustrates the action that T Line might conduct to solve these problems. Additional, strategies might be developed to improve the management of slot allocation.

Containerships might exert an influence on shipping agencies through a fine system, slot allocation reduction, or cancellation of shipping agency authority.

More importantly, they might set up a booking system to control loaded cargo in advance and communicate closely with sales departments in order to adjust slots at each port, thereby eliminating unsold slots.

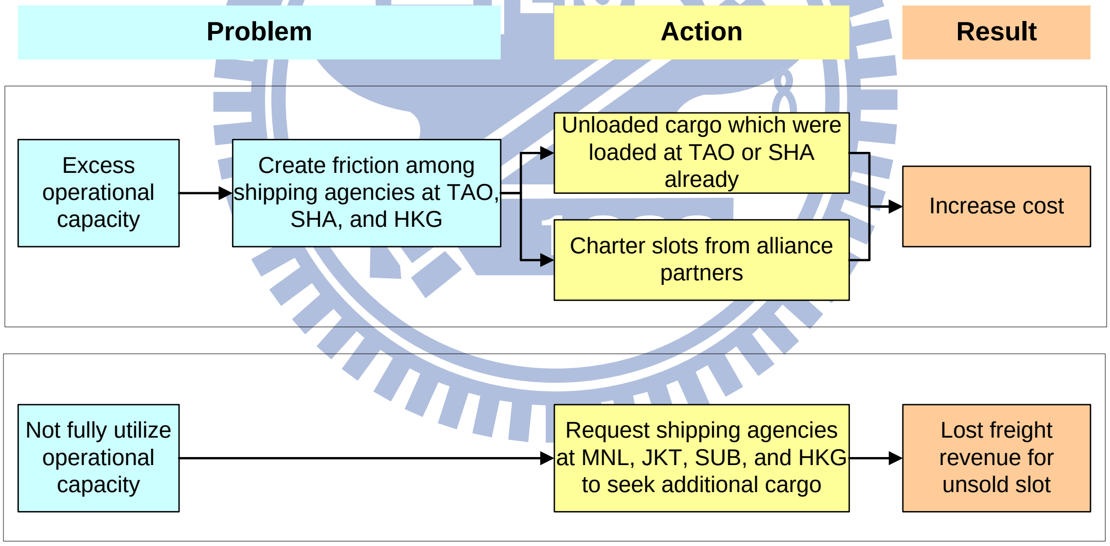


Figure 4.9 Problem, action and result for actual slots on voyage1 and voyage 2

CHAPTER 5 THE PLAN FOR EMPTY CONTAINER REPOSITION

Container carriers often follow a rule of thumb when repositioning empty containers. As a consequence, a large number of empty containers occupying slots on a containership tend to accumulate, and they are frequently repositioned throughout one voyage. The problems resulting from this practice pertain to a loss of freight revenue and the occurrence of storage expenses at empty container depots. This study addresses these problems by grouping them into two categories: the upper problem and the lower problem. The upper problem is concerned with identifying and estimating empty container stock for each port. The lower problem or transportation problem pertains to the cost of empty container reposition (as seen in Figure 5.1). The proposed model provides an effective plan for empty container reposition. In addition, it offers the possibility of providing container carriers with a strategy to improve management of slot allocation.

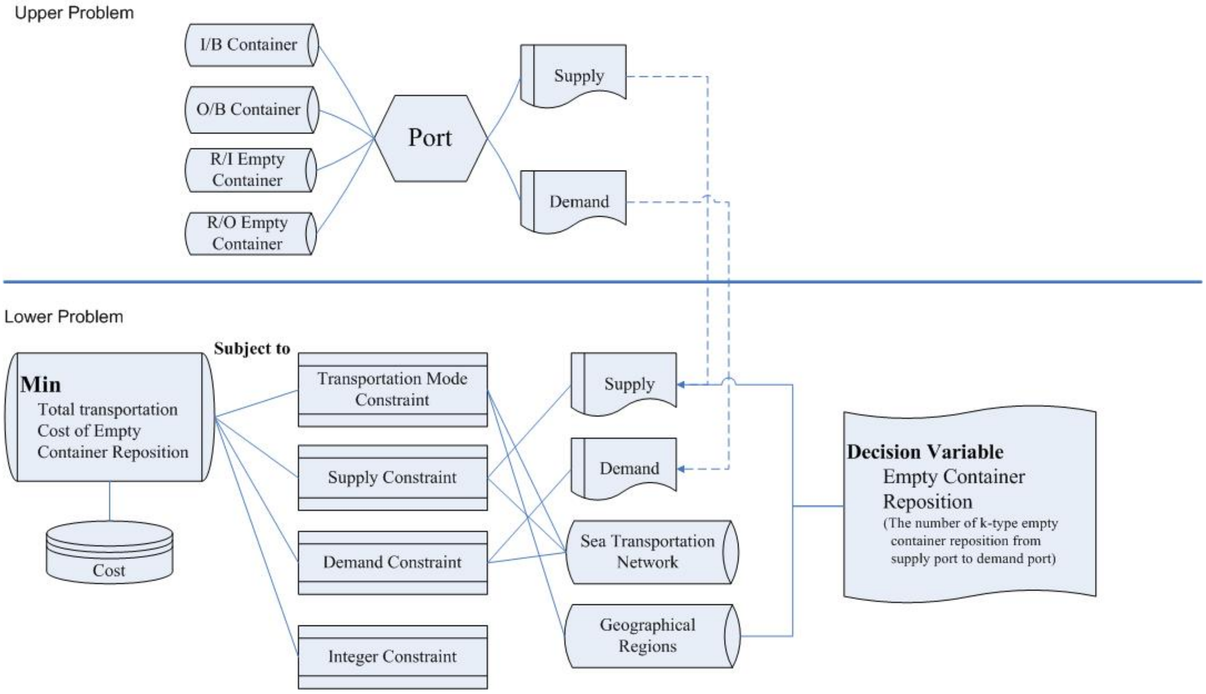


Figure 5.1 A concept chart for empty container reposition

5.1 Assumptions

The following assumptions are imposed for this proposed model：

(1) Owned containers and long-term leased containers are considered. Short-term leased containers are leased in from leasing company for temporary using, such as helping ports having a serious shortage of empty containers to meet demand requirements. Because of high rental cost, short-term containers are leased off to leasing company when the target is achieved. Container carriers do not schedule efficient short-term containers in the same way as owned containers.

(2) The cost of transportation mode for various origin-destination port pairs is given (see Appendix E).

(3) The number of I/B containers and O/B containers at each port is known.

(4) The number of safety stock for empty containers at each port is known.

(5) No limits on the number of slots to allocate empty containers.

(6) The plan for empty container reposition is scheduled in a certain time period and empty containers are split into several voyages to reposition.

5.2 Model Formulation

The problem consists of two parts. One part is the upper-problem, which identified and estimated empty container stock at each port. The other is the lower-problem, which modeled empty container reposition planning as the Transportation Problem by Liner Problem. The upper-problem 【UP】 and the lower-problem 【LP】 may be drawn up as follows:

【UP】

$$\begin{aligned} Q_{ht}^{k} &= Q_{ht-1}^{k} + IB_{ht}^{k} - OB_{ht}^{k} + RI_{ht}^{k} - RO_{ht}^{k} \\ if\ Q_{ht}^{k} - SS_{h}^{k} &> 0,\ \ then\ S_{ht}^{k} = Q_{ht}^{k} - SS_{h}^{k} \\ else\ D_{ht}^{k} &= SS_{h}^{k} - Q_{ht}^{k} \end{aligned} \tag{10}$$

where

H	set of port within sea transportation network, $H = \{TYO, NGO, ..., KEL, ..., SUB\}$
K	set of container specification, $K = \{1:20'DC,\ 2:40'DC,\ 3:40'HQ\}$
h	index of port within sea transportation network, $h \in H$
t	index of time period
Q_{ht}^{k}	quantity of empty container stock of $k \in K$ type in t period at port $h \in H$
SS_{h}^{k}	quantity of safety stock of $k \in K$ type empty container at port $h \in H$
IB_{ht}^{k}	quantity of inbound empty container of $k \in K$ type in t period at port $h \in H$
OB_{ht}^{k}	quantity of outbound empty container of $k \in K$ type in t period at port $h \in H$
RI_{ht}^{k}	quantity of repositioned-into empty container of $k \in K$ type in t period at port $h \in H$
RO_{ht}^{k}	quantity of repositioned-out empty container of $k \in K$ type in t period at port $h \in H$
S_{ht}^{k}	supply number of $k \in K$ type empty container in t period at port $h \in H$
D_{ht}^{k}	demand number of $k \in K$ type empty container in t period at port $h \in H$

Empty container stock, supply of empty containers and demand of empty containers at each port are given. The objective function is minimizing total transportation cost of repositioning empty containers within the sea transportation network. 【LP】may be formulated as follows:

【LP】

Minimize
$$\sum_{\alpha \in G^s} \sum_{\beta \in G^d} \sum_{k \in K} \rho_{\alpha\beta}^m C_{\alpha\beta}^{mk} E_{\alpha\beta}^k \tag{11}$$

Subject to
$$\sum_{\alpha \in G^s} \sum_{\beta \in G^d} \sum_{m \in M} \rho_{ij}^m = 1 \qquad \forall \alpha \in G^s, \forall \beta \in G^d \tag{12}$$

$$\sum_{\beta \in G_p^d} \sum_{k \in K} \delta_{\alpha\beta} E_{\alpha\beta}^k = S_\alpha^k \qquad \forall \alpha \in G_f^s, \forall f \in F \tag{13}$$

$$\sum_{\alpha \in G_f^s} \sum_{k \in K} \delta_{\alpha\beta} E_{\alpha\beta}^k = D_\beta^k \qquad \forall \beta \in G_f^d, \forall f \in F \tag{14}$$

$$\rho_{\alpha\beta}^m \in \{0,1\} \qquad \forall \alpha \in G^s, \forall \beta \in G^d, \forall m \in M \tag{15}$$

$$\delta_{\alpha\beta} \in \{0,1\} \qquad \forall \alpha \in G^s, \forall \beta \in G^d \tag{16}$$

$$E_{\alpha\beta}^k \in \text{integer} \qquad \forall \alpha \in G^s, \forall \beta \in G^d, \forall k \in K \tag{17}$$

Where

F number of port group within sea transportation network

H set of port within sea transportation network,

$H = \{TYO, NGO, \ldots, KEL, \ldots, SUB\}$

K set of container specification.

$K = \{1: 20'DC,\ 2: 40'DC,\ 3: 40'HQ\}$

M set of transportation mode to reposition empty container.

$$M = \left\{ \begin{array}{l} 1: owned\ slot\ on\ vessel\ within\ sea\ transportation\ network, \\ 2: charted\ slot\ \ from\ other\ carriers\ within\ sea\ transportation\ network, \\ 3: charted\ slot\ \ from\ other\ carriers\ without\ sea\ transportation\ network, \\ 4: inland\ drayage\ by\ truck \end{array} \right\}$$

G^s	set of ports having a surplus of empty containers within sea transportation network
G_f^s	set of ports having a surplus of empty containers within $f \in F$ group
G^d	set of ports having a shortage of empty containers with sea transportation network
G_f^d	set of ports having a shortage of empty containers within $f \in F$ group
f	index of port group within sea transportation network, $f \in F$
α	index of loading port within sea transportation network, $\alpha \in H$
β	index of unloading port within sea transportation network, $\beta \in H$
$\rho_{\alpha\beta}^m$	=1, if transportation mode $m \in M$, repositioning empty containers from port $\alpha \in G^s$ to port $\beta \in G^d$, was selected =0, otherwise
$C_{\alpha\beta}^{mk}$	cost of repositioning an empty container of $k \in K$ type from port $\alpha \in G^s$ to port $\beta \in G^d$ by transportation mode $m \in M$
$\delta_{\alpha\beta}$	=1, if it had direct sailing from port $\alpha \in G^s$ to port $\beta \in G^d$ within sea transportation network =0, otherwise
S_α^k	supply number of $k \in K$ type empty containers at port $\alpha \in G^s$
D_β^k	demand number of $k \in K$ type empty containers at port $\beta \in G^d$

The decision variable is $E_{\alpha\beta}^k$ (the number of $k \in K$ type empty container reposition from port $\alpha \in G_f^s$ to port $\beta \in G_f^d$). The objective function (11) is minimizing total transportation cost of empty container reposition in variable transportation modes. Constraint (12) guarantees that just one transportation mode is selected to reposition empty containers from port $\alpha \in G_f^s$ to port $\beta \in G_f^d$. Constraint (13) ensures $k \in K$ type empty containers repositioned out from port

$\alpha \in G_f^s$ to port $\beta \in G_f^d$ are equal to the supply of $k \in K$ type empty containers at port $\alpha \in G_f^s$ for each group $p \in P$. Constraint (14) ensures the number of $k \in K$ type empty containers repositioned into from port $\alpha \in G_f^s$ to port $\beta \in G_f^d$ is the same as the demand of $k \in K$ type empty containers at port $\beta \in G_f^d$ for each group $f \in F$. Constraint (15) and constraint (16) stipulates symbols must equal 0 or 1. Finally, constraint (17) is integer constraint.

5.3 Case Study

To explain the application and results of the proposed model, this study uses a Taiwan Shipping Company (T Line) as an example.

5.3.1 Background and relevant data

The sea transportation network of T Line is composed of 17 service routes. Service coverage is between Japan, Korea, China, Taiwan, Hong Kong, Philippines, Vietnam, Thailand, Malaysia, Singapore, and Indonesia. The main service routes provide long distance shipping in the sea transportation network, and major types of sailing schedules ranging from type 1 to type 4 have been designed. Meanwhile, rapid and short service routes are run to provide high sailing-frequency service with types ranging from type 5 to type 7 (as seen in Table 5.1).

Table 5.1 Types of sailing scheduling for T Line

Types		Sailing Scheduling
Long Distance	Type 1	service routes were designed between Japan, Taiwan, Hong Kong, and Thailand
	Type 2	service routes were designed between Korea, North China, Taiwan, Hong Kong, Singapore, and Indonesia
	Type 3	service routes were designed between North China, Hong Kong, Philippines, and Indonesia
	Type 4	service routes were designed between Middle China, Hong Kong, Philippines, and Thailand
Short Distance	Type 5	service routes were designed between Taiwan and Hong Kong
	Type 6	service routes were designed between Taiwan and Philippines
	Type 7	service routes were designed between Taiwan and China

The sea transportation network was partitioned into five geographical regions because of sailing distance, service routes, and practical operation (as seen in Figure 5.2 and Table 5.2). The two main geographical regions are between East-North Asia and Taiwan and the region between East-South Asia and Hong Kong. The three subordinate regions are between Taiwan and Hong Kong, Kaohsiung and Manila, and Manila and North China. HKG port, KEL port and KHH port provide the highest calling-frequency with eleven service routes in one week (i.e., eleven containerships called ports during one week). OIT port, ICN port, SGN port, PKG port, and PGU port are called only once a week. It is convenient to reposition empty containers at ports with high calling-frequency and a challenge to reposition them at ports with low calling-frequency. T Line looks forward to reducing the cost of empty container reposition by adopting transportation modes of owned slot within the sea transportation network. The transportation mode of inland drayage by truck has been adopted in channels between UKB port and OSA port in Japan, among KEL port, TXG port, and KHH port in Taiwan, between BKK port and LCH port in Thailand, and between JKT port and SUB port in Indonesia. In this case study, we collected statistics of O/B containers and I/B containers for one month and classified them as either supply or demand (as seen in Table 5.3, Figure 5.3, Figure 5.4, and Figure 5.5).

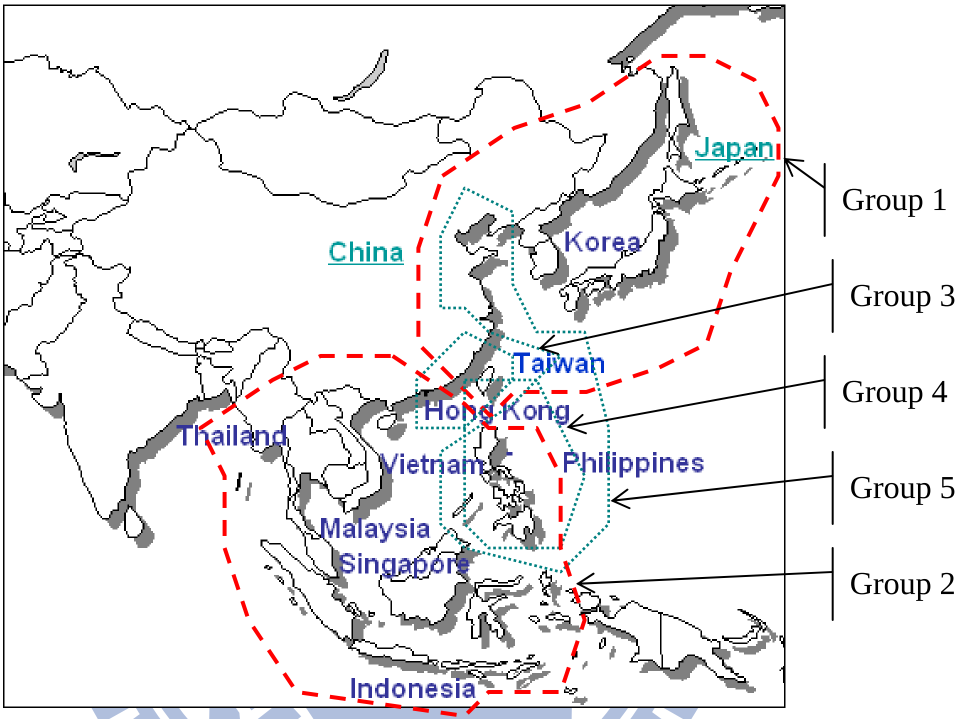


Figure 5.2 Geographical groups in sea transportation network

Table 5.2 A classified catalogue of geographical group

Group	**Region**
1	Japan, Korea, North China, Middle China, and Taiwan
2	Hong Kong, Middle China, South China, Philippines, Vietnam, Thailand, Malaysia, Singapore(SIN), and Indonesia.
3	Taiwan and Hong Kong(HKG)
4	Kaohsiung and Manila
5	Manila, Qingdao, and Shanghai.

Table 5.3 Monthly data of supply and demand

20'DC				40'DC				40'HQ			
Supply		**Demand**		**Supply**		**Demand**		**Supply**		**Demand**	
Port	**Amount (box)**	**Port**	**Amount (box)**	**Port**	**Amount (box)**	**Port**	**Amount (box)**	**Port**	**Amount (box)**	**Port**	**Amount (box)**
TYO	511	TKY	62	TYO	196	UKB	3	TYO	137	TKY	18
YOK	159	PUS	93	YOK	42	TKY	17	YOK	39	PUS	32
NGO	445	KAN	72	NGO	108	PUS	2	NGO	196	TAO	36
OSA	183	DLC	23	OSA	108	TAO	5	OSA	145	XMN	30
UKB	109	TAO	203	OIT	2	SHA	269	UKB	49	TXG	21
MOJ	45	SHA	26	MOJ	13	NGB	2	MOJ	25	KHH	110
HKT	71	NGB	29	HKT	12	XMN	29	HKT	67	HKG	504
QZJ	5	XMN	118	KAN	16	KEL	201	KAN	57	SGN	22
SHK	41	TXG	473	DLC	1	KHH	138	DLC	1	LCH	168
KEL	65	KHH	841	SHK	9	HKG	151	SHA	16	JKT	31
MNL	962	HKG	44	TXG	23	SGN	2	NGB	22	SUB	174
JKT	420	SGN	71	MNL	180	SUB	61	SHK	2		
		BKK	45	BKK	94			KEL	4		
		LCH	733	LCH	12			MNL	370		
		SUB	183	JKT	64			BKK	16		
TOTAL	**3,016**		**3,016**		**880**		**880**		**1,146**		**1,146**

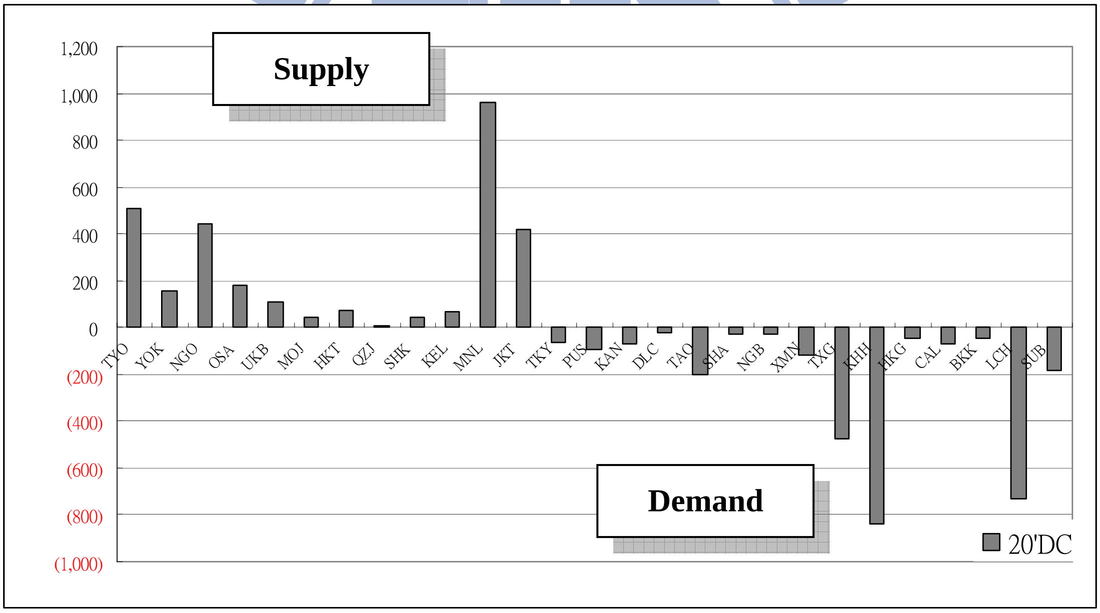


Figure 5.3 Supply port and demand port for 20’DC

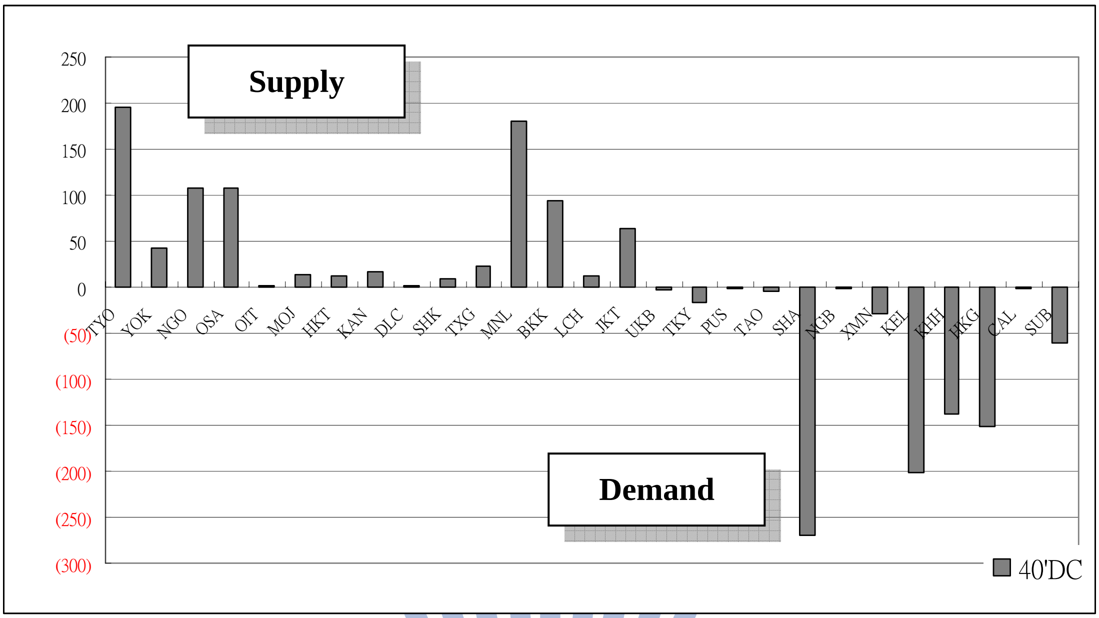


Figure 5.4 Supply port and demand port for 40’DC

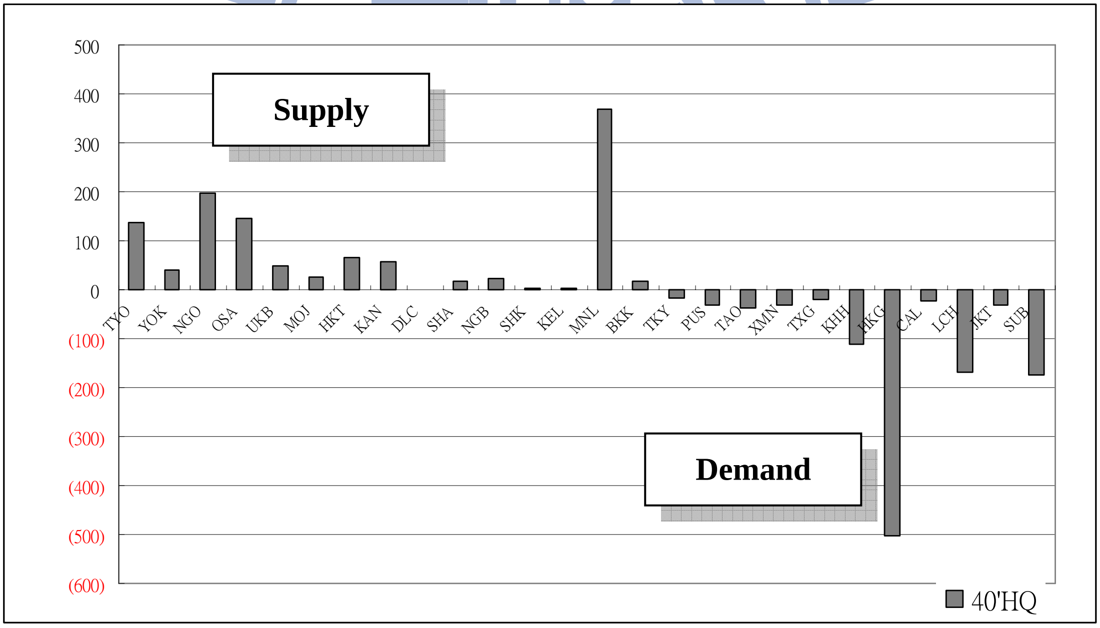


Figure 5.5 Supply port and demand port for 40’HQ

5.3.2 Computational results

The computational results of the optimal solution are shown in Table 5.4 which presents a plan that T Line might implement for empty container reposition. For example, 511 boxes of 20’DC empty containers and 138 boxes of 40’DC empty container from TYO port to KHH port were slotted for reposition during one month. There was an uncertain number of available slots on the containership, which meant that empty containers might be repositioned over several voyages. Two service routes were sailed between TYO port and KHH port and provided eight voyages during one month. They repositioned out 64 boxes of 20’DC (511 boxes/8 voyages) and 18 boxes of 40’DC (138 boxes/ 8 voyages) from TYO port to KHH port through one voyage.

Table 5.4 An optimal plan of empty container reposition

20'DC				**40'DC**				**40'HQ**			
Supply	**Demand**	**BOX**	**TEU**	**Supply**	**Demand**	**BOX**	**TEU**	**Supply**	**Demand**	**BOX**	**TEU**
TYO	KHH	511	511	TYO	KHH	138	276	YOK	XMN	30	60
YOK	XMN	24	24	YOK	XMN	29	58	OSA	TKY	18	36
	KHH	135	135	NGO	KEL	84	168		PUS	7	14
NGO	TXG	250	250	OSA	UKB	3	6		TXG	21	42
	KHH	195	195		TKY	17	34		KHH	53	106
OSA	TKY	62	62		PUS	2	4	MOJ	PUS	25	50
	PUS	48	48		KEL	86	172	KAN	KHH	57	114
	KAN	1	1	OIT	KEL	2	4	DLC	TAO	1	2
	TXG	72	72	MOJ	KEL	13	26	SHA	HKG	16	32
UKB	TXG	109	109	KAN	KEL	16	32	NGB	HKG	22	44
MOJ	PUS	45	45	DLC	TAO	1	2	KEL	HKG	4	8
HKT	KAN	71	71	TXG	SHA	23	46	MNL	HKG	218	436
KEL	DLC	23	23	MNL	TAO	4	8		LCH	152	304
	TXG	42	42		SHA	176	352	BKK	LCH	16	32
MNL	TAO	184	184	BKK	HKG	94	188				
	CAL	45	45		LCH	12	24				
	LCH	733	733	JKT	HKG	45	90				
JKT	HKG	44	44		SUB	19	38				
	SUB	183	183								
TOTAL		**2,777**	**2,777**			**764**	**1,528**			**640**	**1,280**

Notes: 20'DC equals to 1 TEU (Twenty-Foot Equivalent Unit)
40'DC equals to 2 TEU (Twenty-Foot Equivalent Unit)
40'HQ equals to 2 TEU (Twenty-Foot Equivalent Unit)

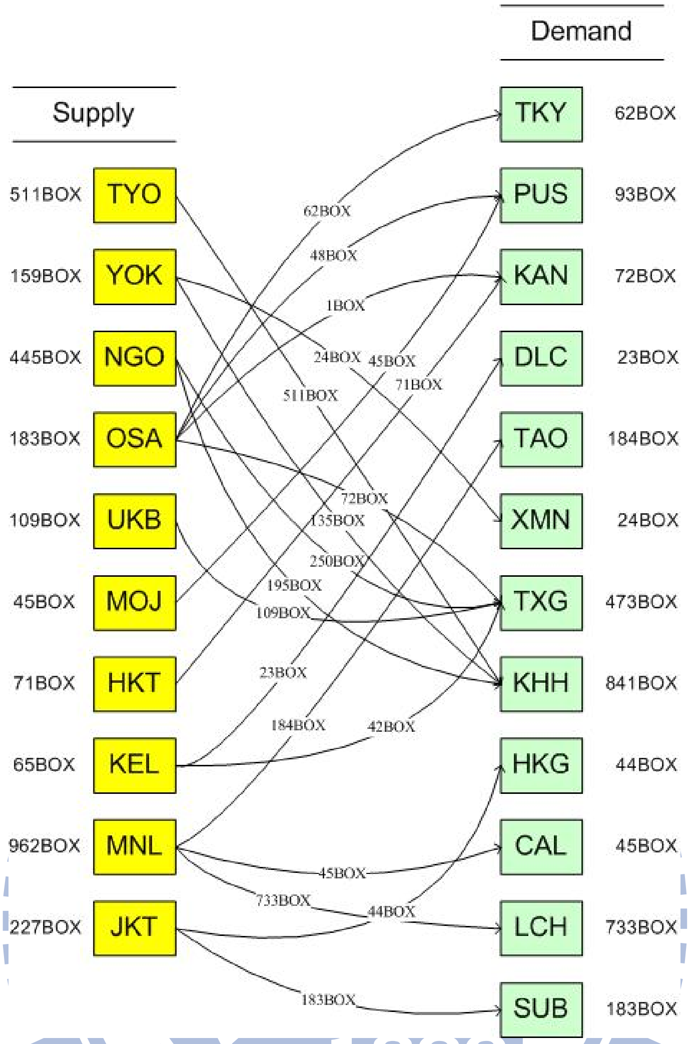


Figure 5.6 The plan of empty container reposition for 20’DC

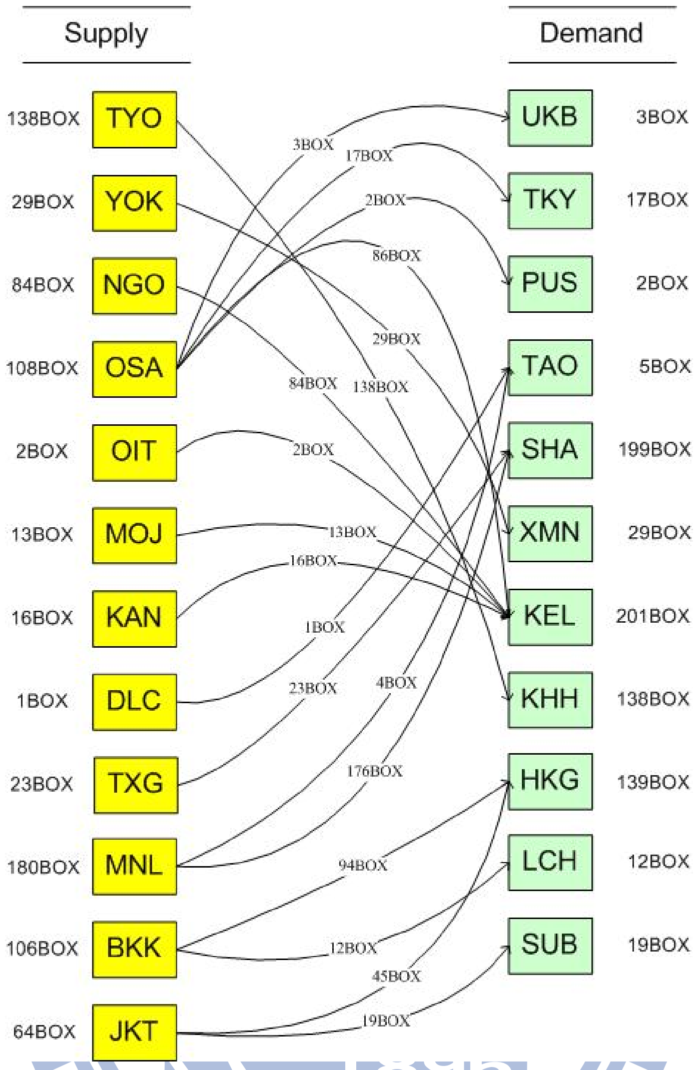


Figure 5.7 The plan of empty container reposition for 40’DC

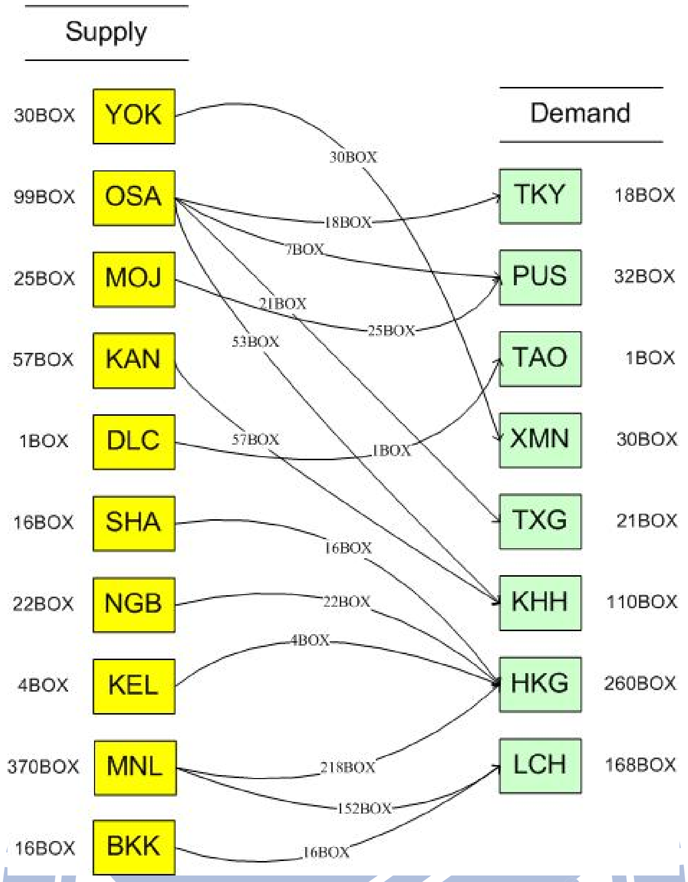


Figure 5.8 The plan of empty container reposition for 40’HQ

5.4 Strategy Analysis

In this section, we selected some ports having distinct characteristics to produce a series of experimental results for further iteration (5 months). Safety stock of empty containers was estimated by averaging the difference between I/B containers and O/B containers over a period of two weeks. The comparative results between the model and actual practice are presented in Table 5.5 and Figure 5.9.

Table 5.5 Compare results between models and practice

Port	Container Type	Month	O/B Container	I/B Container	Model		Practice	
					Amount	Safety Contianer Stock	Amount	Safety Container Stock
TYO	20'DC	1	727	216	511*	200	656*	55
		2	530	263	267*	200	301*	21
		3	705	332	373*	200	374*	20
		4	720	232	488*	200	471*	37
		5	634	367	267*	200	301*	3
TAO	20'DC	1	187	390	184**	581	1* / 505**	901
		2	190	229	58**	600	0	862
		3	175	432	257**	600	120**	725
		4	238	577	339**	600	151**	537
		5	243	656	350**	537	299**	422
HKG	20'DC	1	3,086	3,130	44**	1,500	919*	537
		2	3,289	1,781	1,508*	1,500	589* / 34**	1,490
		3	4,038	3,346	692*	1,500	1,044* / 136**	1,274
		4	3,679	3,774	95**	1,500	40* / 48**	1,171
		5	3,569	3,318	251*	1,500	51* / 30**	1,443
JKT	20'DC	1	779	359	227*	543	100*	670
		2	530	589	79*	405	460*	151
		3	803	766	92*	350	20*	168
		4	1,098	465	179*	804	60*	741
		5	1,093	441	199*	1,257	380*	1,013
KHH	20'DC	1	1,470	2,311	841**	1,000	674**	833
		2	1,527	1,878	351**	1,000	660**	1,142
		3	1,725	2,401	676**	1,000	332**	798
		4	1,696	2,032	336**	1,000	375**	836
		5	1,879	2,028	149**	1,000	692**	1,379
SGN	20'DC	1	329	400	0	129	0	129
		2	209	163	25**	200	34*	141
		3	492	209	0	483	20*	404
		4	449	401	95*	436	75*	377
		5	258	432	0	262	102*	101

Notes: 1) unit: box
2) * repositioned-out; ** repositioned-in

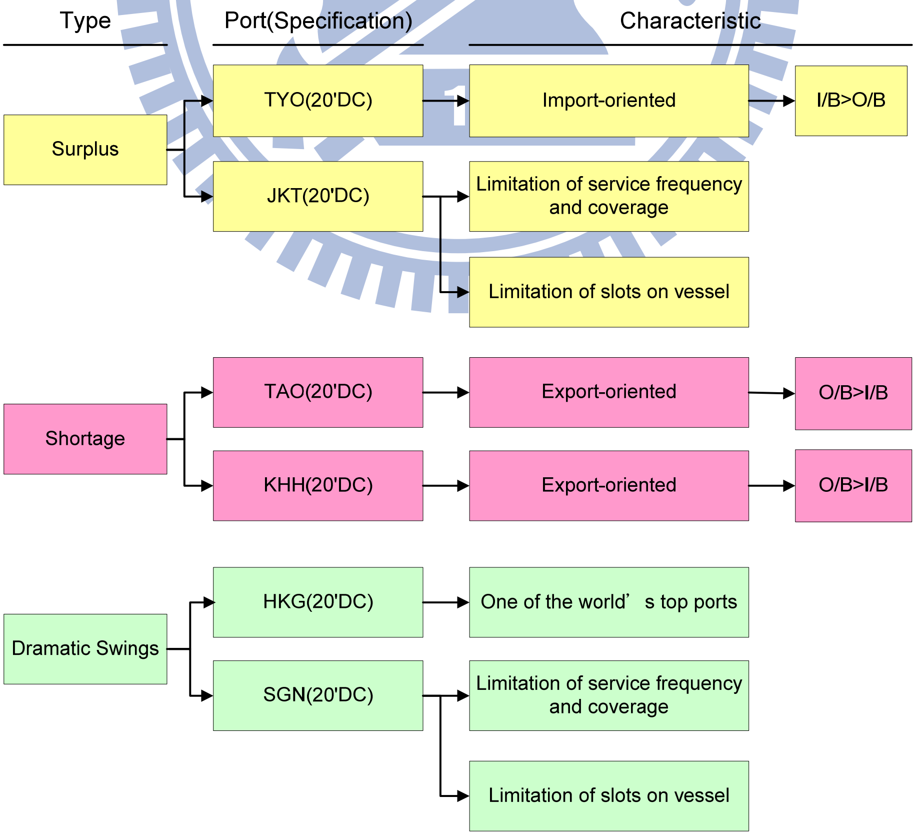


Figure 5.9 Illustration of characteristic for selected ports

5.4.1 The typical pattern of a port having a surplus of empty containers

In this section, we selected TYO port and JKT port for discussion, as these two ports showed significant results with respect to a surplus of empty containers.

At TYO port, the total number of I/B containers was greater than the total number of O/B containers (as seen in Figure 5.10 a), T Line repositioned out a large number of empty containers on one voyage while also collecting a large number of empty containers (as seen in Figure 5.10 c). The results of the proposed model, which depended on data obtained from I/B and O/B containers, indicated that it is easy to manage empty container stock and reduce safety stock (as seen in Figure 5.10 b).

T Line might reduce the level of safety stock at TYO part for 20'DC to increase container utility.

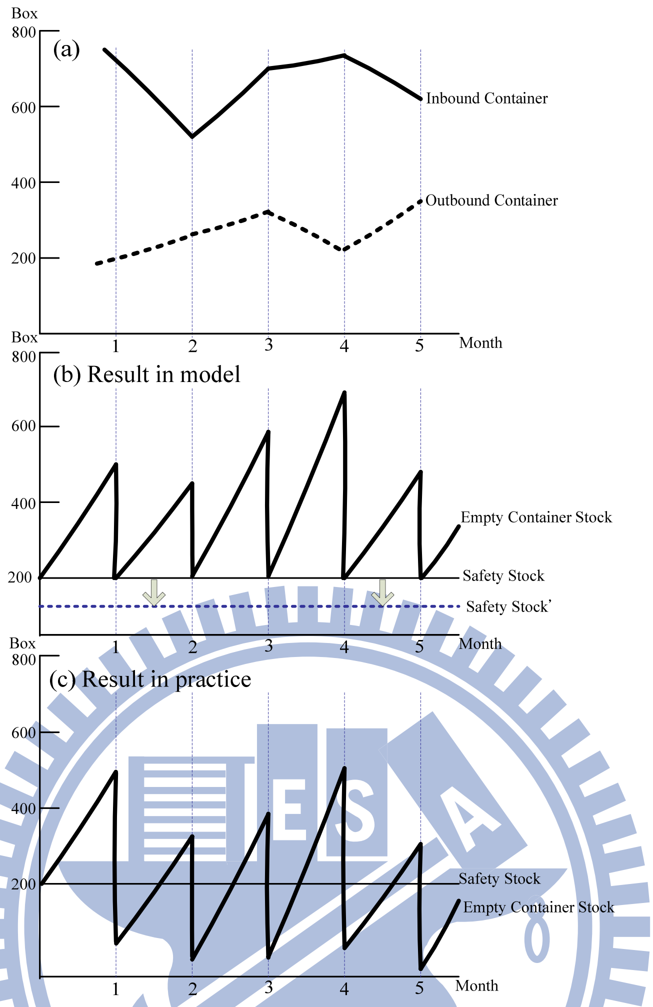


Figure 5.10 Tend of 20'DC empty container stock at TYO port

The total number of I/B containers was greater than the total number of O/B containers at JKT port (as shown in Figure 5.11a). Within the sea transportation network, there are three service routes calling at JKT port with destination ports in North China and Japan. The empty containers accumulated rapidly with the result that inventory cost and storage fees increased. It was difficult to reposition out empty containers because of limits in service coverage and sailing-frequency (as seen in Figure 5.11b and 5.11c).

Strategies to solve this problem (as seen in Figure 5.12)

In the short-term, they might charter slots from other carriers, launch a containership for extra service, or introduce a temporary change in service routes to add calling at JKT port. However, these strategies are costly for the container carriers.

In the long-term, they might adjust the sea transportation network to improve service route planning and ship scheduling.

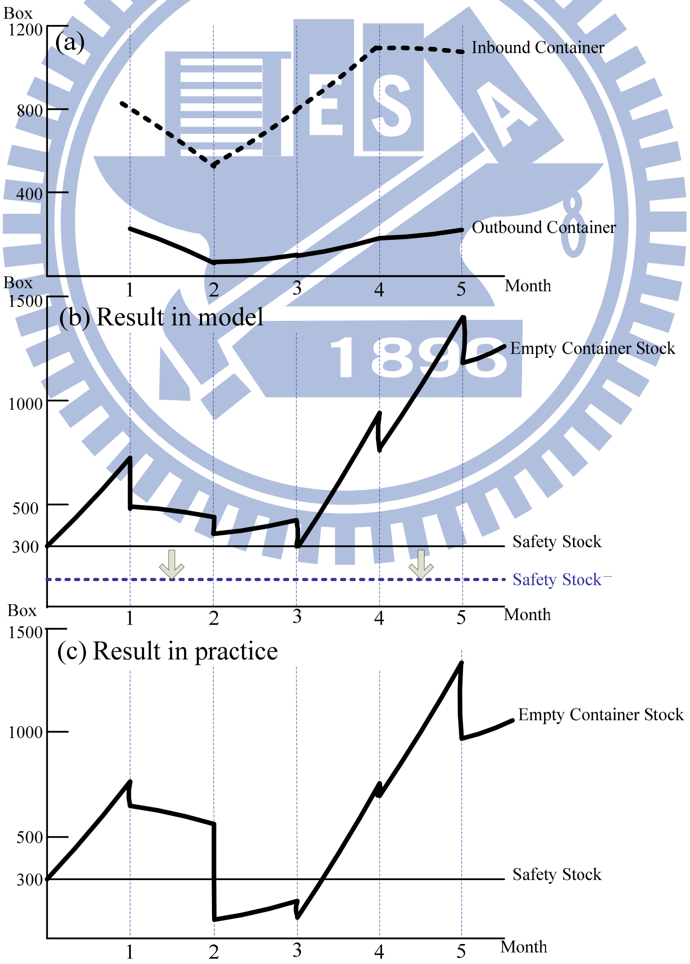


Figure 5.11 Trend of 20’DC empty container stock at JKT port

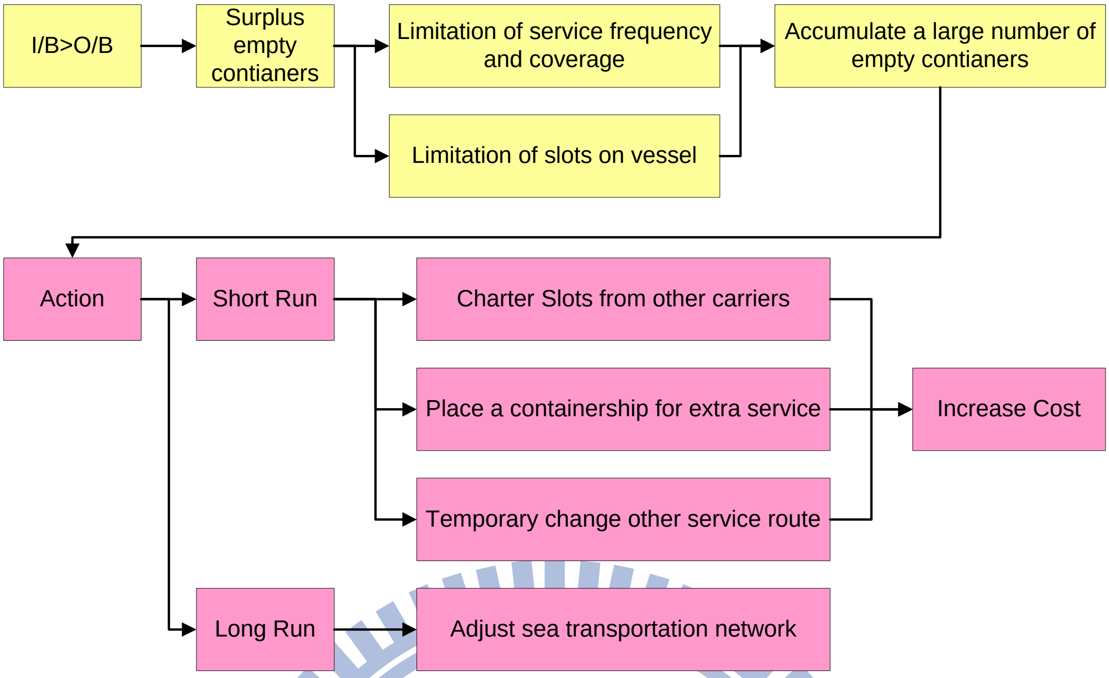


Figure 5.12 Illustration of problem and action in JKT port

5.4.2 The typical pattern of a port having a shortage of empty containers

In this section, we selected for discussion TAO port and KHH port, as both ports showed significant results with respect to a shortage of empty containers.

The total number of O/B containers was greater than the total number of I/B containers at TAO port and KHH port. T Line repositioned a large number of empty containers into TAO port on one voyage (as seen in Figure 5.13 c). The empty container stock was considerable varied, resulting in high storage costs. A plan was needed to allocate these empty containers (as seen in Figure 5.13 and Figure 5.15).

T Line might adopt the results of the proposed model to develop a plan for empty containers reposition (as seen in Figure 5.14).

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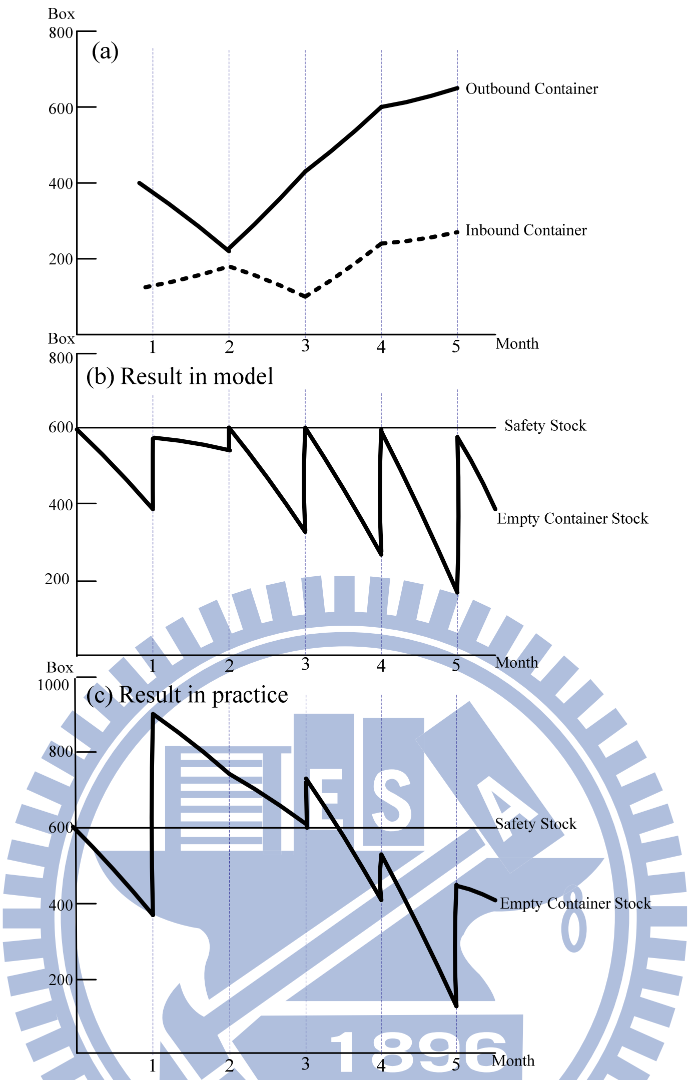

Figure 5.13 Trend of 20'DC empty container stock TAO port

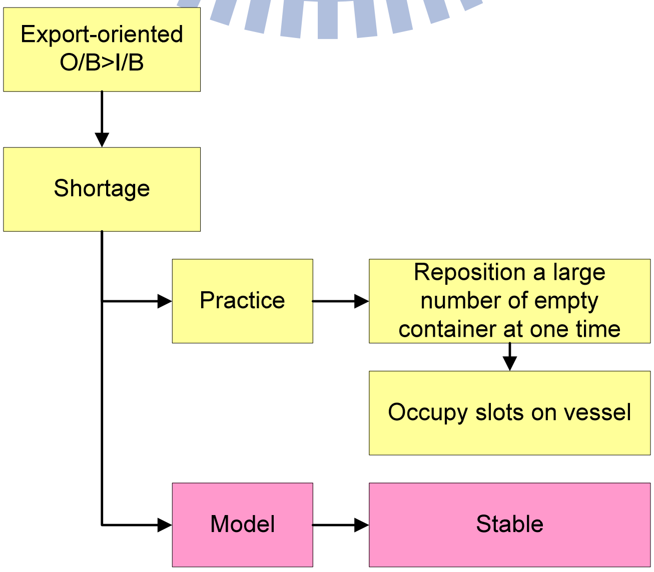

Figure 5.14 Illustration of problem and action in TAO port

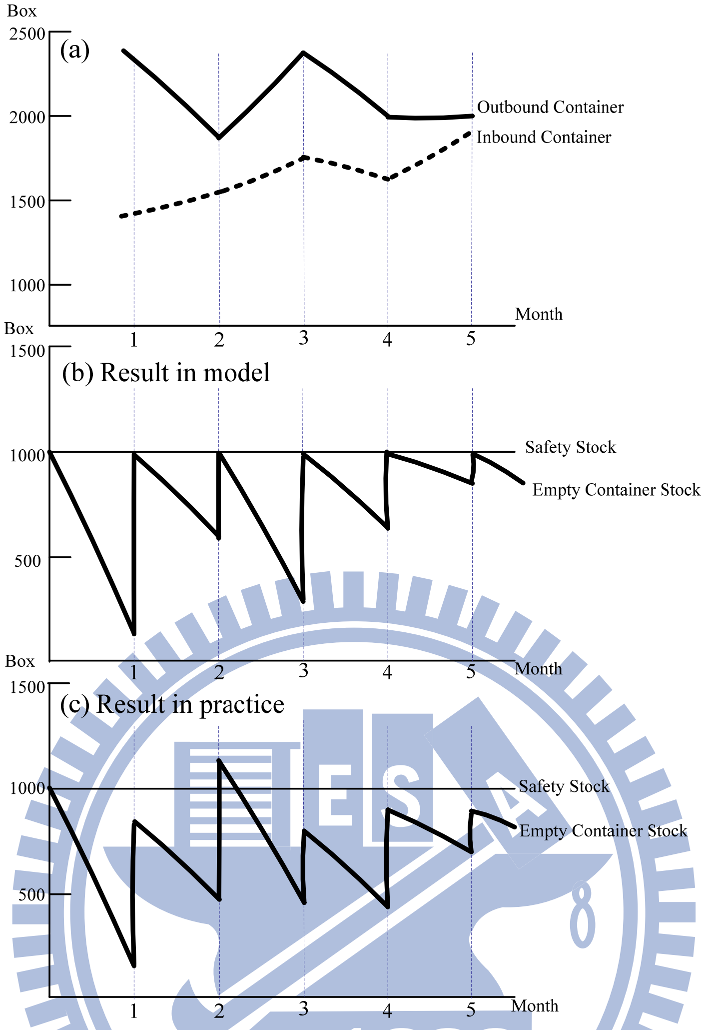

Figure 5.15 Trend of 20’DC empty container stock at KHH port

5.4.3 The typical pattern of a port having dramatic swings in empty container stock

In this section, we selected for discussion HKG port and SGN port, as both ports showed significant results with respect to dramatic swings in empty container stock.

HKG is one of the world’s top ports: the market is booming, rapid and varied. HKG port has a great quantity of I/B and O/B containers (as seen in Figure 5.16 a). Here, T Line faces a challenge with respect to the repositioning of empty containers. Since the stock of empty containers was considerably varied, it was recommended that T Line increase the safety stock of empty containers to meet market demand (as seen in Figure 5.16 c). The results of the proposed model showed that the stock of empty containers needed to be stabilized (as seen in Figure 5.16 b).

T Line might adopt the results of the proposed model to reduce the level of safety stock and develop a plan for empty containers reposition.

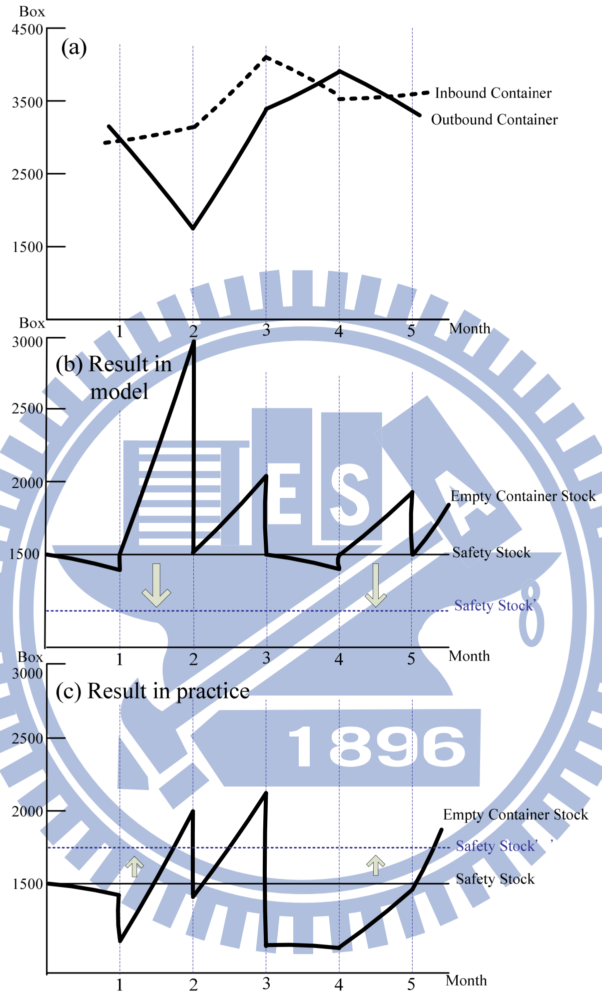

Figure 5.16 Trend of 20'DC empty container stock at HKG port

At SGN port, I/B containers were greater than the number of O/B containers, although empty containers began to accumulate at the depot (as seen in Figure5.17 a). SGN port had the same problem as JKT port; service coverage was limited and sailing-frequency was deficient. Here T Line struggled to reposition empty containers.

Strategies to solve this problem (as seen in Figure 5.18)

In the short-term, they might charter slots from other carriers, launch a containership for extra service, or introduce a temporary change in service routes to add calling at SGN port. However, these strategies are costly for the container carriers.

In the long-term, they might adjust the sea transportation network to improve service route planning and ship scheduling.

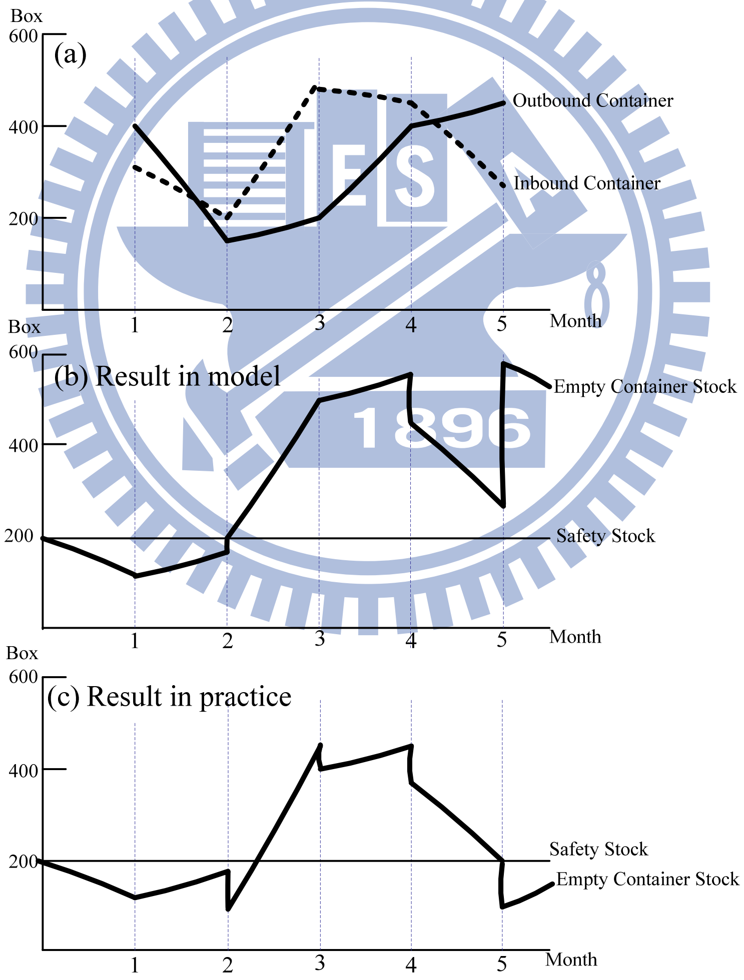

Figure 5.17 Trend of 20’DC empty container SGN port

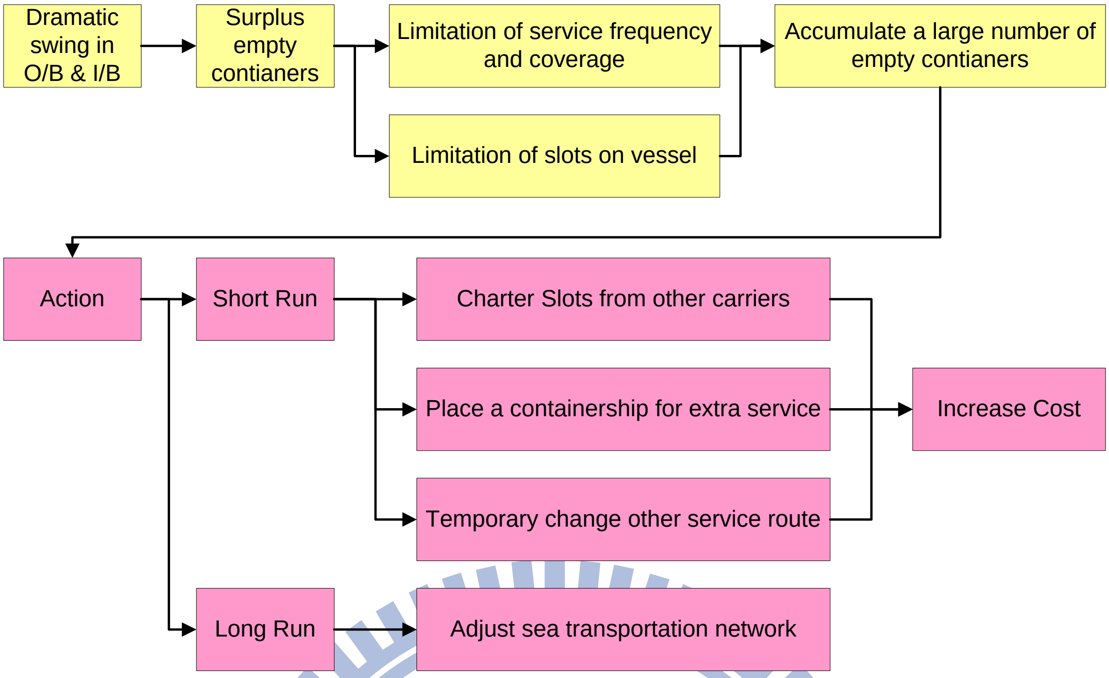

Figure 5.18 Illustration of problem and action in SGN port

5.4.4 Summary

Because of limited service frequency, service coverage, slots on vessel and cargo imbalance between inbound cargo and outbound cargo, container carriers face problems concerning empty container repositioning. They might develop strategies to solve these problems, such as chartering slots from other carriers, launching a containership for extra service, or introducing a temporary change in service route. However, these measures would increase costs; therefore, they can only be considered as temporary solutions. As a permanent solution, container carriers might develop a slot allocation plan to reduce or avoid cargo imbalance (as seen in Figure 5.19)

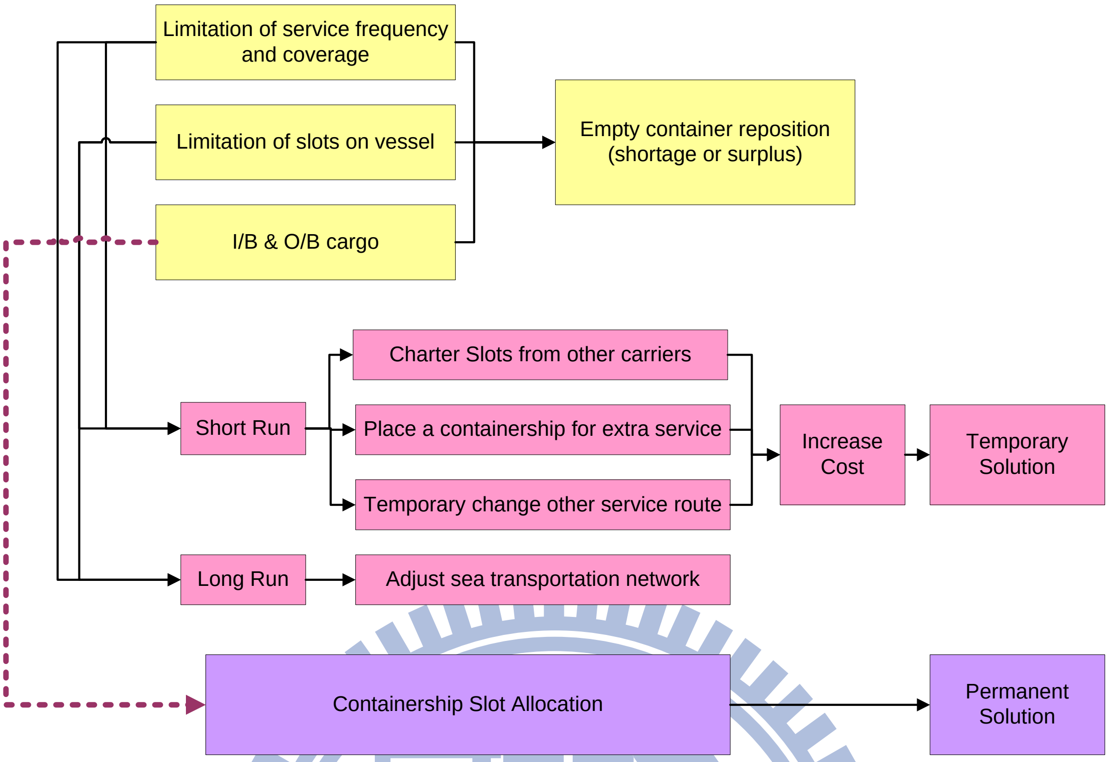

Figure 5.19 Illustration of cause and solution for empty container reposition

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes the findings of this study and points out several implications for management. It also suggests areas that might be considered for future research.

6.1 Conclusions

The major results and findings of this study are summarized as follows:

6.1.1 Containership slot allocation

1. This study incorporated the concept of revenue management for the purpose of developing a plan for containership slot allocation. The proposed model was formulated via linear programming to maximize operational profit subject to constraints of containership: capacity, deadweight and demand. It was suggested that container carriers use a quantitative model to execute revenue management.

2. This study estimated the expected cost of empty container reposition within the objective function. Functions of the proposed model could reduce the cost of cargo imbalance and improve performance for containership slots.

3. The results showed that the proposed model of slot allocation might result in higher profits than those of actual voyages. Also, the ratio of empty containers to allocated slots was lower in the proposed model.

4. The proposed plan for slot allocation might serve as a guideline to manage shipping agencies and maximize the operational profit of container carriers.

5. Strategies are needed to reduce costs and improve the operational capacity of container carriers. Short-term strategies involve maximizing present operational capacities. Long-term strategies involve adjusting the pattern of alliance and re-structuring the sea transportation network.

6. The results showed that by setting up a booking system to control loaded cargo in advance, container carriers might improve their management and also communicate more effectively with the sales department and containership operation department, in order to adjust differences between slot allocation and actual slots.

6.1.2 Empty container reposition

1. This study defined particular challenges of an import-export imbalance in the intra-Asian region and proposed a plan for empty container reposition to solve this problem.

2. This study proposed partitioning the sea transportation network into several geographical regions in order to minimize the number of occupied slots on a containership over a long distance. To achieve this goal, empty containers were distributed within a single region.

3. This study proposed a model to minimize the total cost of empty container reposition, which is concerned with the flow of empty containers from supply points to demand points.

4. The results indicated that the proposed model could provide a way of distributing empty containers that is optimal for container carriers in terms of cost and efficiency.

5. This study considered three patterns emerging from actual ports. Some ports had a shortage of empty containers, others had a surplus of containers, and the third group showed dramatic swings in empty container stock. The following characteristics for each port were also examined: the relationship between I/B cargo and O/B cargo, the level of safety stock, and the sea transportation network. The findings of this study might provide container carriers with the information needed to adjust their management strategy. In order to solve the problem of repositioning out empty containers at ports with a surplus of containers, containerships might reduce the level of safety stock, charter slots from other carriers, launch a containership for extra service, or introduce a temporary change in services routes. However, these are short-term solutions. In the long-term, container carriers might need to re-structure their sea transportation network.

6.2 Recommendations

Recommendations for further study are as follows:

1. In general, the slot allocation model appears to be suitable for a stable market environment with a surfeit of demand. In an unstable market, container carriers might need to change the demand data to obtain optimal slot allocation. A stochastic model of slot allocation for enhancing practical application might be developed.

2. Container carriers might put into place safety stock management at each depot to control empty container stock and avoid inventory cost and storage expense. Having a high level of safety stock means that container carriers can meet shippers' demands and prepare for future demands; however, it also means paying substantial operational expenses. A low level of safety stock means that container carriers run the risk of running short of empty containers and being unable to meet shippers'

demands. Future research might be conducted on how this risk can be reduced by putting into place safety stock management so that levels of inventory can be estimated in advance.

3. This study estimated the expected costs of empty container reposition by evaluating probabilities. Only five grades were classified and the supposed probability was calculated as 0, 0.5, or 1. Further studies might extend this probability evaluation by considering actual situations.

4. This study proposed partitioning the sea transportation network into several geographical regions in order to minimize the total cost of empty container repositioning. Further studies might evaluate this partition principle to determine whether it is adequate to sailing distance, service routes and practical operation.

5. The research scope of this study focused on the intra-Asian region, and one Taiwan shipping company was chosen as a research target. While this approach has its obvious limitations, it suggests a model for deep-sea trading that might be developed through further research.

6. This study consisted of two parts. The first part focused on containership slot allocation on a specific shipping service route. The second part focused on the entire distribution of empty containers in a shipping company. Future research is required to integrate slot allocation and empty container reposition into one model.

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APPENDIX CONTENTS

Appendix A Freight Revenue

Table A: Freight revenue for various port-pairs

POL \ POD		TAO	SHA	HKG	MNN	MNS	JKT	SUB	MNS	HKG
TAO	20'DC			428	487	487	531	531		
	40'DC			691	841	841	935	885		
	40'HQ			691	841	841	935	885		
SHA	20'DC			343	577	577	671	671		
	40'DC			541	1,071	1,071	1,271	1,271		
	40'HQ			541	1,071	1,071	1,271	1,271		
HKG	20'DC				299	299	313	303		
	40'DC				535	535	638	578		
	40'HQ				535	535	638	578		
MNN	20'DC						176	176		
	40'DC						290	290		
	40'HQ						290	290		
MNS	20'DC						176	176		
	40'DC						290	290		
	40'HQ						290	290		
JKT	20'DC	216	231						391	477
	40'DC	640	545						671	737
	40'HQ	640	545						671	737
SUB	20'DC	341	301						406	462
	40'DC	645	590						736	837
	40'HQ	645	590						736	837
MNS	20'DC	252	252							438
	40'DC	371	371							693
	40'HQ	371	371							693
HKG	20'DC	298	248							
	40'DC	524	424							
	40'HQ	524	424							

Unit:USD

Appendix B Variable Cost

Table B: Variable cost for various port-pairs

POL	POD	TAO	SHA	HKG	MNN	MNS	JKT	SUB	MNS	HKG
TAO	20'DC			151	135	127	127	137		
	40'DC			222	202	182	182	205		
	40'HQ			222	202	182	182	205		
SHA	20'DC			172	156	148	148	158		
	40'DC			252	232	212	212	235		
	40'HQ			252	232	212	212	235		
HKG	20'DC				140	132	132	142		
	40'DC				212	192	192	215		
	40'HQ				212	192	192	215		
MNN	20'DC						124	134		
	40'DC						172	195		
	40'HQ						172	195		
MNS	20'DC						124	134		
	40'DC						172	195		
	40'HQ						172	195		
JKT	20'DC	137	137						144	134
	40'DC	205	205						218	195
	40'HQ	205	205						218	195
SUB	20'DC	137	137						144	134
	40'DC	205	205						218	195
	40'HQ	205	205						218	195
MNS	20'DC	127	127							124
	40'DC	182	182							172
	40'HQ	182	182							172
HKG	20'DC	135	135							
	40'DC	202	202							
	40'HQ	202	202							

Unit:USD

1896

Appendix C The Maximum Container Demand

Table C: The maximum container demands for port-pairs

POD POL		TAO	SHA	HKG	MNN	MNS	JKT	SUB	MNS	HKG	TOTAL	
											(BOX)	(TEU)
TAO	20'DC			21	30	18	42	14			125	197
	40'DC			7	1	3	1	1			13	
	40'HQ			12	1	3	4	3			23	
SHA	20'DC			40	9	20	32	6			107	243
	40'DC			11	2	4	22	0			39	
	40'HQ			11	2	7	9	0			29	
HKG	20'DC				16	37	36	10			99	181
	40'DC				3	3	1	0			7	
	40'HQ				7	17	8	2			34	
MNN	20'DC						2	0			2	4
	40'DC						1	0			1	
	40'HQ						0	0			0	
MNS	20'DC						28	8			36	66
	40'DC						2	0			2	
	40'HQ						12	1			13	
JKT	20'DC	0	56						17	14	87	181
	40'DC	0	0						6	5	11	
	40'HQ	0	1						32	3	36	
SUB	20'DC	4	16						18	28	66	122
	40'DC	0	1						0	4	5	
	40'HQ	0	2						6	15	23	
MNS	20'DC	0	2							22	24	48
	40'DC	0	0							4	4	
	40'HQ	0	2							6	8	
HKG	20'DC	56	15								71	175
	40'DC	24	1								25	
	40'HQ	25	2								27	
TOTAL	20'DC	60	89	61	55	75	140	38	35	64	617	
	40'DC	24	2	18	6	10	27	1	6	13	107	
	40'HQ	25	7	23	10	27	33	6	38	24	193	
	(TEU)	158	107	143	87	149	260	52	123	138	1,217	

Appendix D Actual Slot

Table D: Actual slot on voyage 1

POL	POD	TAO	SHA	HKG	MNN	MNS	JKT	SUB	MNS	HKG	TOTAL	
											(BOX)	(TEU)
TAO	20'DC			20	21	3	27	8			79	139
	40'DC			7	3	2	0	0			12	
	40'HQ			17	0	0	1	0			18	
SHA	20'DC			7	8	16	11	14			56	120
	40'DC			1	0	4	1	0			6	
	40'HQ			7	1	7	11	0			26	
HKG	20'DC				1	30	15	3			49	127
	40'DC					2	8	0			10	
	40'HQ				5	23	0	1			29	
MNN	20'DC						2	2			4	4
	40'DC						0	0			0	
	40'HQ						0	0			0	
MNS	20'DC						8	5			13	21
	40'DC						0	0			0	
	40'HQ						2	2			4	
JKT	20'DC	0	44						4	0	48	78
	40'DC	0	0						4	2	6	
	40'HQ	0	0						9	0	9	
SUB	20'DC	0	5						12	42	59	69
	40'DC	0	0						0	1	1	
	40'HQ	0	0						3	1	4	
MNS	20'DC	0	0							30	30	70
	40'DC	0	2							4	6	
	40'HQ	0	5							9	14	
HKG	20'DC	33	1								34	110
	40'DC	17	0								17	
	40'HQ	21	0								21	
TOTAL	20'DC	33	50	27	30	49	63	32	16	72	372	L/F=2.11
	40'DC	17	2	8	3	8	9	0	4	7	58	
	40'HQ	21	5	24	6	30	14	3	12	10	125	
	(TEU)	109	64	91	48	125	109	38	48	106	738	

Notes: (1) POL:Port of Loading
(2) POD: Port of Discharging
(3) Load Factor (L/F): Total Loaded Cargo / Operational Capacity

Appendix D Actual Slot

Table D: Actual slot on voyage 2(cont'd)

POL	POD	TAO	SHA	HKG	MNN	MNS	JKT	SUB	MNS	HKG	TTL	
											(BOX)	(TEU)
TAO	20'DC			31	22	5	34	0			92	204
	40'DC			25	2	0	0	0			27	
	40'HQ			27	1	0	1	0			29	
SHA	20'DC			38	14	21	18	3			94	198
	40'DC			5	1	0	0	0			6	
	40'HQ			22	2	16	5	1			46	
HKG	20'DC				42	23	3	4			72	124
	40'DC				0	6	0	0			6	
	40'HQ				11	8	0	1			20	
MNN	20'DC						1	0			1	1
	40'DC						0	0			0	
	40'HQ						0	0			0	
MNS	20'DC						2	2			4	24
	40'DC						0	0			0	
	40'HQ						10	0			10	
JKT	20'DC	0	98						0	0	98	98
	40'DC	0	0						0	0	0	
	40'HQ	0	0						0	0	0	
SUB	20'DC	38	1						15	47	101	203
	40'DC	0	0						0	14	14	
	40'HQ	14	0						6	17	37	
MNS	20'DC	4	0							33	37	41
	40'DC	0	0							1	1	
	40'HQ	0	0							1	1	
HKG	20'DC	23	2								25	87
	40'DC	25	0								25	
	40'HQ	6	0								6	
TOTAL	20'DC	65	101	69	78	49	58	9	15	80	524	L/F=2.80
	40'DC	25	0	30	3	6	0	0	0	15	79	
	40'HQ	20	0	49	14	24	16	2	6	18	149	
	(TEU)	155	101	227	112	109	90	13	27	146	980	

Notes: (1) POL:Port of Loading
(2) POD: Port of Discharging
(3) Load Factor (L/F): Total Loaded Cargo / Operational Capacity

Appendix E Cost of repositioning an empty container

Table E: Cost of repositioning an empty container for 20'DC (cont'd)

POL	POD	JP									KR		CN										TW			HK	PH		VN	TH		ID	
		TYO	YOK	NGO	OSA	UKB	OIT	TKY	MOJ	HKT	PUS	KAN	XGG	DLC	TAO	LYG	SHA	NGB	FOC	QZJ	SHK	XMN	KEL	TXG	KHH	HKG	MNN	MNS	CAL	BKK	LCH	JKT	SUB
JP	TYO		170	170	168	168	272												187	85	277	231	153	135	133	137				137	110		
	YOK			170	168	168	272												145	85	277	188	153	135	133	137				137	110		
	NGO	213	213		168	168	196												204	85	201	248	153	135	133	137				137	110		
	OSA					122	220	151	163		142	131										195	151	133	131	135				135	108		
	UKB				122		220	151	163		142	131										229	151	133	131	135				135	108		
	OIT																						136		116	120				120	93		
	TKY								148		126	115											136	118	116	120							
	MOJ									187	138	127				80						191	148	130	127	131						149	149
	HKT										166	154				107							175		155	159						176	176
KR	PUS											105				58							126	108	106	110						127	127
	KAN															47							115	97	95	99						116	116
CN	XGG														93								108		88								
	DLC														99								114		94								
	TAO																109						121		101	105	106	106				122	122
	LYG																									52						69	69
	SHA												96	142									124	106	104	108	109	109		108	81	125	125
	NGB																108									103		105		103	77		
	FOC	85	85	85																0		43											
	QZJ	85	85	85																		43											
	SHK	158	158	158																													
	XMN	129	129	129	127	127			123																								
TW	KEL	153	153	153	151	151	136	136	148		126	115	108	114	121		124							63	85	120	121	121	95	120	93	137	137
	TXG	135	135	135	133	133	118	118	130	157	108	97					106						63		62	102				102	75		
	KHH	133	133	133	131	131	116	116	127	155	106	95	88	94	101		104						85	62		99	101	101	75	100	73	117	117
HK	HKG	137	137	137	135	135	120	120	131	159	110	99			105		108	103			125	95	120	102	99		105	105	79	103	77	121	121
PH	MNN																															122	122
	MNS														106		109									105				105	78	122	122
VN	CAL																						95		75	79							
TH	BKK	137	137	137	135	135	120										108	103					120	102	100	103					42		
	LCH	110	110	110	108	108	93										81	77					93	75	73	77				42			
ID	JKT				152	152			149	176	127	116			122		125							119	117	121		122					200
	SUB								149	176	127	116			122		125							119	117	121		122				200	

Notes: **INLAND DRAYAGE COST** ▨

Appendix E Cost of repositioning an empty container

Table E Cost of repositioning an empty container for 40’DC (cont’d)

POD		JP									KR		CN											TW			HK	PH		VN	TH		ID	
POL		TYO	YOK	NGO	OSA	UKB	OIT	TKY	MOJ	HKT	PUS	KAN	XGG	DLC	TAO	LYG	SHA	NGB	FOC	QZJ	SHK	XMN	KEL	TXG	KHH	HKG	MNN	MNS	CAL	BKK	LCB	JKT	SUB
JP	TYO		209	209	207	207	385												258	105	393	321	203	176	153	182				186	145		
	YOK			209	207	207	394												190	105	402	253	203	176	153	182				186	145		
	NGO	273	273		207	207	271												271	105	278	334	203	176	153	182				186	145		
	OSA					179	306	193	200		185	169										268	200	173	150	179				183	142		
	UKB				179		306	193	200		185	169										293	200	173	150	179				183	142		
	OIT																						200		150	179				183	142		
	TKY								189		174	158											189	162	139	168							
	MOJ				200	200				248	181	165				98						264	196	169	146	176						203	203
	HKT										232	216				150							248		198	227						255	255
KR	PUS											149				83							180	154	130	160						188	188
	KAN															67							164	138	114	144						172	172
CN	XGG														139								158		108								
	DLC														147								166		116								
	TAO																161						176		126	156	146	146				183	183
	LYG																									77						105	105
	SHA												143	231									181	154	131	160	151	151		164	123	188	188
	NGB																160									154		145		158	117		
	FOC	105	105	105																0		64											
	QZJ	105	105	105																		64											
	SHK	214	214	214																													
	XMN	168	168	168	166	166			162																								
TW	KEL	203	203	203	200	200	200	189	196		180	164	158	166	176		181							118	162	175	166	166	138	179	138	203	203
	TXG	176	176	176	173	173	173	162	169	221	154	138					154						118		116	148				152	111		
	KHH	153	153	153	150	150	150	139	146	198	130	114	108	116	126		131						162	116		125	116	116	88	129	88	153	153
HK	HKG	182	182	182	179	179	179	168	176	227	160	144			156		160	154			187	141	175	148	125		145	145	117	158	117	182	182
PH	MNN																															173	173
	MNS														146		151									145				149	108	173	173
VN	CAL																						138		88	117							
TH	BKK	186	186	186	183	183	183										164	158					179	152	129	158					84		
	LCH	145	145	145	142	142	142										123	117					138	111	88	117				84			
ID	JKT				207	207			203	255	188	172			183		188							176	153	182		173					400
	SUB								203	255	188	172			183		188							176	153	182		173				400	

Notes: **INLAND DRAYAGE COST** 🟥

Appendix E Cost of repositioning an empty container

Table E Cost of repositioning an empty container for 40'HQ

POL	POD	JP									KR		CN										TW			HK	PH		VN	TH		ID	
		TYO	YOK	NGO	OSA	UKB	OIT	TKY	MOJ	HKT	PUS	KAN	XGG	DLC	TAO	LYG	SHA	NGB	FOC	QZJ	SHK	XMN	KEL	TXG	KHH	HKG	MNN	MNS	CAL	BKK	LCH	JKT	SUB
JP	TYO		209	209	207	207	385												258	105	393	321	203	176	153	182				186	145		
	YOK			209	207	207	394												190	105	402	253	203	176	153	182				186	145		
	NGO	273	273		207	207	271												271	105	278	334	203	176	153	182				186	145		
	OSA					179	306	193	200		185	169										268	200	173	150	179				183	142		
	UKB				179		306	193	200		185	169										293	200	173	150	179				183	142		
	OIT																						200		150	179				183	142		
	TKY								189		174	158											189	162	139	168							
	MOJ				200	200				248	181	165				98						264	196	169	146	176						203	203
	HKT										232	216				150							248		198	227						255	255
KR	PUS											149				83							180	154	130	160						188	188
	KAN															67							164	138	114	144						172	172
CN	XGG														139								158		108								
	DLC														147								166		116								
	TAO																161						176		126	156	146	146				183	183
	LYG																									77						105	105
	SHA												143	231									181	154	131	160	151	151		164	123	188	188
	NGB																160									154		145		158	117		
	FOC	105	105	105																0		64											
	QZJ	105	105	105																		64											
	SHK	214	214	214																													
	XMN	168	168	168	166	166			162																								
TW	KEL	203	203	203	200	200	200	189	196		180	164	158	166	176		181							118	162	175	166	166	138	179	138	203	203
	TXG	176	176	176	173	173	173	162	169	221	154	138					154						118		116	148				152	111		
	KHH	153	153	153	150	150	150	139	146	198	130	114	108	116	126		131						162	116		125	116	116	88	129	88	153	153
HK	HKG	182	182	182	179	179	179	168	176	227	160	144			156		160	154			187	141	175	148	125		145	145	117	158	117	182	182
PH	MNN																															173	173
	MNS														146		151									145				149	108	173	173
VN	CAL																						138		88	117							
TH	BKK	186	186	186	183	183	183										164	158					179	152	129	158					84		
	LCH	145	145	145	142	142	142										123	117					138	111	88	117				84			
ID	JKT				207	207			203	255	188	172			183		188							176	153	182		173					400
	SUB								203	255	188	172			183		188							176	153	182		173				400	

Notes: **INLAND DRAYAGE COST** ▨

Appendix G Transportation Mode

Table G: Coefficient of transportation mode

POD		JP									KR		CN										TW			HK	PH		VN	TH		ID	
POL		TYO	YOK	NGO	OSA	UKB	OIT	TKY	MOJ	HKT	PUS	KAN	XGG	DLC	TAO	LYG	SHA	NGB	FOC	QZJ	SHK	XMN	KEL	TXG	KHH	HKG	MNN	MNS	CAL	BKK	LCB	JKT	SUB
JP	TYO		1	1	1	1	1												1	0	0	1	1	1	1	0				0	0		
	YOK			1	1	1	1												1	0	0	1	1	1	1	0				0	0		
	NGO	1	1		1	1	1												1	0	0	1	1	1	1	0				0	0		
	OSA					1	1	1	1		1	1										0	1	1	1	0				0	0		
	UKB				1		1	1	1		1	1										0	1	1	1	0				0	0		
	OIT																						1		1	0				0	0		
	TKY								1		1	1											1	1	1	0							
	MOJ									1	1	1				1						0	1	1	1	0						0	0
	HKT										1	1				1							1		1	0						0	0
KR	PUS											1				1							1	1	1	0						0	0
	KAN															1							1	1	1	0						0	0
CN	XGG														1								1		1								
	DLC														1								1		1								
	TAO																1						1		1	1	0	0				0	0
	LYG																									1						0	0
	SHA													1									1	1	1	1	0	0		0	0	0	0
	NGB																1									1		0		0	0		
	FOC	1	1	1																0		1											
	QZJ	0	0	0																		0											
	SHK	1	1	1																													
	XMN	1	1	1	1	1			1																								
TW	KEL	1	1	1	1	1	1	1	1		1	1	1	1	1		1							1	1	1	0	0	0	0	0	0	0
	TXG	1	1	1	1	1	1	1	1	1	1	1					1						1		1	1				0	0		
	KHH	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1						1	1		1	0	0	0	0	0	0	0
HK	HKG	0	0	0	0	0	0	0	0	0	0	0			1		1	1			1	1	1	1	1		1	1	1	1	1	1	1
PH	MNN																															1	1
	MNS														1		1									1				1	1	1	1
VN	CAL																						0		0	1							
TH	BKK	0	0	0	0	0	0										0	0					0	0	0	1					1		
	LCH	0	0	0	0	0	0										0	0					0	0	0	1				1			
ID	JKT				0	0			0	0	0	0			0		0							0	0	1		1					1
	SUB								0	0	0	0			0		0							0	0	1		1				1	

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