A BENCHMARKING STUDY OF THE IMPACTS OF SECURITY REGULATIONS ON CONTAINER PORT EFFICIENCY

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DECLARATION OF CONTRIBUTION

At various stages during this PhD, I have been involved in collaborative efforts with both academic and industrial colleagues. In certain cases, the output of this collaboration is included in this thesis to better explain and support the research presented. In particular, my research has built upon collaborative work with my supervisors and other colleagues, working on an edited book and several collaborative research papers that were presented at various conferences and submitted for journal publication. These are listed in the reference section and are all my own work.

I hereby declare that besides the collaboration referred to above I have personally carried out the work described in this dissertation.

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Professor Andrew Evans

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Visiting Professor Robert Cochrane

Dedication

This work is dedicated to my wife and my mother

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ABSTRACT

Since the terrorist attacks in the USA in September 2001, several regulations have been introduced with a special emphasis on the security of containerised port operations. Global security measures specifically targeting container-port operations include the International Ship and Port Facility Security (ISPS) code, the Container Security Initiative (CSI), and the 24-hour Advance Vessel Manifest Rule (the 24-hour rule). Nevertheless, no attempt has been made to-date to investigate the ex-post impacts of security on the operational efficiency of container ports and terminals. This PhD research seeks to adopt an approach that incorporates within an analytical framework the association of security with operational efficiency, tools for modelling procedural security, and techniques for benchmarking container-port efficiency. A panel data set of 39 ports and 60 container terminals from 2000 until 2006 is used resulting into 420 container-terminal decision-making units (DMUs).

In order to account equally for container terminal operational configurations and the multi-input/ multi-output nature of container port production, we apply both process modelling and analytical benchmarking techniques. These are the Integrated Computer Aided Manufacturing Definition (IDEF0) for operational and security modelling, and Data Envelopment Analysis (DEA) for efficiency measurement and benchmarking. Based on the results of IDEF0 modelling, we disaggregate container-port operations by terminal sites (quay, yard and gate) and spatial scope of security and apply alternative DEA models to analyse (i) the operational impact of individual and aggregate security regulations and (ii) the influence of operating and exogenous factors on port efficiency. We then estimate a Malmquist productivity index (MPI) to measure and decompose productivity changes following the introduction of new security measures.

The results of the research confirm that both handling configurations and operating procedures have a direct effect on container terminal's productive efficiency. The analysis of the impact of security on operational efficiency shows that the latter varies greatly by security regulation and terminal group but there is evidence of generalised productivity gains from the technological progress prompted by investments in the new security technology. More importantly, the implementation of the new port security measures revealed several inherent logistical inefficiencies especially in the way terminal policies and work procedures are being designed, operated, and managed.

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GLOSSARY OF ABREVIATIONS AND ACRONYMS

AAPA: American Association of Port Authorities
ABC: Activity Based Costing
ACI: Advance Cargo Information
ACS: Automated Commercial System
AE: Allocative Efficiency
AEO: Authorised Economic Operator
AGV: Automatically Guided Vehicle
AHP: Analytical Hierarchy Process
AIPV: Association Internationale des Ports et Villes (International Association of Ports and Cities)
AIS: Automated Identification System
AMR: Advanced Manifest Rule
AMS: Automated Manifest System
ANOVA: Analysis of Variance
APEC: Asia Pacific Economic Co-operation
ASEAN: Association of South East Asian Nations
ASC: Automated Staking Cranes
ATO: Assemble to Order
ATS: Automated Targeting System
ATU: Advanced Targeting Units
BASC: Business Alliance for Secured Commerce (formerly the Business Anti-Smuggling Coalition)
BCC: Banker, Charnes, Cooper (DEA Model)
BCC-I: BCC Input-oriented (DEA Model)
BCC-O: BCC Output-oriented (DEA Model)
Bioterrorism Act: Public Health Security, Bioterrorism Preparedness and Response Act
BPR: Business Process Reengineering
BSC: The Balanced Scorecard
CBA: Cost-Benefit Analysis
CBP: US Bureau of Customs and Border Protection
CCR: Charnes, Cooper, Rhodes (DEA Model)
CCR-I: CCR Input-oriented (DEA Model)
CCR-O: CCR Output-oriented (DEA Model)
CEA: Cost Efficiency Analysis
CGE: Computable General Equilibrium
CIM: Computer integrated manufacturing
COLS: Corrected Ordinary Least Square
COTP: Captain of the Port
CPH: Crane productivity per Hour
CPV: Cost-Performance-Value
CRS: Constant Returns to Scale
CSI: Container Security Initiative

CSO: Company Security Officer
CSR: Continuous Synopsis Record
CTQI: Container Terminal Quality Indicator
C-TPAT: Customs and Trade Partnership against Terrorism
DFC: Discount Factor
DEA: Data Envelopment Analysis
DHC: Double Hoist Cranes
DHS: The US Department of Homeland Security
DMU: Decision Making Unit
DP World: Dubai Ports World
DPP: Direct-Product Profitability
DwT: Dwell Time
e.g.: For example
EC: European Commission
E-Commerce: Electronic Commerce
EDI: Electronic Data Interchange
EEA: Economic Engineering Analysis
ERP: Enterprise Resource Planning
EU: European Union
FAK: Freight-all-Kind
FAST: Free and Secure Trade
FDH: Free Disposal Hull
FEL: Front-end-Loaders
FEU: Forty-Equivalent Unit
FF: Freight Forwarders
FSA: Formal Safety Assessment
ft.: Foot
GAO: United States General Accounting Office
GDP: Global Domestic Product
GT: Gross Tonne
HPH: Hutchison Ports Holding
i.e.: Namely
IAME: International Association of Maritime Economists
IAPH: International Association of Ports and Harbours
GAO: The US Government Accountability Office
ICAM: Integrated Computer Aided Manufacturing
ICOM: Inputs, Controls, Outputs, and Mechanisms
IDEF: Integrated computer aided manufacturing Definition
ILO: International Labour Organization
IMF: The International Monetary Fund
IMO: International Maritime Organisation
I-O: Input-Output
IRR: Internal Rate of Return
ISEMAR: Institut Supérieur d'Economie Maritime, France

ISM: International Safety Management Code
ISO: International Standardisation Organisation
ISPS Code: International Ship and Port Facility Security Code,
ISSC: International Ship Security Certificate
IT: Information Technology
KPI: Key Performance Indicators
LCL: Less Than a Container Load
LOA: Length Overall
LP: Linear Programming
MARAD: The U.S. Maritime Administration
MARPOL: Maritime Pollution referring to the International Convention for the Prevention of Pollution from Ships
MARSEC: Maritime Security
MCA: The UK Maritime and Coast Guard Agency
MFP: Multi-Factor Productivity
MODUs: Mobile Offshore Drilling Units
MPI: Malmquist Productivity Index
MPTO: Marine Port Authority and Terminal Operators
MTO: Make to Order
MTS: Make to Stock
MTSA: Maritime Transportation Security Act
NISAC: National Infrastructure Simulation and Analysis Centre
NNI: Non-Intrusive Inspectional (equipment)
NPV: Net Present Value
N-RAT: The US National Risk Assessment Tool
NTC: The US National Targeting Centre
NVOCCs: Non-Vessels Operating Common Carriers
JIT: Just in Time
OECD: Organisation for Economic and Co-operation Development
OLS: Ordinary Least Square
OSC: Operation Safe Commerce, Outer Continental Shelf
P&I: Protection and Indemnity
PCA: Principal Component Analysis
PFP: Partial Product Profitability
PFSA: Port Facility Security Assessment
PFSO: Port Facility Security Officer
PFSP: Port Facility Security Plan
PIP: Partners in Protection
PSA: Port of Singapore Authority
PSA: Port of Singapore Authority
PEC: Pure Efficiency Change
RAE: Return on Assets
RMG: Rail-Mounted Gantry (Cranes/Equipment, Handling System or Configuration)
ROCE: Return on Capital Employed

ROE: Return on Equity
ROI: Return on Investment
RPM: Revealed-Preference Method
RS: Reach Stackers
RSO: Recognised Security Organisation
RTG: Rubber-tired Gantry (Cranes/Equipment, Handling System or Configuration)
RTS: Returns to Scale
SADT: Structured Analysis and Design Technique
SC: Straddle Carrier (Equipment, Handling System or Configuration)
SCD: Straddle Carrier Direct (Handling System or Configuration)
SCR: Straddle Carrier Relay (Handling System or Configuration)
SCM: Supply Chain Management
SCO: Ship Security Officer
SCP: Supply Chain Planning
SE: Scale Efficiency
SEC: Scale Efficiency Change
SEP: Secured Export Partnership
SFA: Stochastic Frontier Analysis
SFI: Secure Freight Initiative
SFP: Single Factor Productivity
SHA: Stakeholder Analysis
SHC: Single Hoist Cranes
SIS: Ship Identification Number
SOLAS: Safety of Life at Sea Convention
SPM: Stated-Preference Method
SPMP: Shanghai Port Machinery Plant
SSA: Ship Security Assessment
SSAS: Ship Security Alert System
SSP: Ship Security Plan
SST: Smart and Secure Trade-lanes
STAR: Secure Trade in the APEC Region
STC: Said to Contain
STCW: The IMO Standards of Training Certification and Watch-keeping
STS (crane): Ship-to-Shore (crane)
SWL: Safe working Load
T/S: Transhipment (Trans-shipment)
TAPA: Technology Asset Protection Association
TC: Technical Change
TCA: Total Cost Analysis
TE: Technical Efficiency
TEC: Technical Efficiency Change
TEU: Twenty-Foot Equivalent Unit
TFP: Total Factor Productivity
TFPC: Total Factor Productivity Change

TFPG: Total Factor Productivity Growth
THC: Terminal Handling Charges
The 24-hour (hr) rule: 24-Hour Advanced Manifest Rule
TOS: Terminal Operating System
TQM: Total Quality Management
TTEC: Total Technical Efficiency Change
US: United States
UAE: United Arab Emirates
UK RAE: The UK Risk Assessment Exercise
UK: United Kingdom
ULCS: Ultra-Large Container Ships
UN: United Nations
UNCTAD: United Nations Conference on Trade and Development
USA: The United States of America
USCG: The US Coast Guard
USD: United States Dollar
VRS: Variable Returns to Scale
WCO: World's Customs Organisation
WTP: Willingness to Pay
YC: Yard Crane

GLOSSARY OF SYMBOLS

N : The number of firms or DMUs (or population size)
n : The n^{th} firm or DMU (or the sample size)
m : The m^{th} input variable for a firm or a DMU
s : The s^{th} output variable for a firm or a DMU
M : The number of input variables for a firm or a DMU
S : The number of output variables for a firm or a DMU
t : The t^{th} time
T : The total number of time observed
X : Matrix if input variables
Y : Matrix of output variables
x : The amount of input or factor used
y : The amount of output or product produced
$\prod$: Productivity index
U : Value of technical efficiency
V : Value of statistical noise component
ϕ^* : Efficiency score for the studied observation (DMU) under output orientation,
θ^* : Efficiency score for the studied observation (DMU) under input orientation,
j : Denotes all the other observations with which the studied observation is compared.
λ: Denotes input or output weights, under DEA, to be determined for the n^{th} observation or DMU
ω : Denotes cost or revenue shares or weights
j : Denotes a distance function
μ: Population mean
σ^2: Population variance
r : Pearson's coefficient of correlation
p : The p-value
€: The Euro
UK £: The British Pound
USD $: The US Dollar
AUD $: The Australian Dollar

CHAPTER I: INTRODUCTION AND BACKRGOUND INFORMATION

I.1 Scope

This thesis is produced in line with the requirements of Imperial College London for the award of the PhD degree. It provides a detailed overview of the PhD work and results with regard to the research subject: "*A Benchmarking Study of the Impact of Security Regulations on Container Port Efficiency*". The dissertation subsequently presents and describes the research work including relevant literature review, the research design and framework of analysis, the theoretical models and analytical techniques, the dataset and methods for data collection, the operationalisation of the research approach and procedure, the results and interpretation, and the conclusion and recommendations.

I.2 Background

Since the terrorist attacks in the USA in September 2001 and the growing concern about the security of the international movement of goods and passengers, several frameworks have been introduced either on a compulsory or voluntary basis with a special emphasis on containerised port operations. Regulatory measures that have been multilaterally endorsed and implemented include the International Ship and Port Facility Security (ISPS) code, the IMO/ILO code of practice on security in ports, and the 'Framework of Standards to Secure and Facilitate Global Trade' commonly referred to as the 'WCO Framework'. Other instruments with less global coverage, yet greater scope and implications, have been introduced on a local or regional scale. Among these, the US-led initiatives are probably the most significant and consist of a multi-layer regulatory regime involving measures such as the Container Security Initiative (CSI), the 24-hour Advance Vessel Manifest Rule (the 24-hour rule), the Customs and Trade Partnership against Terrorism (C-TPAT), and the Secure Freight Initiative (SFI). A third set of initiatives consists of primarily industry-led schemes such as the Smart and Secure Trade-lanes (SST), the Star-Best programme, the Business Alliance for Secured Commerce (BASC), and a series of ISO series notably the ISO 28000.

With such variations in the international maritime and port security framework, much of the literature on the subject has focused on prescriptive details of the measures being put in place, the computation of their costs of compliance, and their *ex-ante* economic evaluation such as in terms of cost-benefit analysis. Nevertheless, no attempt to date has been undertaken to analyse empirically the *ex-post* procedural impacts of the new security framework on the operational efficiency of container ports and terminals.

Benchmarking container-port efficiency is by itself an extremely broad and complex subject. Many authors have studied performance metrics, performance measurement systems, and the relationship between efficiency and the port environment. Too often though, relevant work on the mechanisms and techniques of measuring and benchmarking port efficiency has taken place at different disciplinary levels with fragmented layers of operational, functional, and spatial port systems.

I.3 Research Problem and Objectives

This research seeks to assess and analyse the ex-post impacts of procedural security, stemming from the requirements of the new maritime and port security regime, on the operational efficiency and performance benchmarking of container ports and terminals. The main research question can be formulated as follows: *what is the impact, in terms of efficiency gains or losses, of procedural security on the performance of container terminal and port operations?*

In trying to answer the above question, this study adopts an approach that incorporates within a logical framework of analysis the association of security with operational efficiency, measures and techniques for benchmarking container terminal efficiency, and appropriate tools for assessing procedural security. The ultimate aim of this research is three fold:

1. Construct and apply an analytical model for measuring and benchmarking the operational efficiency of international container-terminal operations,

2. Assess and analyse the ex-post procedural impacts of major security regulations on container-terminal's operational efficiency, and

3. Identify and incorporate the variations in container-port operating sites, production technologies, and handling configurations in the benchmarking exercise as well as in the analytical process for the purpose of port's functional modelling and assessment of security scope and impacts.

Specific objectives and steps of this research include the followings:

(a) Review and critically analyse the port security framework and the associated literature; and identify the security measures that are likely to impact container-terminal and port operational efficiency.

(b) Review and critically analyse the theoretical and practical literature on port operational efficiency and performance benchmarking.

(c) Identify the spatial and operational scope of major port security regulations.

(d) Identify and evaluate the variations in container-terminal production technologies, operating sites, handling configurations, process arrangements, and work procedures.

(e) Design, justify and apply a research framework, combining bottom-up process modelling tools with top-down analytical benchmarking techniques.

(f) Apply appropriate functional modelling techniques for prescriptive analysis of container-terminal operations and process-flow arrangements.

(g) Build up and validate aggregate and specific datasets of container terminal operations, including the definition and selection of relevant input and output variables.

(h) Formulate and apply appropriate models for efficiency benchmarking and productivity change analysis.

(i) Report, assess, and analyse the variations in efficiency levels and security impacts across sampled container terminals and their operating sites.

I.3 Structure of the Thesis

Following a brief introductory section, this thesis is structured in terms of seven chapters. Chapters II and III provide a detailed and comprehensive literature review and analysis of the two subjects under study, namely the port security framework and the benchmarking of port efficiency. Chapter IV outlines the research design and approach adopted in this study. In Chapter IV, we emphasise the need to incorporate terminal operating systems, procedural flows, and configuration typologies in the research framework. In particular, we explain why a combination of top-down and bottom-up methodological approaches, namely the Integration Function Technique For Functional Modelling (IDEF0), Data Envelopment Analysis (DEA), and the Malmquist Productivity Index (MPI), is required for undertaking research on both the benchmarking of operational efficiency and the assessment of security impacts. Chapter V deals with the operationalisation of the research approach and methodology including such aspects as the formulation of the appropriate analytical models and techniques, the selection of the sampling frame, and the definition of the dataset and variables. Chapter VI presents the results and findings of the analytical work. In particular, we test several hypotheses including those investigating the relationship between operational efficiency and procedural security. Chapter VII concludes with a summary of the research procedure, a review of the study limitations, quality and contribution, and a series of recommendations for future research. Chapter VII also introduces a generic framework for assessing the efficiency costs and benefits of future security investment.

CHAPTER II: THE PORT SECURITY FRAMEWORK

Since the terrorist attacks in the USA in September 2001, the international community has acknowledged the new security threats to maritime trading and transportation systems and the need for an improved regulatory regime. As a result, several frameworks aimed at enhancing maritime and port security have been introduced, with a special emphasis being placed on protecting the vulnerability of containerised sea-trade operations. In this chapter, we outline port-related new security initiatives and review the literature on compliance and procedural costs.

II.1 Overview of Maritime and Port Security Programmes

The security of international shipping and port operations has first been formally recognised in the wake of the hijacking of the cruise vessel "Achille Lauro". As result, the International Maritime Organisation (IMO) produced draft guidelines titled "Measures to prevent unlawful acts which threaten the safety of ships and the security of their passengers and crew". The Guidelines became the first internationally approved formula that sets out what ports and ships had to do in order to provide proper protection against terrorists. However, it was not until the events and aftermaths of the terrorist attacks of September 11, 2001 that the port and maritime industry saw the introduction of structured and targeted security legislation and initiatives. Regulatory measures that have been multilaterally endorsed and implemented include the International Ship and Port Facility Security (ISPS) code, the IMO/ILO code of practice on security in ports, and the World's Customs Organisation (WCO) 'Framework of Standards to Secure and Facilitate Global Trade' also referred to as 'SAFE Framework'.

A second set of security initiatives has been introduced at various national and regional levels, with the US-led security initiatives being the most significant. The US measures started with common initiatives such as the Maritime Transportation Act (MTSA) of 2002, which involves both mandatory and voluntary ISPS provisions (DHS, 2003), and later introduced a range of layered security programmes that target specific types of maritime facilities and operations. Major programmes under this category include the Container Security Initiative (CSI), the 24-Hour Advanced Manifest Rule (24-hour rule), the Customs and Trade Partnership against Terrorism (C-TPAT), the Operation Safe Commerce (OSC), the mega-port initiative, and the Secure Freight Initiative (SFA). Except the 24-hour rule, these programmes and others have later been codified into the US Safe Port Act. Other national programmes include Canada's and Mexico's own 24-hour rules, the Swedish Stair-Sec programme, the Canada Partners in Protection (PIP) programme, and the New Zealand Secured Export Partnership (SEP) programme.

Initiatives have also emerged from the European Commission (EC) in the guise of the EC Regulation 725/2004 on enhancing ship and port facility security. The latter incorporates the ISPS Code and extends its application to all Class A passenger vessels, i.e. those on domestic voyages of more than 20 nautical miles from the coast. It goes on to allow Member States to adopt alternative security requirements for passenger ships operating domestic scheduled services. The Authorised Economic Operator (AEO), the status and accreditation of which were introduced in January 2008, is another EU scheme deserving particular attention since it can be seen as the EU response to the US C-TAPAT programme. Other EC security measures include Regulation 884/2005 laying down procedures for conducting Commission inspections in maritime security, and the Directive 2005/65/EC extending security measures from the ship-port interface to the entire port facility. Outside the EU, regional initiatives that are worth mentioning include the US-Canada-Mexico Free and Secure Trade (FAST) programme, the ASEAN/Japan Maritime Transport Security initiative, and the Secure Trade in the APEC Region (STAR) programme for Asia Pacific.

A third set of security initiatives consists of primarily industry-led and voluntary programmes. Initiatives under this category include the ISO/PAS 28000: 2005 standard (Specification for security management systems for the supply chain), the Technology Asset Protection Association (TAPA) initiative, and the Business Alliance for Secured Commerce (BASC), formerly the Business Anti-Smuggling Coalition. Although some of these programmes have not yet been fully implemented, it is believed that they will yield a more effective framework and a higher level of security assurance across and beyond the maritime network. For a detailed review of these initiatives and other port and maritime security measures, the reader is referred to Bichou et al. (2007b).

In the following sections, we outline the requirements for the main port security regulations currently in operations, namely the ISPS Code, the CSI and the 24-hour rule. A summary description of these measures is provided in Table 1. Initiatives that are currently being implemented on a pilot basis, e.g. the Mega-Ports Initiative and the Secure Freight Initiative (SFA), are not included in this review.

II.1.1 ISPS Code

The objectives of the ISPS Code, within an international framework, are to enable the detection and deterrence of security threats, to establish roles and responsibilities, to enable the collection and exchange of security information, to provide a methodology for assessing security, and to ensure that adequate security measures are in place. The ISPS Code is divided into two parts: part A is a mandatory section while part B is a non-obligatory guidance, although many countries are implementing part B on a compulsory basis. The code determines the responsibilities of contracting governments (i.e. signatories to the Code), ship operators and port facility operators. The ISPS Code was adopted in December 2002 and it came into force in July 2004.

As far as ports are concerned, the ISPS Code is applicable to all port facilities servicing 500+ gross ton (GT) cargo and passenger ships engaged in international voyages, but contracting governments are given the option to extend the application of the Code to other types of ports and terminals. The Code sets three maritime security (MARSEC) levels ranging from low (1) to high (3) in proportion to the nature of the incident or the perceived security threat. MARSEC level 1 is compulsory, and is enclosed under ISPS part A. MARSEC level 2 indicates a heightened threat of security, while MARSEC level 3 refers to a probable or imminent threat of a security incident.

To comply with the ISPS Code, ports are required to develop and implement enhanced port facility security plans (PFSP) for each MARSEC level as set and approved by the governmental authority within whose territory the port is located. PFSP are based on the outcome of the port facility security assessment (PFSA), a risk-analysis exercise undertaken by contracting governments or authorised security organisations by them (RSO: Recognised Security Organisation), in order to assess the vulnerability of port facilities against security threats and the consequences of potential incidents. In addition to undertaking PFSA and developing PFSP, ports must also designate port-facility security officers (PFSO) whose duties and responsibilities are specified by the Code, and provide them along with other security personnel with the appropriate training drills and exercises. The Code also describes the identification and evaluation of important assets and infrastructure and requires ports to install and operate a number of security kits and equipment. Appendix 1 provides the list of port security equipment required by the ISPS Code.

Table 1: Outline of ISPS code and selected US-led port and maritime security measures (Source: Compiled by the author from IMO, 2004 and CBP, 2006)

		Aim	Legal arrangements	Targets/ participants	Main requirements and responsibilities	Inspection and certification
ISPS Code		Security of maritime network Prevention of terrorism threats	International amendments to SOLAS 1974 mainly: ISPS code and the new SOLAS XI-2 chapter	1. Ship: 500+ GT vessels engaged in international voyage 2. Ship-owning or operating company 3. Port facility, MODUS included when in port or in transit 4. Port / port operator 5. Contracting government	1/2. Install SSAS & AIS. Keep security records. Display SIS. Provide security equipment. Develop SSP. Appoint SSO & CSO. Undertake SSA. Keep records. Carry out training & drills. → *Obtain ISSC* 3/4. Undertake PFSA. Develop and implement PFSP. Appoint PFSO. Provide security equipment. Carry out security training & drills. 5. Nominate designated authority and RSO. Approve, review and certify SSP, PFSP / PFSA. Set and notify appropriate security levels. Issue CSR. Issue & verify ISSC. Exercise compliance measures. Communicate information to IMO.	1/2. ISSC issued by flag-state government or RSO (e.g. classification society) for ships and shipping companies. Maintenance of certification is up to 5 years for ISSC. Interim ISSC is valid for 6 months. 3/4. Validity period of PFSP/PFSA compliance statements is to be decided locally by the contracting government.
Selected non-ISPS US Initiatives	**CSI**	Secure container trading systems/ lanes between major foreign ports and the USA.	Bilateral agreements between the US customs and foreign countries or port authorities	Foreign ports (US ports under reciprocity) with substantial and direct waterborne container traffic to the USA.	Establish security procedures to identify high-risk container cargo. Work with deployed CBP officers to target containers at risk. Provide NII equipment for container screening & inspection.	Validation process and risk assessment mechanism (updated regularly).
	24-h Rule	Identify / target high-risk US-bound cargo (including cargo being transhipped or remaining on-board the ships) 24 hours in advance of loading on board vessels	Compulsory regulation, not applicable to bulk cargo	Ocean carriers or their agents, Licensed or registered NVOCCs.	Electronic reporting to CBP, via AMS and 24 hours prior to loading at foreign ports, of complete manifest information (14 data elements) for all cargo on board ships calling in US ports, even if the cargo is being transhipped or continues on the ship to a third country after it departs the US.	CBP identification and/or clearance of transmitted information, Non- issuance or delay of permits to unload suspected cargo, or cargo with incomplete or late advance manifest, Penalties may also apply.

Legend:

AIS: Automated Identification System. AMS: Automated Manifest System, ACS: Automated Commercial System, ATS: Automated Targeting System, CBP: US Customs & Border Protection, CSO: Company Security Officer, CSR: Continuous Synopsis Record, DHS: Department of Homeland Security, FAK: Freight-all-Kind, ISSC: International Ship Security Certificate, FF: Freight Forwarders, GT: Gross Tonnage, MODUs: mobile offshore drilling units, NNI: Non-Intrusive inspectional (equipment), NVOCCs: Non-Vessel Operating Common Carriers, RSO: Recognised Security Organisation, PFSA: Port Facility Security Assessment, PFSO: Port Facility Security Officer, PFSP: Port Facility Security Plan, SC: Supply Chain, SCO: Ship Security Officer, SIS: Ship Identification Number, SSA: Ship Security Assessment, SSAS: Ship Security Alert System, SSP: Ship Security Plan, STC: Said to Contain

II.1.2 Container Security Initiative (CSI)

The Container Security Initiative (CSI) introduces a security regime to ensure that all containers that pose a potential risk for terrorism are identified and inspected at foreign ports before they are placed on vessels destined for the United States of America (USA). The objective is to target and pre-screen containers exported or transhipped through foreign ports that have significant export trade to the USA. Through CSI, bilateral agreements are signed between foreign customs and the US Customs and Border Protection (CBP) agency to allow the latter station its teams of customs officers in foreign ports. CBP officers work with host customs administrations to establish security criteria and share information for identifying high-risk containers. CSI is a reciprocal programme where participant countries can also send their customs officers to major US ports, although only Japan and Canada currently have their customs personnel stationed in US ports. As of December 2007, there were 58 CSI active (operational) participating foreign ports. These represent around 90% of US total maritime containerised cargo imports (see Table 2). Appendix 2 lists the CBP's minimum standards for the US CSI port expansion.

Table 2: Active participating ports in the US CSI as of 30/03/2007 (Source: CBP, 2007)

Continent	Ports and Terminals
Americas and the Caribbean	Montreal, Vancouver, Halifax (Canada); Santos (Brazil); Buenos Aires (Argentina); Puerto Cortes (Honduras); Caucedo (Dominican Republic); Kingston (Jamaica); Freeport (The Bahamas); Balboa; Colón, Manzanillo (Panama); Cartagena (Columbia)
Europe	Rotterdam (The Netherlands); Bremerhaven, Hamburg (Germany); Antwerp, Zeebrugge (Belgium); Le Havre, Marseille (France); Gothenburg (Sweden); La Spezia, Genoa, Naples, Gioia Tauro, Livorno (Italy); Felixstowe, Liverpool, Thames-port, Tilbury, Southampton (UK); Piraeus (Greece), Algeciras, Barcelona, Valencia (Spain); Lisbon (Portugal)
Asia and the East	Singapore (Singapore); Hong Kong, Shenzhen, Shanghai (China); Yokohama, Tokyo, Nagoya, Kobe (Japan); Pusan (South Korea); Port Klang, Tanjung Pelepas, (Malaysia); Laem Chabang (Thailand); Dubai (UAE); Kaohsiung, Keelung (Taiwan); Colombo (Sri Lanka); Salalah (Oman); Port Qasim (Pakistan); Haifa, Ashdod (Israel)
Africa	Durban (South Africa); Alexandria (Egypt)

In addition to CSI, the Secure Freight Initiative (SFI) is a key provision of the Safe Port Act. It builds on its current partnership between the CSI and the Mega-ports Initiative to provide an extra layer of port and cargo security. The new requirement specifies that all containers destined to the US to be 100% scanned by July 2012 using non-intrusive imaging (NII) equipment and radiation detection equipment. A pilot programme of SFI was recently deployed on a 100% scanning basis in three container ports namely port Southampton in the UK, Qasim in Pakistan, and Puerto Cortes in Honduras. Three other container-port facilities (Salalah in Oman, Modern terminals in Hong Kong, and Gamman terminals in Busan- South Korea) have been added on a limited capacity. Brani terminal in Singapore was initially part of this pilot programme but it was recently decided not to proceed with the SFI trial in this port.

II.1.3 24-hour Advance Vessel Manifest Rule

The 24-hour Advance Vessel Manifest Rule (hereafter abbreviated to the 24-hour rule) allows the US Customs' officers to analyze the containers' content information and identify potential terrorist threats before those containers are loaded at a foreign port. The objective of the 24-hour rule is to identify and target high-risk US-bound cargo, including cargo being transhipped or remaining on-board the ships, 24 hours in advance of loading on board vessels that are bound to the USA. The 24-hour rule is part of the Advanced Manifest Rule (AMR)/Advance Cargo Information (ACI) initiative, instituted by CBP in conjunction with the Trade Act of 2002, requiring detailed cargo data for all modes to be submitted to the US CBP prior to arrival at a US port or border-crossing.

Table 3: Data required for electronic reporting under the US 24-hour rule (CBP, 2007)

1.	Foreign port of departure
2.	Standard carrier alpha code (SCAC)
3.	Voyage number
4.	Date of scheduled arrival in the first US port
5.	Number and quantity of packages (based on bill of lading descriptions)
6.	First port of receipt by the carrier
7.	Detailed cargo description: shipper's description or the 6-digit harmonized tariff schedule number
8.	Shipper's name and address Alternatively ID numbers as assigned by US customs
9.	Consignee's name and address Alternatively ID numbers as assigned by US customs
10.	Vessel flag, name and number
11.	Names of foreign ports visited beyond the port named in point 6
12.	International hazardous goods code if applicable to cargo
13.	Container number
14.	Numbers on all seals affixed to the container

Under the 24-hour rule, detailed information on container-cargo on board ships calling at, or transiting via, US ports must be submitted electronically by ocean carriers, non-vessel operating common carriers (NVOCCs), and other ship agents to the US customs' authorities; at least 24 hours prior to loading at a foreign port. An exception is made for empty containers whereby notification prior to arrival at a US port can be extended up to 48 hours. In total, 14 data elements must be specified on the electronic manifest with detailed information about the ship, her cargo, and her previous and next ports of call (see table 3). In particular, data information should be sent electronically and the use of such vague cargo descriptions as “Freight-All-Kinds” (FAK), "Said-To-Contain" (STC), “Foodstuffs” or "General Merchandise," is no longer tolerated. An example of the process undertaken in support of regulatory compliance with the 24-hour rule is provided in Figure 1.

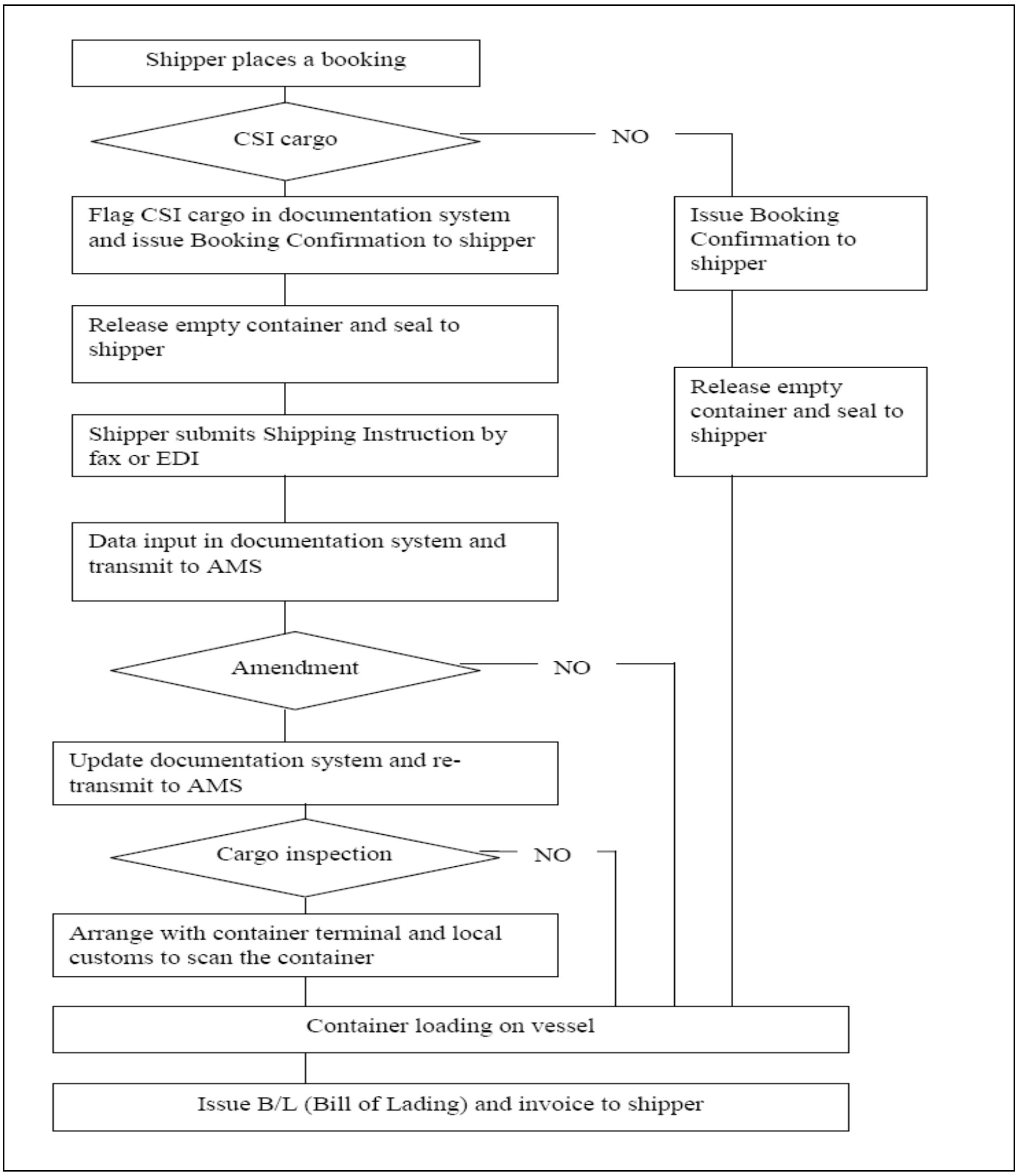


Figure 1: A case decision support system to implement the 24-hour rule (Source: Bichou et al., 2007)

The 24-hour rule was enforced on the 4th of May 2003 and was fully implemented in 99% of the ports with direct export traffic to the USA in January 2005 (CBP, 2005). The 24-hour rule has since then expanded beyond the USA. For instance, Canada and Mexico have established similar US style 24-hour rule requirements while the EU has incorporated a 24-hour notice before arrival (as opposed to the US 24-hour before cargo loading) in its 2005 EC Regulation on enhancing ship and port facility security. However, because of the difficulty of obtaining uniformity across EU member countries, the implementation of the EU 24-hour rule has been postponed until 2011, having originally targeted a June 2009 start date.

II.2 Literature Review of Cost and Operational Impact of Security

In view of the new security regime, ports have had to implement security measures in order to comply with security initiatives and the route to compliance frequently requires investment in security equipment and procedures and the recruitment and training of security personnel. In addition to the cost of compliance, port operators and users alike may incur extra costs stemming from the implementation of new procedural security such as the provisions for data filing, detailed reporting, additional inspections, and other operational requirements. Therefore, the literature on cost impacts of port security may be classified into two main categories: the literature on compliance costs and the literature on procedural and operational costs.

II.2.1 Compliance Cost of Port Security

II.2.1.1 Ex-ante assessment

Even before the entry into force of the new security regulations, several studies have attempted to assess the compliance cost of port security, particularly for formal security regulations such as the ISPS code. *Ex-ante* assessments of the compliance cost of maritime and port security are largely based on data and methods from national regulatory risk assessment models such as the US National Risk Assessment Tool (N-RAT) and the UK Risk Assessment Exercise (RAE). These are ad-hoc programmes undertaken by governmental agencies in order to assess the costs and benefits of new regulatory initiatives. For instance, the US Coast Guard (USCG) has estimated the ISPS compliance cost for US ports to reach USD $1.1 billion for the first year and USD $656 million each year up to 2012. Based on these estimates, the Organisation for Economic Co-operation and Development (OECD, 2003) has produced a comprehensive report on the global economic impacts of maritime security measures. A summary of aggregate *ex-ante* estimates for ISPS cost-compliance is provided in Table 4. Regarding non-ISPS initiatives, a study funded by the European Commission (EC) suggests that voluntary security programmes, based on a participation level of 30% of European Union (EU) operators, would cost port and terminal operators in the EU around €5 Million just for audit expenses (DNV Consulting, 2005).

Table 4: Summary of ISPS ex-ante cost estimates as computed by various regulatory risk assessment impacts (Source: Bichou, 2005b)

Source of estimates	Cost items	Scope	Initial Costs*	Annual Costs*	Total cost* over 10 years (2003-13) @ 7% DFC
USCG	Total ISPS US ports	226 port authorities, of which 5000 facilities are computed (from Fairplay) (ISPS Parts A & B MARSEC Level 1)	1125	656	5399
	Total ISPS US-SOLAS and non-SOLAS vessels subject to the regulation	3500 US-flag vessels, as well as domestic and foreign non-SOLAS vessels (i.e. operating in US waters) (ISPS Parts A & B MARSEC Level 1)	218	176	1368
	Automated Identification System		30	1	50
	Maritime Area (contracting government)	47 COTP US zones	120 (+106 for 2004)	46	477
	OSC facility (offshore installations)	40 U.S OCS Facilities under US jurisdiction	3	5	37
	U.S cost for ISPS implementation	**(ISPS parts A and B)**	**115**	**884**	**7331**
	Cost of elevating MARSEC level from 1 to 2	Based on a twice MARSEC level 2 per annum, each for 21 days	16 per day		
UK	Total ISPS UK port facilities	430 facilities (ISPS Part A MARSEC Level 1)	26	2.5	
	Total ISPS UK-flagged ships and company related costs	620 UK-flag vessels (ISPS Parts A, MARSEC Level 1) (Calculations based on an exchange rate of UK= £1.6 USD	7.4	5.2	
OECD	AIS	Based on 43,291 international commercial fleet of more than 1,000 GT (Passenger and cruise vessels not included), MARESC Level 1, ISPS Part A only	649.3	Undetermined	
	Other vessel measures		115.11	14.6	
	Ship operating companies		1163.89	715.4	
	Total ships & shipping companies		**1279**	**730**	
	PFSA, PFSA, PFSP	2180 port authorities worldwide of which 6500 facilities are computed (from Fairplay) (ISPSA only MARSEC Level 1)	390.8	336.6	
	Total ISPS ports		Undetermined	Undetermined	
	Global cost for ISPS implementation	(MARESC level 1, ISPS part A only)	Undetermined	Undetermined	
Australian Government	Total costs for Australia	70 Australian flag ships, 70 ports, and 300 port facilities	240 AUD	74 AUD	

*: All cost figures are expressed in 2003 USD $ million, except for Australia where costs are expressed in 2002 AUD $ million

Legend

AIS: Automated Information System, AUD: Australian Dollar, COTP: Captain of the Port, DFC: Discount Factor, GT: Gross tons, MARSEC: Maritime Security Level, OSC: Outer Continental Shelf, PFSA: Port Facility Security Assessment, PFSO: Port Facility Security Officer, PFSP: Port Facility Security Plan, SOLAS: The IMO International Convention on the Safety of Life at Sea

II.2.1.2 Ex-post assessment

Following the entry into force and implementation of the new port security measures, a number of *ex-post* assessments of the cost of compliance have been undertaken. In so doing, researchers have used a variety of approaches ranging from survey inquiries and economic impact studies to financial appraisal and insurance risk modelling:

A. Among the plethora of survey inquiries on the subject, it is worth mentioning the United Nations Conference on Trade and Development (UNCTAD) global survey on initial and annual costs of ISPS compliance. The survey results suggest that for each ton or TEU handled, the average cost for ISPS compliance would amount USD $0.08 and $3.6 respectively, of which $0.03 and $2 in terms for annual (recurrent) costs, respectively (UNCTAD, 2007). However, a recent survey by the World Bank found that the average ISPS compliance costs amount to $0.22 per ton and $4.95 per TEU handled (Kruk and Donner, 2008). Such contradictory findings may be explained by the variety of methods used to calculate the ISPS costs (unit versus average, initial versus running, etc.), but can also stem from the different interpretations of the Code across world ports and terminals (Bichou, 2004; Bosk, 2006). While the ISPS Code provides general provisions on security requirements in ports, it does not prescribe detailed and uniform instructions on how to comply with them, for instance in terms of the exact instructions on the type and height of fences required for each port or terminal facility.

Another problem with survey inquiries occurs when the findings of a case-specific survey are generalised to all stakeholders and/or security programmes. For instance, Thibault et al. (2006) found that small ocean carriers generally enjoy lesser initial compliance costs but incur higher recurrent costs because of the difficulty to spread fixed costs across a small business base. However, Brooks and Button (2006) found that the costs of enhanced maritime and supply chain security only accounts for 1% or less of shippers' total costs. Even when survey inquiries investigate a single security programme, their results may show inconsistent cost figures either over time or between participants. For example, when first enrolments in the C-TPAT programme began in 2004, the industry widely quoted Hasbo's figures of USD $200,000 initial costs and USD $113,000 annual operating costs as being the benchmark for C-TPAT average compliance cost for a multinational firm (Googley, 2004). However, in a recent survey of 1756 C-TAPAT certified participants, Diop et al. (2007) report that C-TPAT implementation and operating costs only amount to USD $38,471 and $69,000 USD, respectively. Furthermore, according to the same survey 33% of respondents said that the benefits of C-TPAT participation outweighed the costs while an additional 25% found that the CTPAT costs and benefits were about the same. Other surveys on the subject also provide contradictory results -see Lloyd's List (2003) and BDP (2004).

B. As with survey inquiries, economic impact studies on the cost of port and maritime security also depict inconsistent results. For example, Damas (2001) estimated that the new security measures introduced in the awake of the 9/11 terrorist attacks would cost the US economy as much as USD $151 billion annually, of which USD $65 billion just for logistical changes to supply chains. However, a study undertaken by the International Monetary Fund in the same year has estimated the increase to business costs due to higher security costs to amount around USD $1.6 billion per year, with an extra financing burden of carrying 10% higher inventories at $7.5 billion per year (IMF, 2001). Such discrepancies are also noticeable in studies seeking to quantify the economic and supply chain cost of port security incidents and other similar disruptions such as industrial actions and natural disasters. For instance, Martin Associates (2001) estimated that the cost of US West-Coast port lockout in 2001 to the US economy to reach USD $1.94 billion a day, based on a 10-day shutdown of port facilities. However, by the time the labour dispute was resolved, Anderson (2002) priced the total economic cost at around USD $1.7 billion, based on a longer shutdown period of 12 days.

Other researchers have looked at the knock-on effect of US ports' closure on other dependent economies and foreign ports. For example, Saywell and Borsuk (2002) estimated the loss from this disruption be as high as 1.1% of the combined GDP of Hong Kong, Singapore and Malaysia. In a similar vein, Booz Allen Hamilton (2002) run a port security war game simulation to assess the impacts of a terrorist incident in a US port followed by a nation-wide port and border-crossing closure for 8 days (see Figure 2). With an estimated cost of USD $50 billion on the US economy, their results show inconsistent results with those of similar studies. Pritchard (2002) and Zuckerman (2002) suggest even lower costs than those reported by Booz Allen.

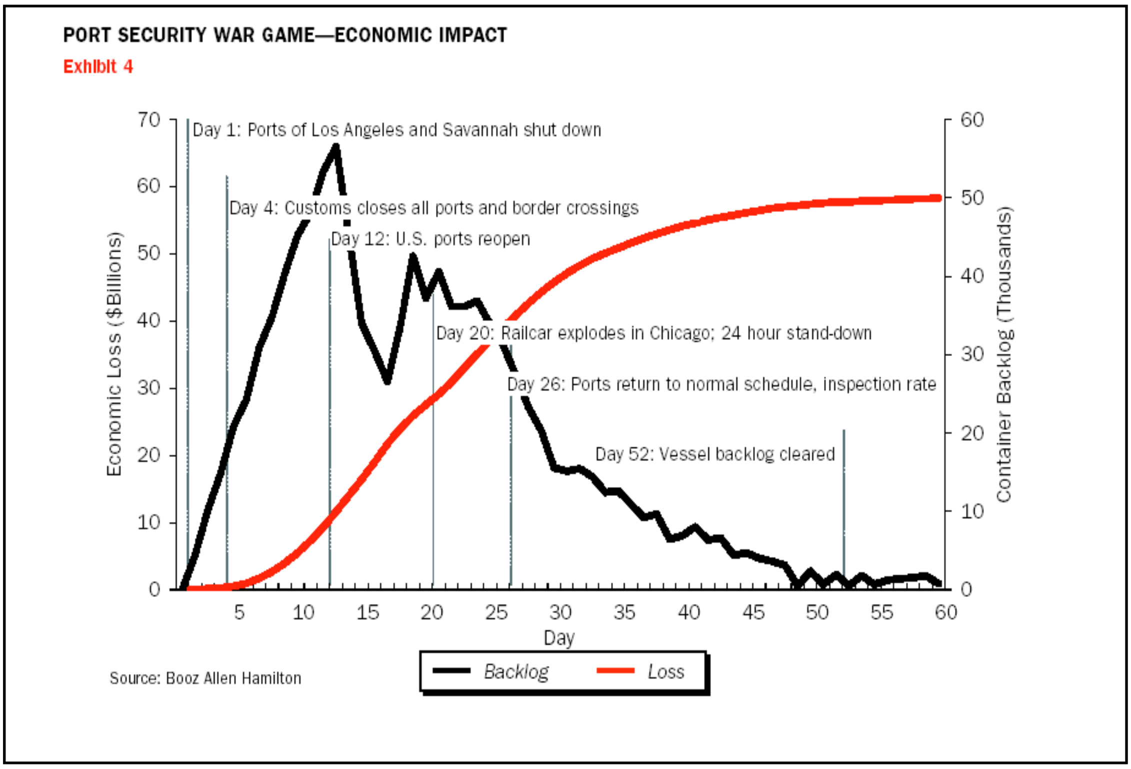


Figure 2: The Booz Allen Hamilton's port security war game simulation (BAH, 2002)

C. Cost assessment of regulatory initiatives may also be undertaken using financial models and insurance risk modelling techniques. For the former, ex-post costs are typically assessed by analysing market response to risk-return performance, for instance by translating security provisions into port investments and analysing their ex-post impact using models and techniques of financial appraisal and risk analysis (e.g., pay-back, NPV, IRR). For the latter, researchers typically use premium-price analysis whereby security costs and benefits are added to or subtracted from the price of port and shipping services; referring inter-alia to the variations in freight rates and insurance premiums. For instance, Richardson (2004) reports that insurance premiums trebled for ships calling at Yemeni ports after the 2002 terrorist attack on the oil tanker *Limburg* off the Yemeni coast, which has also forced many ships to cut Yemeni ports from their schedules or divert to ports in neighbouring countries.

D. Trade facilitation studies can also been used to analyse the ex-post impacts of security such as by measuring the time factor (delay or speed-up) that emanates from implementing new security measures. Nevertheless, despite the rich literature on the interface between trade facilitation and economic development (Hummels, 2001; Wilson et al., 2003), few studies have investigated the role of the new security regime either as a barrier or an incentive to trade (Raven, 2001). For instance, the OECD (2002) reports that the post 9/11 trade security measures would have cost the world trade between 1% and 3% less of North American trade flows, which corresponds to a cost of USD $60 billion and USD $180 billion in 2001 figures, respectively. Another estimate places the global costs for trade of post 9/11 tighter security at about USD $75 billion per year (Walkenhorst and Dihel, 2002).

E. Another popular approach for analysing the cost-benefit of a regulatory change is to contrast transfer costs against efficiency costs. The former refer to the costs incurred and recovered by market players through transferring them to final customers (e.g. from ports to ocean carriers and from ocean carriers to shippers), while the latter represent net losses and benefits in consumer and producer surpluses. Compiled cost figures from industry and press reports suggest an average security charge of USD $6 per shipped container for the ISPS Code, and up to USD $40 per bill of lading for the 24-hour rule. Note that this approach is not without bias, including the common practice of cost spin-off and exponential computations of security expenses. In a highly disintegrated and fragmented maritime and logistics industry, there is no guarantee that additional security charges accurately reflect the true incremental costs incurred by each operator, including ports (Bichou, 2004). Standard practices in the industry suggest that market players try to generate extra profits by transferring costs to each other (Evers and Johnson, 2000; Fung et. al, 2003), and there is already evidence of similar practices in the recovering of security costs by the port industry (see Table 5).

Table 5: Sample of container ports' security charges
(Source: Compiled by the Author from various trade journals)

Port or terminal			Security fee USD* ($)/TEU
Europe	Belgian ports		10.98
	France and Denmark		6.1
	Dutch ports		10.37
	Italian ports		9.76
	Latvian ports		7.32
	Norwegian ports		2.44
	Spanish ports		6.1
	Irish ports		8.54
	Swedish ports (Gothenburg)		2.6
	UK ports	Felixstowe, Harwich and Thames port	19 for import and 10 for export
		Tilbury	12.7
USA	Charleston, Houston and Miami		5
	Gulf seaports marine terminal conference		2
Others	Shenzhen (China)		6.25
	Hong Kong (China)		6.41
	Mexico		10
	Australian ports (those operated by DP Worlds)		3.8

*: Figures are expressed in 2006 USD $.

In evaluating the costs and benefits for of regulatory decisions, Cost Benefit Analysis (CBA) is regarded as a fair and objective method of making assessments. While the costs of security compliance are possible to quantify either by direct surveys or through aggregate estimations, its benefits are very difficult to measure directly. Instead, researchers assess the benefits of regulations by looking at the cost of non-compliance or failure, usually through the assessment of economic impacts of terrorist attacks and other similar events such as industrial actions and safety accidents. Cost-Efficiency Analysis (CEA) is an alternative method to CBA, and is usually applied when the output is fixed and the economic benefits cannot be expressed in monetary terms. However, both CBA and CEA make little consideration to cost sharing and distribution of benefits. To correct this, Stakeholder Analysis (SHA) was introduced in the early 1980s with a view to identify the key players (stakeholders) of a project or a regulation and assess their interests and power differentials.

CBA, CEA and SHA approaches have been extensively used in the field of maritime safety but their empirical applications in the context of maritime and port security are difficult to undertake. Bichou and Evans (2007) provide a critical review of economic valuation methods and their applications in port, maritime and supply chain security. In particular, they pointed out the difficulty to assess the cost of preventing principal losses in security incidents, much of which stems from economic losses and human casualties.

Nevertheless, while economic losses can be measurable, the value of human losses is difficult to observe in market transactions, especially in shipping and ports where the value of human life differs between countries, trades, and routes (cruise shipping, container shipping, Trans-Atlantic routes, etc.). Traditional safety methods such as the 'Willingness to Pay' (WTP) approach are simply not suitable in a security context. A good discussion on the limitations of survey and economic costing approaches to port security is provided by Bichou (2004).

II.2.2 Procedural and Operational Impacts

The increasing interest into procedural and operational impacts of security has been fed largely by the continuing debate between those who anticipate productivity losses because of operational redundancies and those who advocate higher efficiency due to better procedural arrangements:

- On the one hand, many argue that procedural requirements of the new security regime act against operational and logistical efficiency. Proponents of this view list a number of potential inefficiencies ranging from direct operational redundancies, such as additional inspections and lengthy procedures, to a series of derived supply chain disruptions such as in terms of longer lead times, higher inventory levels, and less reliable demand and supply scenarios. The 24-hour rule provides a typical example of procedural requirements with potential negative impacts on operational and logistics efficiencies. For example, the requirements of advanced cargo reporting under the 24-hour would result in ocean carriers declining any late shipment bookings but also bearing, under customary arrangements, the cost of at least one extra day of container idle time at ports. The latter may be extended to three or more days for carriers and forwarders that are not electronically hooked into the US CBP Automated Manifest System (AMS).

Shippers and receivers alike will then have to adjust their production, distribution and inventory management processes accordingly. Ports will also bear commercial and cost impacts of the 24-hour rule, including potential congestion problems and possible delays in both ships' departures and arrivals. Additional costs to shippers may also stem from the extra time and resources needed for carriers to compile and record detailed data information. In fact, shipping lines have already started transferring the cost of the 24-hour rule data filing and processing requirements to shippers and cargo owners who now have to pay an extra USD $40 levying charge per bill of lading (Lloyd's List, 2003), plus any additional indirect costs from advanced cut-off times and changes in production and distribution processes. Ocean carriers and NVOCCs may also be faced with a violation fine of USD $5000 for the first time and USD $10000 thereafter in case they submit missing or inaccurate data to CBP. A detailed review of the 24-hour rule requirements, costs and benefits is provided by Bichou et al. (2007a).

- On the other hand, proponents of the new security measures argue that their implementation is not only necessary but can also be commercially rewarding. The main argument put forward is that measures such as the CSI, the 24-hour rule and the C-TPAT fundamentally shift the focus from inspection to prevention, the benefit of which offsets and ultimately outweighs initial and recurrent costs of implementation. Detailed data recording, electronic reporting and other procedural requirements brought about by the new security regulations would allow for pre-screening and deliberate targeting of 'suspected' containers, which is proven as more cost-effective and less time-consuming than the traditional approach of random physical inspections. In addition to the benefits of access certification and fast-lane treatment, compliant participants would also benefit from reduced insurance costs, penalties and risk exposure. Other advantages that go beyond the intended security benefits include the protection of legitimate commerce, the exposure of revenue evasion, reduced risk of cargo theft and pilferage, real-time sharing of shipping and port intelligence, advanced cargo processing procedures, and improved lead-time predictability and supply chain visibility.

Nevertheless, both arguments are rarely supported by empirical analysis and much of the research on procedural security impacts uses either modelling techniques or simulation to predict the operational costs and benefits of the new security regulations. Lee and Whang (2005) have developed a mathematical model to assess the benefits of reduced lead times and inspection levels in the context of SST. White (2002) also used mathematical modelling and developed a min-depth heuristic model to minimise the number of container moves in the case of CSI. Using simulation, Babione et al. (2003) examined the impacts of selected security initiatives on import and export container traffic of the port of Seattle. Rabadi et al. (2007) used a discrete event simulation model to investigate the impact of security incidents on the recovery cycle for the container terminal of Virginia. Other simulators have been specifically designed to run pre-defined disruption scenarios and predict their impacts on port efficiency. For example, the US national infrastructure simulation and analysis centre (NISAC) has developed two port simulators, an operations simulator to evaluate the short-term operational impacts and an economic simulator to assess long-term economic impacts (NISAC, 2005).

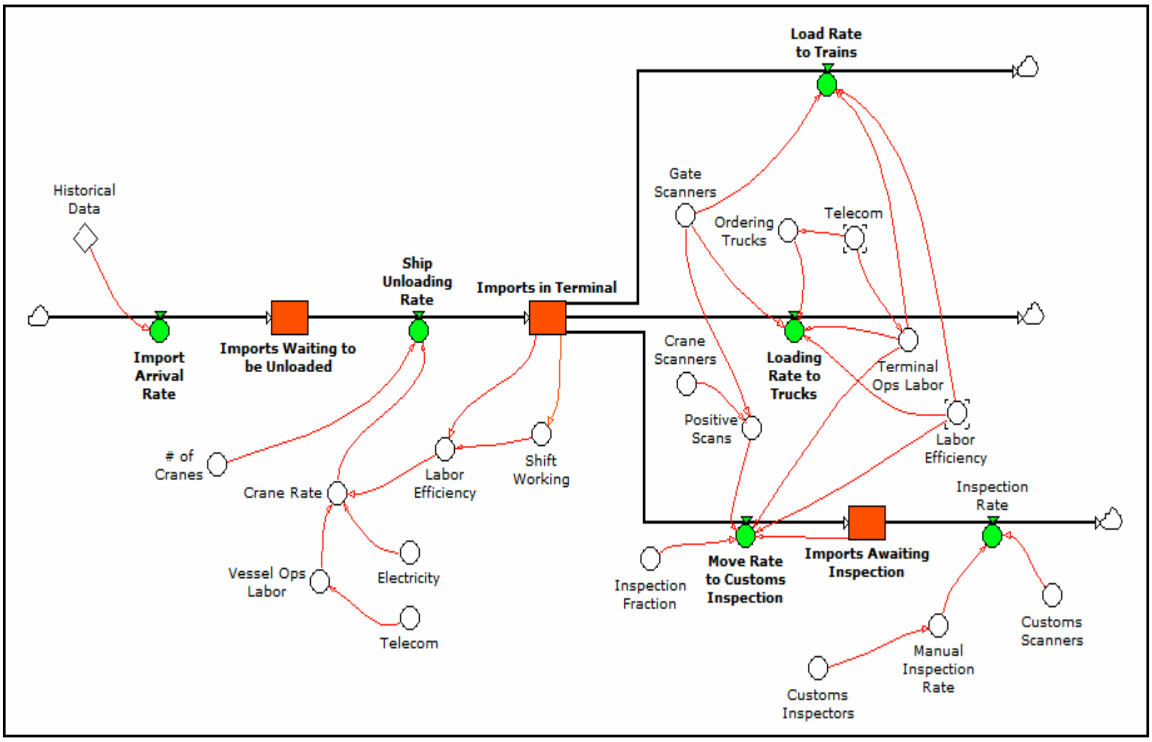


Figure 3: Illustration of NISAC port operations simulator diagram (Source: NISAC, 2005)

II.3 Chapter Conclusion: Security and Cost Impact

From the above review of the literature on cost and operational impacts of security, it is clear that there is a gap in assessing the ex-post impacts of security measures on port operations, especially in terms of efficiency gains and losses:

- On the one hand, few attempts have been made to analyse the *ex-post* operational and procedural impacts of port security. Published research on the subject only uses simulation and/or mathematical modelling. As far as we are aware and at the time of writing this thesis, no previous work has attempted to assess empirically the impact of the procedural arrangements stemming from the new security regime on the operational efficiency and benchmarking of global container port and terminal operations.

- On the other hand, the methodological approaches and techniques used for assessment have generally fallen short in capturing and assessing the ex-post operational impacts, particularly when the costs and benefits of various security initiatives are aggregated across various port users and stakeholders. In particular, and as will be discussed further in the next Chapter, neither economic impact analysis nor simulation-based modelling are appropriate for conducting an empirical assessment of the impacts of procedural security on container-port efficiency and benchmarking.

CHAPTER III: LITERATURE REVIEW ON PORT EFFICIENCY AND PERFORMANCE BENCHMARKING

The bulk of the literature on performance measurement and benchmarking in ports can be grouped into four broad categories: economic-impact studies, performance metrics and productivity index methods, frontier methods, and process approaches. Table 6 provides a brief outline of the main analytical techniques used in each category.

III.1 Economic Impact Studies

Port impact studies have emerged as an area of applied research that can bridge port and trade with the wider economic and social impacts. The literature on the subject may be divided into two lines of research: port economic impact and port trade efficiency.

III.1.1 Port Economic Impact

Port economic impact may be considered as a branch of economic geography, extended to the fields of social development, urban planning and environmental economics due to the increasing importance of the port-city interface. Port impacts on the economy are measured to assess the economic and social impacts (direct, indirect and induced) of ports on their respective hinterlands or forelands. In this approach, ports are seen as economic catalysts for the regions they serve whereby the aggregation of port services and activities generates socio-economic benefits. Here, the performance of a port is depicted in terms of its ability to generate maximum output and economic wealth. Relevant conceptual work in the field can be found in the AIPV (International Association of Ports and Cities) references and in the related academic literature (See for instance De Langen, 2002; Verbeke and Debisschop, 1996; Rodrigues et al., 1997).

Much of the applied research on the subject is based on input-output (I-O) analysis as derived from the early work of Leontief (1936). I-O models are sets of linear equations where the outputs of various branches in the economy are calculated based on an empirical estimation of inter-sector transactions, assuming that input demand is a fixed proportion of total output (Miller and Blair, 1985). Most available I-O models have been developed to assess the aggregate impacts of the maritime industry as a whole (Kwak et al., 2005; Van Der Linden, 2001) rather than those of the port sector per se. I-O models for ports typically follow the usual steps of defining the structure of the output matrix, collecting information from public data and industry surveys, and calculating the impacts through the aggregation of direct, indirect and induced contributions.

Table 6: Main benchmarking techniques (Source: Author)

Classification of literature	**Technique/ Methodology**	**Disadvantages**
Economic Impact Studies - Port Economic Impact - Port Trade Efficiency	I-O tables, mass-calculation, CGE models, etc. Cost/production function, gravity models	Analyse ports either as regions or as trade /transport components rather than business or operating units.
Index Methods - Financial ratios - Snapshot indicators - SFP - PFP/MFP - TFP	Financial ratios: NPV, IRR, Gearing ratio, etc. Snapshot indicators: Throughput in TEU, total turn-around time, service time, cargo dwell time, etc. SFP: Single output/single input PFP: Subset of outputs/subset of inputs TFP: - The Törnqvist & Fisher (superlative) indexes -The Malmquist index: Does not require functional form, and can be decomposed into different sources of efficiency	Financial ratios: Little correlation with the efficient use of resources, focus on short-term profitability, dissimilarity between various port costing and accounting systems, problems with price regulation and access to private equity Snapshot indicators: Provide an activity measure rather than a performance measure. SFP/PFP: Provide average productivity but does not capture overall productivity. Non-statistical approach TFP: Requires estimation of cost, production or distance function (otherwise unable to separate scale effects from efficiency differences). Non-statistical approach
Frontier analysis - Deterministic versus stochastic - Parametric versus non-parametric	- COLS: deterministic /parametric - DEA/FDH : deterministic /non-parametric - SFA: stochastic/parametric	COLS: Requires functional form and dominated by the position of the frontier firm SFA: Requires functional form, specification of exact error terms and probability of their distribution DEA: Sensitivity to choice of weights attached to input and output variables. No allowance for stochastic factors and measurement errors
Process approaches - Bottom-up approaches - Benchmarking toolkits - Expert judgement - Perception surveys	- Engineering economic analysis (EEA) - Enterprise modelling (ERP) - Process benchmarking (BSC, TQM) - Business process modelling (BPR) - Action research, focus groups, etc. - Statistical techniques for survey inquiry and hypothesis testing	EEA: Data intensive, Relies on expert judgement and knowledge of the system BPR/ERP: Expensive to build and maintain Process benchmarking: Process approach, does not capture operational efficiency component & trends

The direct impacts are usually measured using industry and employers' survey, while indirect and induced impacts are estimated from direct impacts using a multiplier index derived from the I-O matrix or from an economic census. However, since different cargoes have different propensities to generate economic and social wealth, different multipliers are used for each type of cargo or activity. For instance, Leonard (1989) calculated the value added per ton in French ports per category of ship and cargo operation while ISEMAR (1999) estimated multiplier indices by type of cargo to range between 4 and5 for dry bulk and 12 and 25 for general cargo. Direct and multiplier effects may be reported in terms of job creation as well. For instance, Martin Associates (2001) estimate the port-dependent impacts by multiplying the value of cargo passing through the port by an estimate of the jobs per dollar of goods produced for export or import as an intermediary input. In the case of inter-dependent economies, the analysis may be extended with the spillovers to other countries when inter-country I-O tables exist (Van der Linden, 1998; the EU Impact Study, 1997).

The US MARAD 'Port-Kit' is probably the most referenced and regularly updated I-O port model. Since its first publication in the mid-1970s, it has become the standard model for assessing economic impacts of US ports. The latest Port-Kit version was released in 2000 in the form of PC-based software comprising a 30-sector table. Hamilton et al. (2000) developed similar software versions for US inland ports. Outside the USA, I-O models for ports have been used to assess the impacts of existing facilities (Villaverde-Castro and Coto-Millan, 1997; Moloney and Sjostrom, 2000; Lagneaux, 2004) or to justify future port investments (Le Havre Port, 2000).

When I-O tables are not available, the computation of economic impacts is based on mass calculations as usually reported in ports' annual reports. Although mass-calculation is not a very refined method, it is more convenient to use when it is too expensive or too long to undertake a direct-flow survey. The method consists of calculating the overall value added by the firms geographically located in the port or its hinterland, and sometimes incorporates the multiplier factor. In general, the more the distribution of output is diversified, the higher the multiplier factor. The latter is broadly estimated to fall between 1 and 1.5 according to the structure of the economy. Appendix IV outlines conventional methodologies used to assess port impact on the economy.

An alternative method of assessing port impact on the economy relies on the estimation of computable general equilibrium (CGE) models. CGE models typically simulate a multitude of different goods' markets using a bottom-up approach that combines the abstract general equilibrium structure as formalised by Arrow and Debreu (1954) with real economic data. The objective is to analyse the relationship between an assigned or given size 'shock' to productivity growth on the GDP of a region, country or group of countries. CGE models have gained more popularity in the last decade or so, including for cross-sectoral applications used for quantifying the impacts of port efficiency on trade facilitation (APEC, 1999). A good reference to CGE applications in trade reform is provided by Devarajan and Rodrik (1991). In a unique application to ports, Dio et al.

(2001) applied a CGE model to analyse the impacts of port efficiency on the Japanese economy. Their results show that improved port productivity has a substantial impact on the shipping industry, but only a minor contribution into the country's GDP. CGE modelling is a separate branch of theoretical econometrics, and deserves a thorough analysis beyond the scope of this thesis. What one needs to know is that CGE data and model equations are typically calibrated to national accounts and I-O table references.

Port impact studies have been criticised because of their inability to deal with long-term changes in macro-economic, industrial and production conditions. Heikkila et al. (1992) and Hall (2004b) criticised the long-run utility of the port I-O model because it fails to capture changes in freight systems, cargo volumes, and geographic shifts in the economic activity. Bichou and Gray (2005b) listed a series of contemporary structural changes in the port industry and disputed the appropriateness of port impact studies for measuring and benchmarking port performance and efficiency.

III.1.2 Port Trade Efficiency

Port trade efficiency assesses port efficiency in relation to maritime, transport and/or trade costs. This part of the literature is rapidly establishing itself as a 'separate' branch due mainly to the recent emphasis on the role of ports in trade facilitation. Research on trade facilitation is however still at its infancy as both the definition of the subject and the approach to it have not stabilised yet.

Sanchez et al. (2003) used principal component analysis (PCA) to estimate the impacts of port efficiency on maritime transport costs of Latin American countries. Their PCA port index was composed of three factors namely time efficiency, productivity, and stay per vessel. These components were then included into a regression model in order to estimate a maritime transport cost function. The results suggest that time efficiency is the most statistically significant and that port productivity is a major determinant of a country's international trade competitiveness. De and Ghosh (2003) examined the causality between traffic and performance in 12 Indian ports using a PCA aggregation similar to that developed by Sanchez et al. (2003), with the difference that financial indicators are included in the weighting of the port performance index. Their results show that performance causes traffic and that financial productivity is the least important performance factor compared with asset and operational efficiency.

Gravity models analysing the relationship between geographical distance and trade flows have also been used to investigate the impacts of selected trade facilitation indicators including port efficiency. Clark et al. (2004) investigated the determinants of liner shipping costs in the USA for the period 1996-2000 and found that an improvement of port efficiency from the 25th to 75th percentiles reduced shipping costs by more than 12%. To measure port efficiency, the authors constructed proxies for port infrastructure coupled with an aggregate country-port index as derived from the Global Competitiveness Report. Using the same port index, Blonigen and Wilson (2006) examined the relationship between import charges, trade flows and port efficiency using data on US imports from 1991 through to 2003. The authors specify a simplified cost model for freight transportation, with foreign port efficiencies being estimated with fixed effects. This approach is contrasted with previous work investigating the relationship between port efficiency and maritime and trade flows using proxies such as infrastructure indicators (Micco and Perez, 2001) and GDP per capita (Fink et al., 2000), or relying on port measures drawn from perception surveys (Hoffmann, 2001; Wilson et al., 2003; Wilmsmeier et al., 2006).

Despite the wide literature on the subject, it is fair to claim that a consensus is yet to be reached on the methodological approach that best captures the relationship between port efficiency and trade facilitation. The same can be said for the appropriate indicators that best reflect port efficiency in the context of trade facilitation, e.g. single-port efficiency *versus* country-port efficiency, operational efficiency *versus* cross-border efficiency, throughput *versus* traffic figures.

III.2 Performance Metrics and Productivity Index Methods

Like most other operating and management systems, performance measurement in seaports and terminals starts with individual metrics at each functional or operational level. A performance measure or metric is presented numerically to quantify one or many attributes of an object, product, process, or any other relevant factor, and must allow for the comparison and evaluation vis-à-vis goals, benchmarks and/or historical figures. A performance metric generally falls within one or a combination of three main categories, namely input measures (e.g. time, cost, resource), output measures (e.g. production, throughput, profit), and ratio indices (productivity, efficiency, etc.). The latter are usually presented in the form of output-input ratios, with the typical objective of maximising the former and/or minimising the latter. Furthermore, each ratio may be broken down into two or more components depending on the approach and dimensions of performance. For instance, in the engineering literature efficiency may encompass both cost efficiency (low production) and capital efficiency (low investment) (Wheelwright, 1978), whereas in production economics efficiency is usually decomposed into technical, allocative and scale efficiencies.

III.2.1 Financial Performance Measures

Financial measures use metrics applied in costing and management accounting to measure a firm’s financial performance. In ports, financial metrics are used widely and published in annual financial reports of port authorities and port operators, with the annual survey of financial performance of US public ports being the most cited (MARAD, 2005). Financial indicators that are used frequently for ports include the operating ratio, the operating surplus, the return on investment (ROI), the return on assets (RAE), and the capital structure. Other financial indicators used in the context of port benchmarking include the capital and labour expenditures per handled ship or cargo unit, and the berth occupancy and handling revenues per cargo-ton (UNCTAD, 1976). However, the use of financial metrics may not be appropriate for performance benchmarking because financial performance may have little correlation with the efficient use of resources. For instance, higher profitability may be driven by cost or price inflation or other external conditions rather than by efficient productivity or utilisation. Kaplan (1984) argues that superior financial performance may be attributable to using novel financing or ownership arrangements rather than being the product of efficient operating and management systems. Vitale and Marvinac (1995) criticise financial ratios because they are incapable of assessing the contribution of intangible activities such as innovation. In recent years, logistics costing approaches using techniques such as activity-based costing (ABC) and direct-product profitability (DPP) have taken the lead over traditional financial performance.

In ports and terminals, a common feature across published financial reports is the absence of cost and price information, which makes port benchmarking based on financial performance very difficult to undertake. Moreover, the focus of financial measures on short-term profitability is inconsistent with the nature and objectives of long-term port investments. Dissimilarity between various costing and accounting systems is equally a major problem when one tries to compare ports from different countries or with different accounting procedures. Even within a single country, port financing and institutional structures (private, landlord, tool, etc.) are hardly comparable. Many other aspects influence port financial performance including price regulation, statutory freedom, and access to private equity.

III.2.2 Snapshot and Composite Measures

Much of the conventional port literature (UNCTAD, 1976; De Monie, 1987; Bendall and Stent, 1987; Talley, 1988; Frankel, 1993; Fourgeaud, 2000) only provides snapshot measures such as for a single port resource (labour, capital, etc.), facility (crane, berth, warehouse, etc.), and/or operation (handling, movement, storage, etc.). Annual container throughput in Twenty Foot Equivalent Units (TEUs) is a typical example of such measures and is widely, but quite misleadingly, used to rank world container ports and terminals. Non-quay activities may also feature as snapshot indicators, for instance cargo Dwell Time (DwT) or the time elapsed from when cargoes are unloaded from a ship until they leave through the gate, or vice versa (Bichou, 2005a). Sometimes, composite indicators are calculated to account for the relationship between two snapshot measures, for example berth throughput per square-meter capacity, the number of TEUs per hour versus ship's size (Drewry Shipping Consultants, 2005), and the net crane rate by liner shipping trade (Australian Productivity Commission, 2003).

The problem with snapshot and composite measures is that they only provide an activity measure rather than a performance measure. A performance index can be loosely defined as the ratio of the output quantity to the quantity of input. Depending on the definition and scope of the inputs and outputs selected and on the methodology used to calculate them, existing productivity measures for ports can be divided into two major categories: single and partial productivity indices versus multi-factor and total factor productivity indices.

II.2.3 Single and Partial Productivity Indexes

A single productivity index or single factor productivity (SFP) compares the volume measure of an output to a volume measure of an input use. The input is typically based on an input resource (e.g. labour, land, capital) while the output is based on a quantity index or a value added index. The latter is preferred in economic impact and productivity growth studies since it tends to be less sensitive to processes of substitution between factors of production. In the single output and single input technology, it is possible to calculate the average productivity (P) of a firm, or a port, by contrasting the quantities or values of its output and input. For ports A and B, a single productivity index can be calculated to measure either the productivity over time ($\prod_{A(t+1),\ A(t)}$; $\prod_{B(t+1),\ B(t)}$) for a single port or the productivity of one port relative to another's ($\prod_{A,B}$) in the same period.

$$
\begin{aligned}
& P(A) = \frac{OutputA}{InputA} = \frac{y_A}{x_A} \quad \text{and} \quad P(B) = \frac{OutputB}{InputB} = \frac{y_B}{x_B} \\
& \prod_{A(t+1),\ A(t)} = \frac{P(A_{t+1})}{P(A_t)} \qquad \prod_{B(t+1),\ B(t)} = \frac{P(B_{t+1})}{P(B_t)} \qquad (1) \\
& \prod_{A,B} = \frac{P(A)}{P(B)} = \frac{y_A / x_A}{y_B / x_B}
\end{aligned}
$$

The concept behind partial factor productivity (PFP) index is similar to that of SFP with the difference that the former seeks to compare a subset of outputs to a subset of inputs when multiple inputs and outputs are involved. The objective is to construct a performance index that compares one or several outputs to one or several inputs. Suppose the case of the two ports A and B, each using multiple inputs and multiple outputs. We want to compare a subset of two inputs (x_1, x_2) to produce a subset of two outputs (y_1, y_2) in each port. When market prices are available, we can then use input prices (ω_i) and output prices (ω_o) to calculate a total index of average productivity.

$$P(A) = \frac{Y_A}{X_A} = \frac{\omega_{o1} y_{1A} + \omega_{o2} y_{2A}}{\omega_{i1} x_{1A} + \omega_{i2} x_{2A}}$$

$$P(B) = \frac{Y_B}{X_B} = \frac{\omega_{o1} y_{1B} + \omega_{o2} y_{2B}}{\omega_{i1} x_{1B} + \omega_{i2} x_{2B}} \qquad (2)$$

$$\Pi_{A,B} = \frac{P(A)}{P(B)}$$

Single and partial productivity indices may be calculated either in monetary units or in physical units. For the former, productivity indices are expressed using data on market costs and prices, while for the latter quantities of production (tones, TEUs, moves, etc.) and resources (time, workers, etc.) are used instead. In ports, data on market prices are hardly available and physical attributes are used in preference to monetary values. Even though, the relationship between variations in the number and type of physical indicators has been difficult to establish in the port industry.

The literature in the field depicts a wide range of SFP and PFP indices but there is no consensus among professionals or researchers on the indicator(s) that best captures a port's physical performance, even for a single operation or facility. Moreover, SFP and PFP measures are difficult to combine or aggregate. The problem with single and partial indicators is that under the multiple-input and multiple-output port production, the concept of productivity measured by one or a subset of output-input volume ratios becomes no longer valid. Port studies often compare SFP and PFP indicators, such as equipment or labour productivity, in order to capture the change in productivity over time or between ports, but this fails to reflect total factor productivity because no account is taken for the quantities of other inputs and outputs.

III.2.4 Multifactor and Total Factor Productivity Indices

The basic definition of total factor productivity (TFP) is the rate of transformation of total input into total output. In this thesis, we focus on total factor productivity change, hereafter abbreviated to TFP, rather total factor productivity growth (TFPG), the latter being an established branch of economic growth and statistical accounting[1].

---

[1]: A comprehensive guide of the TFPG literature, including the main TFPG index numbers and the methodological approaches used to calculate them, is provided by OECD (2002).

The TFP concept incorporates multiple inputs (M) and outputs (S) to measure (and sometimes decompose) productivity change over time or between firms. So often, the TFP concept is reduced to multi-factor productivity (MFP) measures relating one measure of output to a bundle of inputs. A TFP index is determined by calculating the ratio of the weighted sum of outputs with respect to the weighted sum of inputs, with its general formula being expressed as follows:

$$TFP = \sum_{s=1}^{S} \omega_s Y_s \Big/ \sum_{m=1}^{M} \omega_m X_m \qquad (3)$$

Where ω_m are input weights and ω_s are output weights, each must sum to 1

In general, the weights are the cost shares for the inputs and the revenue shares for the outputs under the assumption that input and output markets achieve productive efficiency. This is the case of the Törnqvist index (Törnqvist, 1936), a widely used TFP index in productivity studies. Equations (4) and (5) show Törnqvist input and output[2] indices from the base period t to the period $t+1$, respectively. Because they attempt to construct a measure of total output over total input, TFP indices such as the Törnqvist index are widely used in benchmarking studies.

$$T_i = \prod_{m=1}^{M} \left[x_{mt} / x_{m(t+1)} \right]^{\frac{\omega_{m(t+1)}+\omega_{mt}}{2}} \qquad \text{Input index (4)}$$

$$T_o = \prod_{s=1}^{S} \left[y_{st} / y_{s(t+1)} \right]^{\frac{\omega_{s(t+1)}+\omega_{st}}{2}} \qquad \text{Output index (5)}$$

Where

$x_{m(t+1)}$ and x_{mt} are quantity of m^{th} input in periods $t+1$ and t, respectively

$y_{s(t+1)}$ and y_{st} are quantity of s^{th} output in periods $t+1$ and t, respectively

ω_{mt} and $\omega_{m(t+1)}$ are the m^{th} input cost shares in periods t and $t+1$, respectively

ω_{st} and $\omega_{s(t+1)}$ are the s^{th} output revenue shares in periods t and $t+1$, respectively

---

[2]: Input orientations (input savings) versus output orientations (output augmenting) are used throughout this paper to denote measures where the output and the input are held constant, respectively.

The above TFP measures are based on quantity data and market prices but the latter may not be available or may not be appropriate for weight aggregation. Port data are often not available at terminal or cargo-type level. Sometimes, prices may have little economic meaning for productivity measurement of non-market activities such as port operations in certain countries or under specific institutional and management systems. In addition, the non-frontier approach to TFP measurement relies on a number of assumptions, for instance the competitive characteristic of markets and the efficient behaviour of firms, but such conditions rarely hold in practice. The approach is usually unable to disassociate scale effects from efficiency differences.

To incorporate all such sources of efficiency while recognising the limitations of the non-frontier TFP approach, researchers use the Malmquist TFP index constructed by estimating a distance frontier. The Malmquist productivity index (MPI) is defined as the measure of TFP change of two data points by calculating the ratio of the distances of each point relative to a common technology. To avoid deciding on which period to define as the reference technology, Färe et al. (1994) proposes a geometric mean of two TFP indices evaluated between periods t and $t+1$ as the base and the reference technology periods, respectively (see Equations 6 and 7 below). This allows input and output weights to be calculated directly, which eliminates the need for price data. In addition, no assumption is required on the firm's efficient behaviour (i.e. profit maximisation or cost minimisation).

$$M_o(y_t, x_t, y_{t+1}, x_{t+1}) = \left[\frac{d_o^t(y_{t+1}, x_{t+1})}{d_o^t(y_t, x_t)} \frac{d_o^{t+1}(y_{t+1}, x_{t+1})}{d_o^{t+1}(y_t, x_t)} \right]^{1/2} \qquad \text{(Output orientation)} \quad (6)$$

$$M_i(y_t, x_t, y_{t+1}, x_{t+1}) = \left[\frac{d_i^{t+1}(y_t, x_t)}{d_i^{t+1}(y_{t+1}, x_{t+1})} \frac{d_i^t(y_t, x_t)}{d_i^t(y_{t+1}, x_{t+1})} \right]^{1/2} \qquad \text{(Input orientation)} \quad (7)$$

Few studies have estimated or used a TFP index for ports. Early attempts were made by Kim and Sachish (1986) who propose an aggregate TFP index consisting of labour and capital expenditure as the inputs and throughput in metric tonnes as the output. The index was also decomposed to account for scale economies and technical change. Later, Sachish (1996) proposes a weighting mechanism of partial productivity measures while Talley (1994) suggests a TFP index using a shadow price variable. More recently, Lawrence and Richards (2004) decomposed a Törnqvist index to investigate the distribution of benefits from productivity improvements of an Australian container terminal, while De (2006) used a TFP index to assess the total productivity growth in Indian ports over the period 1981-2003. As for the application of the Malmquist index to port efficiency, fewer studies exist in the literature. Among these, Lui et al. (2006) applied the MPI to measure productivity change of several container terminals in China during the period 2003-2004. Their MPI was decomposed into two sources of efficiency: technical efficiency change and technical change. Estache et al. (2004)

decomposed further the MPI by adding a scale efficiency measure to assess Mexico's port productivity changes following the country's recent port reform.

The main advantage of TFP indices is that they reflect the joint impacts of the changes in combined inputs on total output. This feature is not accounted for when single or partial factor productivity indicators are used. However, the TFP methodology is a non-statistical approach and does not allow for the evaluation of uncertainty associated with the results. Furthermore, TFP results depend largely on the technique used and the definition of weights, which implies that different TFP indices may yield different efficiency results. In many cases, the choice of the appropriate TFP approach is reduced to a trade-off between the requirement of large datasets in the econometric approach and the simplifying assumptions in the index number approach.

Another important aspect to consider when using productivity index methods is the fundamental difference between productivity and efficiency. Although the two measures seem to be closely related, each denotes a different performance measurement concept. Productivity is a descriptive measure whereby a productivity index provides a comparison between firms but uses no reference technology for a benchmark. Efficiency, on the other hand, is a normative measure in that the benchmarking of firms is undertaken with reference to an underlying technology. In fact, several TFP specifications for productivity measurement use technology for aggregation and require the estimation of cost/production or distance functions, meaning that the TFP concept is a derived rather than a stand-alone technique for performance benchmarking.

III.3 Frontier Approach

The frontier concept denotes the lower or upper limit to a boundary-efficiency range. Under this approach, a firm is defined efficient when it operates on the frontier and inefficient when it operates away from it (below it for a production frontier and above it for a cost frontier). Early attempts to construct a frontier use ordinary least squares (OLS) regression by plotting an average curve through the sample points in order to identify a central tendency or an averaged function. This is clearly not satisfactory because OLS allows observed points to lie above and below the fitted line and therefore fails to construct a bounding frontier. This has led to attempts to construct a non-observable frontier from a set of best obtainable positions. Such frontier can be either absolute or relative (best practice) depending on the method of parameter construction, respectively the parametric estimation *versus* the non-parametric estimation. In the simple example of one input and one output, Figure 4 depicts the main frontier approaches and how efficiency ratings differ from an approach to another.

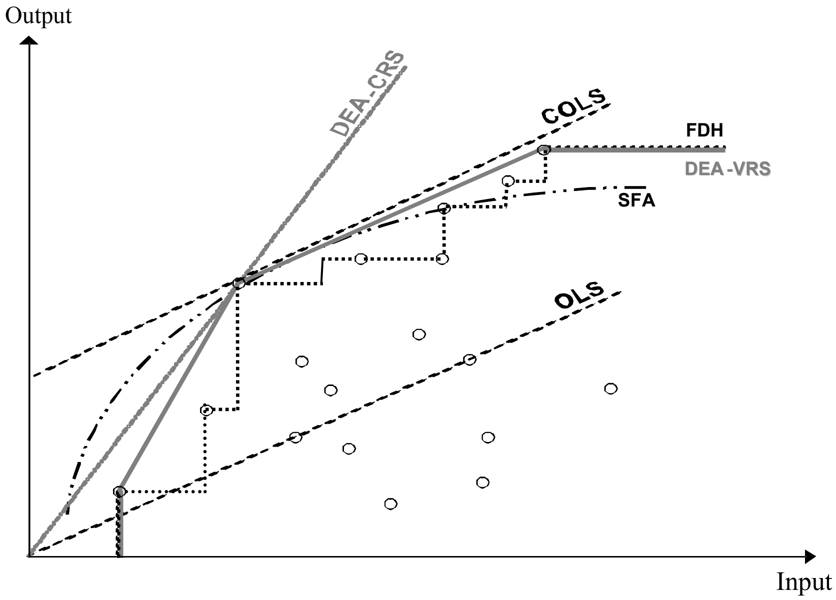


Figure 4: Graphical illustration of frontier methodologies
(Adapted from De Borger et. al, 2002)

Legend: DEA-CRS: Data Envelopment Analysis (constant-returns to scale), COLS: Corrected Ordinary Least Square, DEA-VRS: Data Envelopment Analysis (variable-returns to scale), FDH: Free Disposal Hull, OLS: Ordinary Least Square, SFA: Stochastic Frontier Analysis.

The literature in the field depicts various efficiency concepts mainly technical efficiency, allocative efficiency, scale efficiency and total economic efficiency:

- Technical efficiency (TE), also referred to as productive efficiency, indicates the ability to produce maximum output from a given set of inputs (output orientation) or the ability to achieve a given level of output at minimum input use (input orientation). TE is based on engineering relationships where management and operation practices directly affect efficiency scores but there is no consideration of price or cost factors.

- Allocative efficiency (AE) reflects a firm's ability to use inputs and outputs in optimal proportions given their respective prices and production technology. Thus, an organisation that is technically operating at best practice could still be allocatively inefficient because it is either not using inputs in the proportions that minimise its costs or not producing outputs in optimal proportions that maximise its revenues, given their relative input and output prices respectively.

- TE and AE may exist simultaneously or in isolation, and can be both combined into a measure of total economic efficiency (EE), also referred to as cost efficiency. EE is calculated as the product of the TE and AE scores and an organisation will only be economically efficient if it is both technically and allocatively efficient.

- Finally, scale efficiency (SE) reflects a firm's scale properties, i.e. the size and scale of the activity, such as in terms of constant returns (CRS) and variable returns (VRS) to scale technologies.

The next sections review the literature and applications of the frontier approach to port's efficiency and benchmarking. However, given the objective of this research, *X-efficiency* applications for yardstick benchmarking such as for price setting, competitive or incentive-based regulation are not covered in this thesis. For a review of the port literature on this subject, the reader is referred to Estache et al. (2002), Grans and King (2003), and Defilippi (2004).

III.3.1 Parametric (Econometric) Approach

Early attempts to estimate a cost function for ports may be attributable to Wanhill (1974) and UNCTAD (1978). Both studies and a series of subsequent papers (Sheneerson, 1983; Jansen, 1984; Fernandez et al, 1999) consider that the optimal use of berths is a result of minimising port's (operation and capacity) and ship's (service and waiting time) costs. Other studies (Burgess, 1974; Hooper, 1981) have challenged this assumption claiming that the functional form in a port production process of multiple inputs and outputs should not assume their prior separation but instead contrast them empirically. A detailed review on cost and production functions in ports is provided by Tovar et al. (2003) who distinguish between those estimating a production function (Tongzon, 1993; Reker et al., 1990) and those estimating a cost function, be it single-productive (Martinez-Budria, 1996) or multi-productive (Jara-Diaz et al., 2002).

Cost and production function presentations of technologies typically imply that firms are operating technically efficient. To allow for inefficiencies, cost and production functions have been replaced by distance functions. The latter form the essence of a new branch of research that allows the assumption of cost minimising or revenue maximising behaviour to be breached. The general formulation of distance functions reflects an engineering-based relationship whereby an output (input) function describes the factor by which the production (consumption) of all output (input) quantities could be increased (reduced) while still remaining within the feasible production possibility set for a given input (output) level.

As far as their parametric representation, frontier distance functions can be either deterministic or stochastic depending on whether or not certain assumptions are made regarding error composition and the data used. In the deterministic model, the frontier is estimated such that all deviations from the frontier are due to inefficiency. Estimating efficiency in a deterministic model is achieved by using either parametric techniques, such as the corrected ordinary least squares (COLS), or non-parametric techniques such as data envelopment analysis (DEA) and the free disposal hull (FDH).

Because OLS fails to construct a frontier, a function is estimated under COLS and then moved so that all firms lie either on or below the production frontier, or on or above the cost frontier. Nevertheless, the efficiency frontier under COLS is parallel to OLS regression implying that both frontiers depict the same structure. Moreover, COLS can be very sensitive to outlying observations, the latter representing firms that are either very atypical or appear to perform exceptionally well due to measurement errors.

To correct this, stochastic frontier analysis (SFA) is used to take account of outliers. The thrust of SFA is that deviations from the frontier may not be entirely under the control of the economic unit being studied, with at least some of the deviations being allowed to be attributable to random errors. In a SFA model, one includes a composite error term, which is a sum of a one-sided non-negative disturbance term measuring technical inefficiency, and a two-sided disturbance term representing upward or downward shifts in the frontier itself due to random shocks. A simple SFA formulation may be in terms of a basic regression model with error decomposition (see equation 8) but advanced econometric models of stochastic formulation require technically complex assumptions regarding distributions and error mixtures.

$$y_n = f(x_{1n}, x_{2n}, \ldots, x_{Nn}, U_n, V_n) \qquad (8)$$

Where: U_n : Technical efficiency component of firm (DMU) n

V_n : Statistical noise component

Among the numerous SFA applications to ports, worth mentioning Liu (1995) who applied a stochastic trans-log frontier production function to measure the productivity of 28 British ports. Cullinane et al. (2002) used a similar model to analyse the efficiency of selected Asian container ports. Cullinane and Song (2003) used SFA to benchmark the efficiency of major UK ports against their South Korean counterparts. Tongzon and Heng (2005) applied the SFA model from Battese and Coelli (1995) to study the relationship between port ownership, competitiveness and efficiency. Cullinane et al. (2006) specify a logarithmic SFA model for a cross-sectional analysis of container-port efficiency. Sun et al. (2006) estimate an SFA model for panel data analysis of the efficiency of 50 terminal operators across Asia, Europe and North America.

The main argument against the use of parametric models stems from the requirement of a functional specification, which does not allow for relative comparisons with the best practice. In the context of container port operations, the imposition of a specified functional form implies certain assumptions that may not be compatible with both the nature and the distributional characteristics of container-port production technologies. Another problem with SFA and parametric models in general is that the attempt towards specifying exact error terms not only proves difficult to establish but can also create an additional source of error. For instance, the frontier and efficiency value for each input/output bundle depend on the functional form chosen. Parameter estimates are also sensible to the choice of the probability distributions specified for the error terms. Furthermore, most SFA models only use a single output variable, which is a limitation against the multi-output nature of port production.

Parametric techniques may be difficult to apply in the context of international port benchmarking where each port depicts different operational, management, institutional and economic structure. SFA models are particularly relevant to situations with a single overall output measure or relatively complete price data, but this is hardly the case for ports. As revealed by Kim & Sachish (1986) and Braeutigam et al. (1984), the structure of port production may limit the econometric estimation of a cost or production function to the level of a single port or terminal. Furthermore, many argue that the theoretical assumptions underlying efficiency measurement under econometric approaches are unlikely to hold true in port operational and managerial settings (Ravallion, 2003; Bichou, 2006) and may be more relevant for studies with a strong policy orientation.

III.3.2 Non-Parametric (Programming) Approach

Unlike econometric models, non-parametric approaches do not require a pre-defined functional formulation but use linear programming techniques to determine rather than estimate the efficiency frontier. Much of the research using linear programming techniques involves the application of data envelopment analysis (DEA) and the free disposal hull (FDH). FDH is a non-parametric technique but differ from DEA by excluding linear combinations of production units from the analysis.

Primarily, DEA seeks to measure technical efficiency (TE) without using price and cost data or specifying a functional formulation. However, when information about costs and prices is available, DEA allows for the calculation of allocative efficiency (AE). Assuming a set of N $(n = 1,2,...,N)$ DMUs (Decision Making Units)[3] in the sample, each observation, DMU_j $(j = 1,2,...,n)$, uses m inputs x_{ij} $(i = 1,2,...,m)$ to produce s outputs y_{rj} $(r = 1,2,...,s)$. The efficiency ratio of DMU_j can be defined as the ratio of its weighted sum of outputs over its weighted sum of inputs:

$$E = Efficiency\, of\ DMU_j = \frac{\sum_{r=1}^{s} \lambda_j y_{rj}}{\sum_{i=1}^{m} \lambda_j x_{ij}} \qquad (9)$$

Where: x_{ij} and y_{rj} are the amounts of i^{th} input and r^{th} output consumed and produced by DMU j, respectively; and λ_j $(j = 1,2,...,n)$ are non-negative scalars representing input and output weights such that $\sum_{j=1}^{n} \lambda_j = 1$.

---

[3] We use the phrase Decision-Making Units (DMUs) throughout this thesis to refer to benchmarked units or firms under study. The phrase was first used by Charles (1978) to include non-market units such as schools and hospitals.

In an output orientation, we seek to find the maximum output that can be produced while holding the input at its current level. This is a maximisation problem, which can be solved using linear programming with the following objective function:

$$
\begin{aligned}
& Max\phi_k \qquad w.r.t \qquad \lambda_1,.....,\lambda_n \\
& s.t \ \sum_{j=1}^{n}\lambda_j x_{ij} - x_{ik} \leq 0 \qquad i = 1,2,...,m \\
& \quad \phi y_{rk} - \sum_{j=1}^{n}\lambda_j y_{rj} \leq 0 \qquad r = 1,2,...,s \qquad (10) \\
& \quad \lambda_j \geq 0 \qquad\qquad j = 1,2,...,n
\end{aligned}
$$

Where:

DMU$_k$ is under evaluation, ϕ_k is the efficiency score to be determined for observation k (If $\phi_k^* = 1$, then DMU$_k$ is a frontier point).

In equation 10, each DMU selects input and output weights that maximize its efficiency score and the problem is run N times to identify the relative efficiency scores of all DMUs. Input-oriented models can be formulated in the same way by minimising the input while holding the output constant. Equation (11) shows the CCR formulation for the input oriented model.

$$
\begin{aligned}
& Min\theta_k \qquad w.r.t \qquad \lambda_1,.....,\lambda_n \\
& \text{s.t. } \theta x_{ik} - \sum_{j=1}^{n}\lambda_j x_{ij} \geq 0 \qquad i = 1,2,...,m \\
& \quad -y_{rk} + \sum_{j=1}^{n}\lambda_j y_{rj} \geq 0 \qquad r = 1,2,...,s \qquad (11) \\
& \quad \lambda_j \geq 0 \qquad j = 1,\ldots,n \qquad \text{(CCR)}
\end{aligned}
$$

The formulations in (10) and (11) are known as DEA-CCR (due to Charnes, Cooper, and Rhodes) for CRS but can also be expressed as a DEA-BCC model (due to Banker, Charnes and Cooper) to account for VRS by adding the extra constraint $\sum_{j=1}^{n}\lambda_j = 1$. The choice of orientation depends on the objective of benchmarking (input conservation versus output augmentation), and on the extent to which inputs and outputs are controllable. Both models should estimate exactly the same frontier, with the same set of DMUs being identified as efficient under either model. However, efficiency scores of inefficient DMUs may differ under VRS.

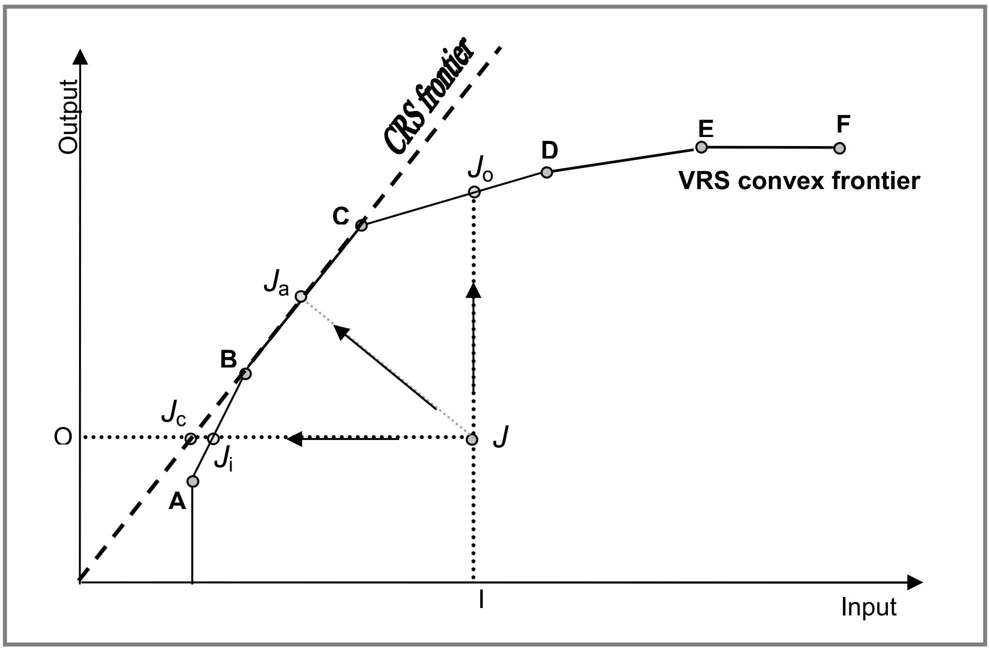


Figure 5: DEA production frontier under the single input and single output scenario (Adapted from De Borger et. al, 2002)

In the simple scenario of a single-input and a single-output, Figure 5 illustrates DEA models and efficiencies under different orientations and scale technologies. The DEA frontier consists of a convex hull of intersecting planes that envelops the efficient data points A, B, C, D, E and F. Note that only units B and C are efficient under both CRS and VRS, which confirms that DEA-CRS is more restrictive than DEA-VRS. For the inefficient DMU_j, the projection towards the CRS frontier (the straight line) makes point j_c the new target, while j_i j_o and j_a are the VRS targets for the input, output and additive orientations, respectively. Unlike for CCR and BCC, the additive model is un-oriented and combines simultaneous input reduction and output increase.

In Figure 5, both DMUs E and F are on the frontier indicating that they have an efficiency score of 1. However, DMU F can still reduce its inputs by some units to reach DMU E. This individual input reduction is called input slack. Input and output slack formation is the product of the convex structure of the DEA frontier. The revised input-oriented VRS model from equation 11 can write as in equation 12 where ε is an infinitesimally small positive number, while is s_i^- and s_r^+ are the input and the output slacks, respectively.

$$
\begin{aligned}
& Min\ \ \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\
& \text{s.t.}\ \ \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{ik} \\
& \qquad \sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rk} \qquad\qquad (12) \\
& \sum_{j=1}^{n} \lambda_j = 1 \qquad j = 1, \dots , n \\
& \lambda_j \geq 0
\end{aligned}
$$

Another way of illustrating graphically DEA input and output orientations is by analysing production sets of either two inputs (x_1, x_2) and one output (y) for the input-oriented model, or one input (x) and two outputs (y_1, y_2) for the output-oriented model. Figure 6 depicts TE and AE measures in both orientations. When cost and price information is available, one can draw the iso-cost line (CC' combination of x_1 and x_2 giving rise to the same level of cost expenditure) for the input-oriented model and the iso-revenue line DD' (combination of y_1 and y_2 giving rise to the same level of revenue) for the output-oriented model. Allocative efficiencies for input (AE_i) and output (AE_o) orientations can therefore be calculated, corresponding in our example to the ratios *OJ_b/OJ* and *OJ/OJ_b*, respectively. Finally, note that the reference set or peers for the inefficient DMU_j are E and F in the input-oriented model, and F and G in the output-oriented model.

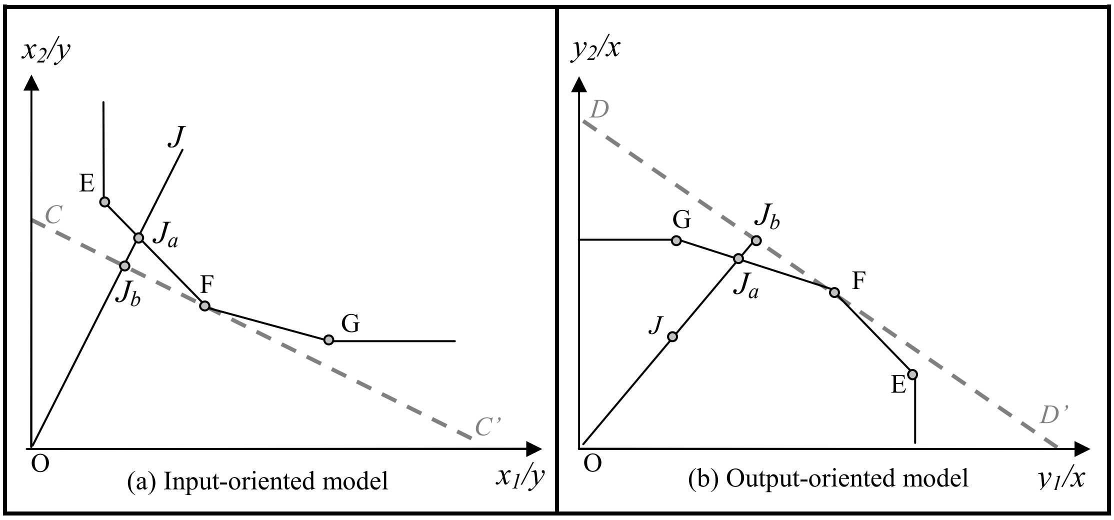


Figure 6: Illustration of DEA input and output orientations, excluding the effect of technological change (Adapted from De Borger et. al, 2002)

DEA applications in ports are quite recent with the first attempt being attributed to Roll and Hayuth (1993). Estache et al. (2002) provide a detailed review of the use of DEA techniques in ports although since then many studies have been published on the subject. The literature in the field may be divided into a-four categorisation criteria:

- Between DEA-CCR models (Valentine and Gray, 2001; Tongzon, 2001) and DEA-BCC models (Martinez-Budria et al., 1999; Serrrano and Castellano, 2003), although recent studies use both models;

- Between input-oriented models (Barros, 2003) and output oriented models (Wang and Cullinane, 2005);

- Between applications looking at aggregate port operations (Barros and Athanassious, 2004) and those focusing on a single port operation (Cullinane et. al, 2004);

- Between studies relying on DEA results solely and those complementing DEA with a second stage analysis such as regression or bootstrapping (Turner et. al, 2004; Bonilla et. al, 2002).

The DEA approach to efficiency analysis has many advantages over parametric approaches. The methodology accommodates multiple inputs and outputs, and provides information about the sources of their relative (factor specific) efficiency. DEA neither imposes a specification of a functional form, nor requires assumptions about the technology. In DEA, firms (or DMUs) are benchmarked against the achievable best performance rather than against a statistical measure, an average or theoretical standard. There is also no necessity to pre-define relative weight-relationships, which should free the analysis from subjective weighting. Similarly, each input/output variable can be measured in its natural measurement units, e.g. dollar values versus physical measures. Another useful feature of DEA is that it attempts to find one or more efficient reference point(s) (a peer or combination of peers) for each inefficient DMU, which also informs about improvement projection possibilities in terms of specific input reductions, output increases, or both. In addition and although DEA requires a dataset of at least three to four times the number of input and output parameters (Bowlin, 1998), this is still smaller than the dataset required under SFA. All such features and others make DEA particularly attractive for port-related efficiency studies; which justifies the increasing number of academic literature on the subject.

On the other hand, one could argue that the same features that make DEA a powerful tool also create major limitations. Primarily, one may question the logic behind the virtual output/input construction under DEA, especially when outputs and inputs of a different nature are considered. A major drawback of DEA stems from the sensitivity of efficiency scores to the choice of, and the weights attached to, input and output variables. This is of major concern because a DMU can appear efficient simply because of its patterns of inputs and outputs. Moreover, input (output) saving (increase) potentials identified under DEA are not always achievable in port operational settings, particularly if this involves small amounts of indivisible input or output units.

Another problem with DEA is that while there is no prior requirement of weight selection, the technique does not investigate relationships between variables within and across the sampled DMUs. As such, the technique does not account for substitution possibilities between inputs or transformation possibilities between outputs. This is of particular importance in the context of container port benchmarking because factor endowments, utilisation and substitution vary largely between different port operating systems. A similar issue in DEA is that inefficient DMUs and their benchmarks may not be similar in their operating practices. This is largely because the composite DMU that dominates the inefficient DMUs either depicts an inherently different technology or does not exist in reality. As a solution to these problems, some authors propose to add weight multipliers to DEA models by introducing expert judgements, such as through survey or AHP-based techniques, or by incorporating prior views on efficient firms and on the relationship between inputs and outputs. Others have used performance-based clustering and other similar methods in order to discriminate between efficient firms or identify more appropriate benchmarks (Sharma, 2005; Wang et al., 2006).

Analytically, DEA does not allow for stochastic factors and measurement errors and there is no information on statistical significance or confidence intervals. For economists, the non-statistical attribute of DEA is a major impediment against its validity. Although a second-stage regression analysis is sometimes used to solve this, regression assumes data interdependency and requires the imposition of a functional form which deprives DEA from its major advantage. It is worth underlying that several recent works have tried to close the gap of statistical grounding in DEA analysis (see for instance Banker and Cooper, 1994; Simar and Wilson, 1995 Gstach, 1998; and Cooper et al., 2002). Suggested solutions that allow DEA to work in stochastic environments include chance-constrained programming and DEA bootstrapping, the latter is becoming more popular among researchers. Other solutions include the use of panel data to filter noise across time periods (Banker and Maindiratta, 1992), and the inclusion of some sort of parameterisation, for instance by constructing dummy efficiency variables from DEA to be used as additional repressors in OLS or SFA estimation (Sengupta, 1989).

III.3.3 Issues with Frontier Applications in Container-Port Efficiency

Most applications of both parametric and non-parametric frontier methodologies to container-port efficiency have proven to be difficult and sometimes controversial with very limited discussion on the potential distortions stemming either from the limitations of the selected methodology or from the difficulty to model container-port operations. In the followings, we highlight some shortcomings of the frontier port literature:

(a) A basic requirement for reliable port performance benchmarking is the appropriate definition and selection of homogenous port DMUs. However, this aspect appears to be constantly overlooked in the port literature although recent studies focus on ports with similar traffic type because otherwise typical specialised units such as oil and cruise ports would usually appear as outliers. Even though, disaggregating port DMUs into similar traffic-type units may not be sufficient to ensure homogeneity (Bichou, 2006; Cochrane, 2007). In the case of container terminals, a lack of homogeneity may stem from the differences in production and handling technologies between terminal DMUs or simply from the variations in the ratios of the status (FCL, LCL, empty, special), type (import, export, transhipment), and dimension (TEU, FEU, non-standard) of container throughput among benchmarked terminals. A thorough discussion on the need to identify and account for these differences and on the methodology used to incorporate them in the benchmarking analysis is provided in the Chapter IV of this thesis.

(b) As for variable definition, only a few studies (e.g. Rios and Gastaud-Macada, 2006) have formally justified variable selection. Input and output variables for container-port efficiency are selected either subjectively or at best from previous literature but the latter depicts a prevalent lack of a clear definition as to which factors should make up in the input set and which factors should be included the output set.

Even when variables are clearly defined, researchers tend to exclude other port services (e.g. bunkering, equipment and space rental) and overlook the variations in container-port technology and handling systems. One major shortcoming of the port literature is that most frontier applications to port efficiency tend to focus solely on sea access, which overlooks landside and inland port logistics despite the latter being widely recognised as a key factor influencing the overall efficiency of port and terminal operations (Bichou, 2005a; Hall, 2004a).

(c) In relation with the above, no consensus among port researchers seems to have been reached on the extent to which non-controllable or exogenous variables are included in the frontier analysis. Internal or controllable factors include port management, terminal layout, labour productivity, and the choice and productivity of the operating and handling system. External or exogenous factors include trade volumes, shipping patterns, and the economics of scale and scope. It is important to recognise this aspect in the context of benchmarking container-port efficiency because as one goes down the decision-making hierarchy, the terminal operator is assigned a specific input (e.g. terminal size) and output (e.g. number of containers to be handled) bundle under his control. Even though, port researchers often include non-discretionary variables that either show inconsistency with the type of performance being assessed or fall outside the control of the DMUs under study. Examples of the former include Park and De (2004) who use profitability factors in the analysis of port operational efficiency. For the latter, examples include Tongzon (2001) who incorporate nautical factors such as the number of tugs in the benchmarking of terminal efficiency. Therefore, the appropriate selection and formulation of input and output variables rely on a prior definition of the type of performance being assessed as well as an expert understanding of the spatial and operational scope of container terminal systems.

(d) Traditionally, the focus of most port benchmarking studies is on the estimation of the frontier and on the extent to which port and terminal DMUs deviate from the frontier. An important part of the assessment of port efficiency is not only on the position of the frontier and inefficiency of port DMUs based on current technology, but how this frontier might evolve over time, i.e. frontier shift. Techniques that provide ways to analyse data in this way include DEA Windows Analysis and the Malmquist productivity index. Only a few port researchers have used either technique to assess the shifts in frontier technology (see for instance Cullinane et al., 2004 and Lui et al., 2006).

(e) In DEA, the isotonicity premise requires that the increase of an input should result in some output increase and will not cause a decrease in any output. For studies on container-port efficiency, the lack of isotonicity may occur either because of the way input and output variables are recorded or due to the inherent production characteristics of the industry. For the former, port variables are often recorded in ways that breach the isotonicity requirement. For instance, the output factors ship's service time and cargo dwell-time (DwT) are usually recorded in a way that show that the lower their values the more efficient the port or the terminal. For the latter, the container-port production process (see Figure 7 below) typically portrays a bottleneck structure whereby the performance of the entire system may be constrained by the capacity of one sub-process. As such, an increase in quay site inputs (e.g. quay length, number of quay cranes) may have a negative effect on yard output. Similarly, an increase in terminal area may have little or no effect on terminal (quay) throughput. To satisfy isotonicity for all variables, researchers carry out statistical tests to calculate the inter-correlations between inputs and outputs, but this is hardly performed in the port literature.

(f) DEA requires input and output values to be positive, but this property may be breached in port efficiency especially for variables with zero values. In real-world port operations, two instances arise where input or output variables may take zero values. On the one hand, the analysis of ports with different traffic and cargo mix (passenger, bulk, break-bulk, containerised, etc.) usually involves zero output levels relative to some port DMUs because the latter may handle negligible or zero levels of certain cargo and traffic types. On the other hand, the variations in production technology and handling configurations across container terminals (see Chapter IV) mean that many terminals may have negligible levels of certain inputs or may not need to use them at all to operate. This is the case for instance of terminals operating exclusively on a straddle carrier or on a yard-gantry based configuration.

The DEA literature offers alternative solutions for the zero-output problem such as by relaxing the DEA formulation or by using DEA models (e.g. the DEA additive model and the DEA output-oriented BCC model) that satisfy the translation invariant property. However, the treatment of the zero-input problem is only possible under the DEA additive model (See Seiford and Zhu, 2002; Thanassoulis, 2001; and Bowlin, 1997). Even though, much of the DEA-based port literature does not provide evidence of compliance with the positivity requirement. In the case of container terminal efficiency, a review of the literature shows that many researchers (e.g. Wang and Cullinane, 2005; Cullinane et al., 2005; Cullinane et al., 2006) do not satisfy the positivity property with regard variables with zero inputs, but such assessments are likely to show DMUs with zero-inputs more artificially efficient than they are.

(g) In relation with model specification and orientation, the literature on container-port efficiency depicts several discrepancies. It is reasonable to assume an input-oriented model for operational or strategic planning because only inputs are controllable in the short and medium term. On the other hand, output orientation is more relevant for long-term planning and policy where the emphasis is placed on expanding terminal capacity and increasing throughput levels. However, this reasoning is not always consistent in the port literature with many short-term applications of specified cross-sectional or short-range times-series datasets using an output orientation.

(h) Another drawback of much of the port literature is that only technical efficiency is normally measured. This is due to the unavailability or rather the difficulty in obtaining port costs and price data to measure allocative and total economic efficiencies. Some studies (e.g. Yan et. al, 2007) have attempted to calculate allocative efficiency using data reported in port annual reports, but even when port prices and costs are available, it is very difficult to allocate them to port inputs and outputs because of the way they are calculated, reported, and/or aggregated in published port tariffs and accounts. Furthermore, world ports and terminals depict dissimilar costing and pricing policies, and any benchmarking analysis would therefore require further desegregations such as by accounting, institutional, and contractual arrangements.

The above shortcomings and others explain why the findings of the frontier port literature provide inconsistent results. This is typically the case when analysing the relationships between port size and efficiency (Martinez-Budria et al., 1999 *versus* Coto-Millan et. al, 2000), ownership structure and efficiency (Notteboom et. al, 2000 *versus* Cullinane et. al, 2002), and locational/logistical status and efficiency (Liu, 1995 *versus* Tongzon, 2001).

III.4 Process Approaches

Process approaches seek to assess business processes and plans in view of performance measurement and improvement. They often rely on expert judgement, perception surveys and process benchmarking toolkits, but each of these requires a thorough investigation and may be very expensive and time consuming. Two different groups of methodologies may fall under the banner of process approaches: expert judgement and perception survey approaches versus engineering and process benchmarking models.

III.4.1 Expert Judgement and Perception Surveys

Expert judgement relies on a thorough review to derive assessments of a firm's performance. This is typically done by undertaking a performance review by a panel of experts and external consultants who use their experience and relevant external benchmarks to determine the scope for performance assessment and improvement. Perception surveys may be part of an expert judgement review or a participative inquiry process, but they only report snapshot views of participants who may not necessarily have an expert understanding of the benchmarking process or the firm or industry under investigation. In both approaches, researchers may use statistical techniques for correlation and hypothesis testing. The relevant port benchmarking literature is almost equally split between expert judgement studies (Léonard, 1990; Bichou and Gray, 2005a) and perception surveys (Australian Productivity Commission, 2003; Regan and Golob, 2000). Expert-judgement methods must not be confused with expert systems the latter are optimization-oriented computer programmes that mimic the analytical process of an expert in the field. Expert systems are usually combined with conventional logic and inferential techniques such as heuristics, fuzzy logic and neural networks.

The main drawback of expert judgements and perception surveys is their reliance on subjective impressions to analyse and benchmark a port's performance. To reduce subjectivity, structured ranking methods, such as the analytical hierarchy process (AHP), are sometimes used along with expert judgements and perception surveys (Malchow and Kanafani, 2001; Nir et. al, 2003; Lirn et. al, 2003; Song and Yeo, 2004). Sometimes, AHP and other multi-criteria decision methods have even been used in combination with analytical benchmarking techniques such as DEA in order to incorporate some prior views on benchmarked port entities (Sharma, 2005; Ertay et al., 2006).

III.4.2 Engineering and Process Benchmarking Methods

Engineering and process benchmarking is a modelling and process-oriented exercise for assessing the internal or the external performance (and sometimes both) with a view to comparing a firm's performance against established standards or best-class benchmarks. Under this category, two main methodological approaches may be used:

III.4.2.1 Engineering Approaches

Engineering approaches use bottom-up techniques for modelling business processes (costs, physical movements, information flows, management systems, regulatory procedures, etc.) to capture and improve current processes and ultimately build up a 'model' firm. Popular techniques under this category include business process re-engineering (BPR), enterprise system's analysis, and economic engineering analysis (EEA); the latter requires data on costs, inputs and outputs, and may eventually lead to the creation of a cost or production function. Much of the port literature on this aspect relies on BPR modelling (Paik and Bagchi, 2000; Lyridis et. al, 2005) although recent studies use enterprise-based tools such as Enterprise Resource Planning (ERP) to investigate port performance efficiency (Choi et al., 2003; Victoria Department of Infrastructure, 2004).

Note that port simulation exercises for the purpose of performance optimization do not benchmark against best practice and thus they do not fall under the subject of port performance and benchmarking. For a literature review of simulation applications in container terminal operations, the reader is referred to Vis and De Koster (2003), Steenken et al. (2004), and Stahlbock and Voss (2008) .

III.4.2.2 Process Benchmarking

Process benchmarking takes a strategic view of performance benchmarking such as in terms of a continuous process of measurement and improvement. Therefore, the approach does not use specific techniques of analysis but rely instead on a set of management toolkits such as six-sigma, total quality management (TQM), and the balanced scorecard (BSC). Examples of TQM applications to port performance include Lopez and Poole (1998), Ha (2003) and Cudrado et al. (2004).

In the last two years, Germanischer Lloyd has developed in cooperation with the Global Institute of Logistics the Container Terminal Quality Indicator (CTQI). The aim of the CTQI standard is to establish a performance quality system enabling shipping lines, shippers and other port users to benchmark a container terminal's ability to provide a high quality service and operate at best practice. CTQI includes more than 70 key performance indicators (KPIs) for measuring terminal's efficiency and terminals are scored on a 100-point scale and receive certification if they achieve 50 points or more.

III.5 Chapter Conclusion- Benchmarking Methods

The above literature review on benchmarking techniques has shown that while there to be advantages and disadvantages to each, the application of these techniques to the subject of container-port efficiency has revealed a great degree of inconsistency across researchers and fields. Examples of such core differences include:

1. Fundamental disagreements on both the definition and port applications of performance dimensions, e.g. efficiency, productivity, utilisation, effectiveness, etc.

2. Inter-disciplinary differences about both the scope and the approach applied to port operating and management systems. The first extends across various functional areas such as operations, marketing, pricing, strategy and policy, while the second intersects

with various fields of analysis including engineering, economics, management, and strategy.

3. Perceptual differences among multi-institutional port stakeholders (regulator, operator, user/customer, etc.) and the resulting influence on the objective, design and implementation of performance frameworks and analytical models.

4. Boundary-spanning complexities of port operational (types of cargo handled, ships serviced, terminals managed, systems operated, etc.), institutional (landlord, tool, service, etc.) and spatial (quay, yard, terminal, port, cluster, etc.) systems bring confusion not only on what to measure, but also on what to benchmark against.

III.5.1 Performance Taxonomy and Dimensions

Performance is a broad concept that covers almost any objective of operational or management excellence of a firm and its activities. Performance measures are designed to capture the performance of an activity, a process or both. The main problem with performance measures is that while they depict various dimensions, their definitions and specific applications are not always consistent between researchers or fields.

For instance, productivity may be interpreted differently depending on the approach used. Ghobadian and Husband (1990) suggest that there are three broad concepts of productivity: the economic concept (efficiency of resource allocation), the technological concept (relationship between ratios of outputs to their inputs), and the engineering concept (relationship between the actual and the potential output of a process).

From an economic perspective, productivity and efficiency are widely linked to performance measurement but the two concepts may have different meanings. For instance, a firm that is more productive is not necessarily more efficient. In other words, while the benchmarking of firms under efficiency measurement involves the reference to an underlying technology, productivity measures use no reference technology for a benchmark. Such a fundamental difference is still being overlooked by port academics and researchers, especially in business management fields.

Another significant issue is that the relationship between variations in the indicators and performance dimensions has been difficult to establish in the port literature.

➢ On the one hand, researchers often use industry data to construct input and output variables for the port industry, but little consensus has been agreed on the definition, range and dimensions of port variables. For instance, crane move per hour may differ significantly depending on whether it is reported in a net, elapsed or gross rate. Crane efficiency can also be measured using other indicators, for instance the number of TEUs per crane hour. However, each indicator yields a different productivity and performance level. Sometimes, the same performance ratio is used to measure different performance attributes. Even when input and output variables are clearly defined, researchers often overlook the difference in port handling systems and production technologies.

- On the other hand, performance metrics and ratio indicators that are widely used in the port industry do not always incorporate the various performance dimensions described-above. For example, the volume tonnes (or TEUs) of cargo handled to the number of total worked hours is a ratio that can be used to measure anything from labour efficiency to berth or ship efficiency. Furthermore, metrics such as ship service time and cargo dwell time (DwT) may be interpreted as measures of either utilisation, efficiency, or both. Because of this and other factors, the relationship between variations in physical indicators and performance has been difficult to establish. An example of overlapped port performance metrics is provided in table 7.

Table 7: Sample of port metrics and their corresponding performance dimensions (Source: Author)

Dimension	Metric	Basic formulation
Utilisation	Waiting time (WT)	$\frac{Cummulated\ time\ for\ waiting}{Total\ number\ of\ ships}$
	Service time (ST)	$\frac{Cummulated\ service\ time\ (at\ berth)}{Total\ number\ of\ ships}$
	Grade of Waiting	$\frac{Cummulated\ WT}{Cummulated\ ST}$
	Berth Occupancy	$\frac{Cummulated\ ST}{Unit\ Time\ (e.g.\ month)}$
	Dwell Time (DwT)	$\frac{Units\ (e.g.\ tonnage)\ *\ Dwelling\ Time}{Units\ stored\ or\ stacked}$
Efficiency	Crane move	$\frac{Volume\ of\ cargo\ handled\ (e.g.\ TEU)}{Unit\ Time\ (e.g.\ hour)}$
	Labour efficiency	$\frac{Volume\ of\ cargo\ handled\ (e.g.\ TEU)}{Total\ number\ of\ gangs}$
	Ship Output	$\frac{Tonnage\ of\ cargo\ handled\ (e.g.\ TEU)}{Total\ worked\ hours\ per\ ship}$
Effectiveness	Work reliability	$\frac{Effective\ worked\ hours}{Scheduled\ worked\ hours}$
Quality	Punctuality ratio	$\frac{Total\ delayed\ time}{Number\ of\ calls}$

III.5.2 Multi-disciplinary Approaches to Port Systems

Although extensive literature has addressed theories and practices in port performance measurement, little has emerged on linking and integrating operations, management and strategy within the multi-institutional and cross-functional port context. It is very noticeable in the current body of port literature that the conceptualisation of the port system has taken place at different disciplinary levels without producing an integrated and structured port performance framework.

Existing performance models for ports are typically split between measuring either internal efficiency or external effectiveness, but are hardly used to capture both. On the one hand, the literature on competitiveness and strategic benchmarking in ports rarely incorporates elements of operational efficiency. On the other hand, few port efficiency studies have accounted for external constraints including aspects such as port location, traffic and cargo type. A single focus on either aspect does not seem to be the only way to achieve best-class performance. In fact, this is a common predicament against developing a proper framework for port performance benchmarking (Bichou, 2006). The interaction between port attributes and the approaches to port systems has been thoroughly discussed by Bichou and Gray (2005b). Table 8 draws on their discussion to link major approaches to port systems with their corresponding performance benchmarking methods.

Table 8: Various approaches to ports and their corresponding performance models (Source: Adapted from Bichou and Gray, 2005b)

Sample of approaches to ports in the literature		Decisive factors				Methodological approach
		Missions	*Assets*	*Functions*	*Institutions*	
Macro-economic approaches	Economic catalyst	Major				Economic impact analysis
	Job generator	Major				
	Trade facilitator	Major				
Institutional Models	Private/public	Minor			Major	TFP/ MFP Frontier methods
	Landlord/tool/service		Major		Minor	
Geographic and spatial approaches	Port-city	Major				Economic impact analysis Port trade efficiency
	Waterfront estate	Minor	Major			
	Sea/shore interface	Minor		Major		
	Logistics centre	Minor		Major		
	Clusters				Major	
	Trade and distribution centres	Major		Minor		
	Free and trading zones	Minor		Major		
Hybrid approaches	UNCTAD generations	Major		Major	Minor	Index metrics Economic impact analysis
	World Bank 'Port Authority' Model	Major			Major	
Alternative approaches	Combinative strategies	Major		Major		Process approaches
	Logistics and production systems	Major		Major		
	Business units	Minor		Major		

II.5.3 Differences between Stakeholders' Perceptions

A significant issue in port operations and management is the complex interactions between port missions, institutions, and functions; which makes it difficult to identify who does what and why in ports. In the context of port performance and benchmarking, the question arises on whose (regulator, operator, customer, user, etc.) perspective or standpoint one has to consider. Much of the conventional port literature tends to favour ocean carriers' (as customers) interests hence reducing the subject of port performance to ship's efficiency such as in terms of service time at berth or total time in port. Another approach considers the regulator's (e.g. port authority) perspective such as in terms of socio-economic and regional development, but even port authorities have different, sometimes conflicting, missions and objectives.

A further complexity arises when an outside institution performs a port function, for instance when an ocean carrier or its subsidiary acts as a port operator. In this case, a port's performance is often equated to ships' efficiency, hence blurring the boundaries between the objectives of the carrier as a customer and those of the port as a service provider. A similar instance occurs when a terminal operating port authority such as the port of Singapore authority (PSA) and Dubai ports world (DP World), operate each a range of port facilities worldwide, including their local ports and terminals. In such cases, different ports may have different performance objectives even when they are operated by the same operator. Bichou and Bell (2007) provide a good discussion and an empirical framework on consolidation trends and competitive dynamics between global port operators, and the corresponding impacts on performance definition and objectives.

III.5.4 Comprehension and Coverage

A port can range from a small quay for berthing ships to a very large centre with several terminals and a cluster of industries and services. A port spatial boundary can be limited to few berthing and cargo handling facilities, or extended to a range of trade, logistics and production centres. In a similar vein, operational and management features also vary with the type and range of cargo handled, operated ships and offered services.

In a typical port setting, there is an extensive portfolio of operations extending across trade, distribution and service industries, which makes difficult the grouping of port roles and functions under the same economic or business category. With many ports around the world expanding beyond their traditional service-offering and spatial boundaries, the definition of the port's core businesses and spatial coverage poses a dilemma as to where the demarcation line lies between port and non-port systems and activities. Even when port operations are disaggregated into homogenous port units of similar traffic and spatial features, benchmarking studies tend to overlook the differences in production technologies and operating systems across these units.

Developing an appropriate port efficiency model involves unravelling many discrepancies at both conceptual and analytical levels. From the above discussion and literature review, it seems that there is a methodological difficulty in developing a comprehensive and multi-dimensional container-port performance and benchmarking framework. This has been reflected by the lack of the container port benchmarking literature to provide stable and consistent results over time, across researchers, and in relation to dynamic operating and market conditions. The wide dispersion and inconsistency between port efficiency studies raises the question as to whether there is something not captured by the techniques applied so far or simply whether the techniques used are appropriate and relevant. An applicable framework is therefore required to integrate (i) different processes and technologies of container-port production and operating systems, (ii) appropriate indicators for capturing container-port operational efficiency, and (iii) applicable techniques for measuring and benchmarking container-port performance efficiency. Such framework should then be associated with the port and maritime security regime in order to analyse the impacts of security on operational efficiency and benchmarking of world container ports and terminals.

CHAPTER IV: RESEARCH APPROACH AND METHODOLOGY

Designing a viable research strategy and selecting the proper methodological approach are arguably the most critical stages within any research project or inquiry. In the next sections, we argue that there is a need to link theory with port practice, identify and justify the potential methodologies for our research problem, and introduce the conceptual framework and research design adopted for this study.

IV.1 Understanding Container-Port Practice

Despite the growing amount of research into container-port operations and management, the relationship between theory and port practice has been less evident in the current body of port literature. In fields of port security and performance efficiency, much of the theoretical applications on the subject seem to be incompatible with the operating environment of modern container ports and terminals, particularly with regard to terminal handling systems and operating procedures. In the next sections, we briefly describe container-port configurations, handling systems and terminal procedures and explore the factors that are within and beyond the control of terminal operators. By laying the emphasis on the technology variations in port equipment and handling systems, the operating differences in terminal procedures, and the network links between terminal sites, we demonstrate why such aspects must be taken into account when investigating the impacts of procedural security on container-port efficiency.

IV.1.1 Container Port Configurations and Terminal Operating Sites

Modern port configurations and operating systems are increasingly designed to serve a particular trade or ship's type, although many ports around the world still operate multi-purpose facilities. Nevertheless, even within a single port type, terminals may be designed, operated and managed differently. Seaports must not be confused with terminals; the latter are specialised sometimes multi-purpose units within ports. Thus, it is reasonable to consider terminals instead of ports as the units, or DMUs, for port performance measurement and benchmarking.

Within a single port, container terminals share similar nautical and inland systems. However, each container terminal may be decomposed into three main operating sites namely the quay-apron, the yard and the gate. All such sites must operate jointly for efficient cargo handling and transfer. An illustration of the different sites and equipment used in a typical modern container terminal is depicted in Figure 7 below.

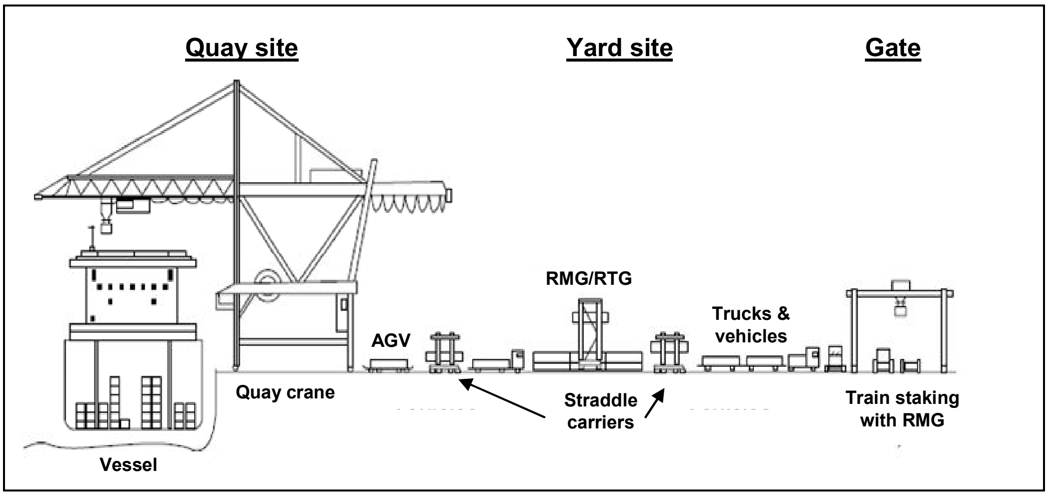


Figure 7: Container terminal sites and main handling equipment (Source: Author)

To illustrate the relationships between different container terminal sites, Figure 8 outlines the configuration of a generic container port operating system. The process depicted in Figure 8 emphasises the existence of many critical processes or bottlenecks whereby the performance and capacity of one site or sub-system is a binding constraint for the performance of another site, which in turn impacts the aggregate efficiency of the container terminal, extended to that of the overall port system. This implies a dual relationship between (i) disproportionate performance and capacity levels at the internal terminal level, for instance when a specific site or subsystem is working fully while concurrent ones remain underutilised, and (ii) uncertainty and variability scenarios at the port and wider supply chain levels. Examples of the latter include aspects such as uncertainty of vessel schedules, shifts in demand and trade patterns, and changes in routing and logistical arrangements of maritime transportation. The failure to integrate and link different terminal operating sites, including the integration of critical processes, denotes a major gap in the port literature particularly for studies on performance benchmarking and terminal security.

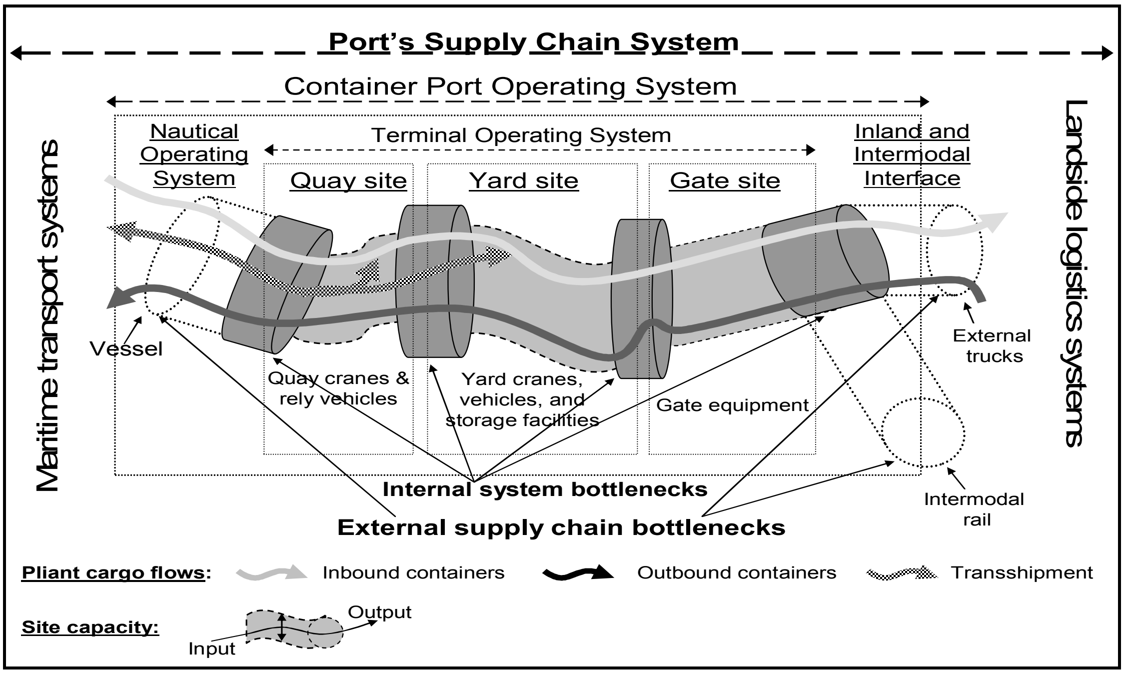


Figure 8: Illustration of operational bottlenecks in container terminal and port operating systems (source: Author)

IV.1.2 Container Port Equipment and Handling Systems

The choice of the appropriate port layout and handling system is a strategic decision that requires detailed planning and long-term forecasts, and is generally taken at the early stages of port design or at periods of long-term and strategic port planning. In the case of container ports, such a decision is dictated by a number of factors including:

✓ Physical (oceanographic, hydrographical, topographic, climate, etc.) and engineering (construction, dredging, pavement, etc.) conditions,

✓ Land (terminal) area, capacity and cost constraints,

✓ Operating factors such as equipment and labour costs

✓ Port's logistical status, traffic type and mix (e.g. inbound *versus* outbound, direct-call *versus* transhipment),

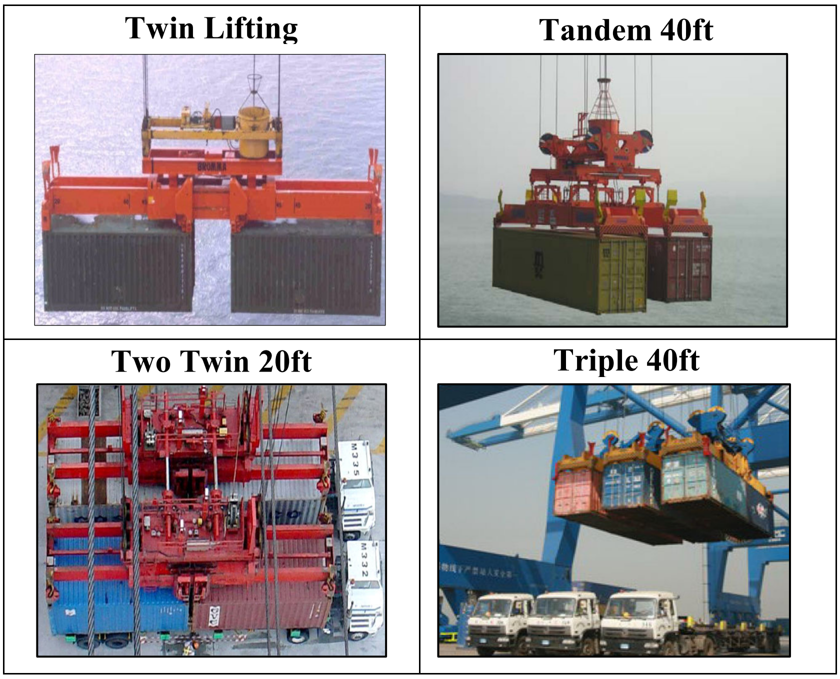
✓ The estimated proportions of handled container categories such as in terms of their status (full container load -FCL-, less-than-full container load -LCL-, empties), type (hazardous, refrigerated, specials) and dimensions (TEU, FEU, non-standards),

✓ The location of the container freight station (CFS), wither within or outside the container terminal (see Appendices A5 and A6).

In addition to physical constraints such as quay length, berth draft and terminal size, much of the operational features of modern container terminals are determined by the typologies of container quay cranes and yard handling systems. Gate operating configurations are almost identical across modern container ports and terminals and will therefore not be covered in this Chapter.

IV.1.2.1 Variations in quay crane performance and technology

A container quay crane is the main equipment used for ship loading and unloading. It can be either mounted on the ship (ship-mounted cranes) or located on the quay (ship-to-shore cranes: STS), the latter being widely used in container ports and terminals. STS cranes come in different types, shapes and configurations. Figure 9 illustrates the range of lifting capabilities of modern STS cranes while Table 9 briefly describes their main operating configurations. Other engineering features such as power, stability and maintenance are beyond the scope of this research and are therefore not discussed in this thesis. The same applies to futuristic crane designs and models such as double and triple trolley systems, float quay-ship-barge handling, and in-slip bridge cranes. For a review of engineering features and futuristic designs of STS cranes, the reader is referred to Tack and Hiuat (2000), Iannou et al. (2000), and Bhimani and Jordan (2003).



Twin Lifting

Tandem 40ft

Two Twin 20ft

Triple 40ft

Figure 9: Illustration of lifting capabilities of modern STS cranes

Table 9: Types and characteristics of modern STS cranes
(Source: Compiled by the author from major container STS crane manufacturers)

QC TYPE		**DESCRIPTION**
Shape		
A-frame		A-shaped crane that can be either simple or articulated
Low profile		Minimum height cranes used for reduced visual impact
Configuration		
Cycle mode	Single	Crane travels back empty from shore to ship or vice versa
	Dual	Crane travels full in each direction
Trolley	Rope-towed	The trolley drive, main hoist and boom hoist are located in the machinery house on the frame.
	Machinery-type	The trolley and main hoist drives are located on board
Hoist	Single	One hoist is operating for both waterside (ship) and landside (wharf/apron) operations.
	Dual	Two hoists, one for the waterside and the other for the landside, are exchanging containers in a single cycle-mode shuttle system.
Lifts	Single twenties	The crane spreader can only handle one 20ft (TEU).
	Twin twenties	The crane spreader can handle one 40ft /FEU container or two 20ft at once
	Tandem 40ft / two twin 20ft	Tandem containers are handled by one head block and two spreaders. The spreaders can handle two 40ft, four 20ft, or each of both.
	Triple 40ft	Tandem containers are handled by one head block and three spreaders.

Driven by the developments in container-ship size and technology, the size of STS cranes has more than doubled since the introduction of the first quay cranes in the late 1950s. A first prerequisite of increased ship size is the requirement of longer crane outreach; the latter denotes the efficient length of the crane trolley across ship container deck. Other important factors to consider include crane back-reach, gauge (distance between legs), cycle-time, lift capacity, and lift height. Table 10 depicts relevant features of modern container-ship generations and the corresponding requirements for STS-crane equipment.

Table 10: Relationship between container-ship size and requirements for STS cranes
Data compiled from the top six global quay crane manufacturers: ZPMC, SPMP, Liebherr, Paceco, Kalmar, and Noell (Cargo Systems, 2007^{a}; 2008^{a})

Container-ship's size and generation	Panamax	Post Panamax	Super-Post Panamax	Super-Post Panamax Plus	Ultra-large container ships -ULCS-	
					Suez Max	Malacca-max
	3rd generation	4th generation	5th generation	6th generation	On-order	Concept-design
TEU capacity	3000-4000	4000-6000	6000-8000	8000-12000	13000-15000	16000-20000
Ship draft (m)	11-12	12-14	13.5-14.5	15-16	16-18	18—21
Ship beam (m)	30-32	33-40	40-45	43-50	50-60	55-60
Container rows	Up to 13	13-16	16-18	18-22	22-23	≥ 24
Corresponding requirements for container quay cranes (typical average values)						
Outreach (m)	35-42	44-47	50-55	55-65	70	Over 70
Gage (m)	15	30.5	30.5	30.5	30.5	30.5
Back-reach (m)	9.1	15.2	20	22	23	23
Capacity (LT)	30	40	50	60	65	65

One of the main shortcomings of the current literature on benchmarking port efficiency is that variations in quay crane's size and technology are hardly captured in STS cranes' variable definition and selection. Most authors include the number of STS cranes as a standard variable in the input set, but none has considered or incorporated the variations in crane performance and technology. A recent field study undertaken by Vazifdar and Rudolf (2003) shows that STS cranes' productivity per hour varies greatly across different types of crane generations (see Figures 10 and 11).

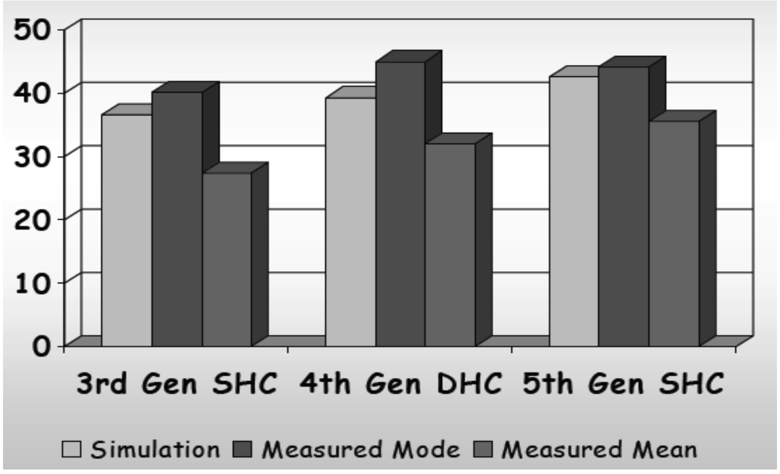


Figure 10: Comparison of cycle time frequency distribution across single hoist crane generations -SHC-, (Source: Vazifdar and Rudolf, 2003)

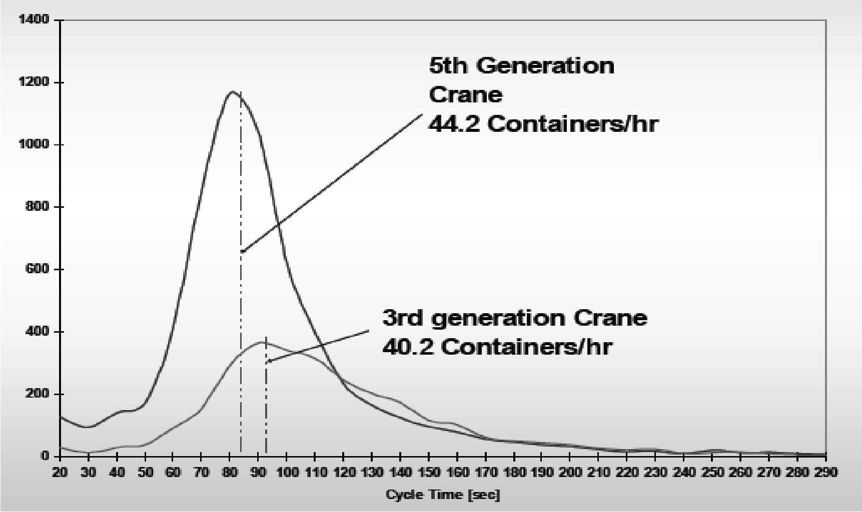


Figure 11: Productivity comparison between 3rd and 5th generations of SHC
(Source: Vazifdar and Rudolf, 2003)

IV.1.2.2 Container yard handling systems

As with the variations in quay crane technology, the port literature on container-port efficiency often overlooks the differences in yard handling systems. Even when various yard equipments are included in the benchmarking dataset, their variable's definition and selection are often incompatible with the configuration typology of yard operations.

Modern container yard configurations depict a variety of cargo handling, transfer and stacking typologies, the aggregation of which results into three generic cargo-handling systems, namely:

1. The tractor-chassis or wheeled system (as opposed to the grounded system),

2. The straddle carrier (SC) and stacking handler systems, which can be based either on a direct system (SCD) or on a relay system (SCR),

3. Yard gantry systems based either on rubber-tired gantry (RTG) or on rail-mounted gantry (RMG) operations, the latter being also assimilated to bridge crane operations.

As with quay cranes, yard cranes and handling equipment also depict different performance and technology features. However, equipment type is only one element of the yard handling system with other operating variables such as terminal size and layout, staking capacity and constraints, availability and cost of skilled labour, and the proportions of traffic and container mix being equally important.

Sometimes, container yards are operated on a hybrid system, for instance when RTG or RMG based configurations use straddle carriers (SC) or other supporting staking handlers such as reach stackers (RS) and front-end loaders (FEL) in interchange points for stacking empty and special containers (see Figure 12 below). Hybrid systems are also found in terminals on a transition phase such as when shifting from a configuration to another (alternating systems). Even though, hybrid systems are usually marked by a dominating configuration. The same applies to automated systems, the operations of which usually follow one configuration or another. For example, yard systems using automated staking cranes (ASC) follow the yard gantry system, while those using unmanned straddle carriers follow the straddle-carrier relay system. When automatically guided vehicles (AGV) are used, they are assimilated to the tractor-chassis system.

Figure 12: Main cranes and handling equipment used in the yard

Table 11 depicts the typical operational features of major container yard handling systems, although such features are constantly changing due to upgrades in handling equipment and technology. Appendices A7 through A11 schematically illustrate the general layout and operating system for each yard-handling configuration. Container handling systems must not be confused with terminal operating systems (TOS), the latter are software products, either developed in-house or bought off-the-shelf (e.g. NAVIS, COSOMS) and used for the execution and monitoring of specific modules of terminal operations such as for berth planning, yard planning, and gate operations.

Because of the unavailability of data on port labour, researchers usually avoid the inclusion of labour data in port benchmarking studies under the assumption that the amount of labour required in a container terminal is proportional to the number of the cranes deployed or equipment used (Marconsult, 1994, Tongzon, 1995, and Notteboom et al., 2000). However, this assumption may be breached when either automated or labour-intensive operations are used.

The main thrust of benchmarking container-port operational efficiency in terms of generic operating typologies (for both quay and yard operating sites) is that each configuration incorporates a corresponding set of capital and labour mix, and thus no cost or labour data is required. Furthermore, the clustering of ports into distinctive configurations is consistent with the variations in crane equipment performance and technology and helps eliminate potential bias in variable (input and output) definition and selection. Equally, the analysis in terms of operating configurations is a perquisite to modelling port processes and security impacts (See the section on IDEF0 modelling in Chapter V). Finally, the desegregation of container terminals into quay, yard and gate operating systems provides insights on the shifts in efficiency at the level of each operating site, which would help in assessing both the individual and combined impacts of security regulations.

IV.1.3 Terminal Operating Procedures

Even with similar quay crane and yard handling systems, port operators may design and implement different terminal operating procedures. The latter include operating policies and work procedures such as opening and service hours (for quay, gate, and/or terminal operations), yard storage policies, strategies for segregation and retrieval, gate-in and gate-out arrangements, cut-off times for loading and late containers, safety and security rules, and procedures for container checking and inspection.

In addition to their central role in improving productivity and operational efficiency, operating terminal procedures are particularly important for planning and implementing security systems design and operations. As described in Chapter II and depending on the type and scope of security regulations, a terminal's security strategy is based on a set of procedures for security assessments and systems design, cargo/vehicle screening and inspection, electronic reporting and information processing, and plans of action and recovery. Therefore, it is reasonable to assume a high correlation between the scope of terminal operating procedures and varying levels of productivity and security impacts. Nevertheless, despite the significant impact of terminal procedures on container-port systems' design and operations (Silberholz et al., 1991; Taleb-Ibrahimi et al., 1993), it seems that they are constantly overlooked by port researchers especially in studies on container-port efficiency and performance benchmarking.

Table 11: Operational characteristics of major container yard handling systems

Data compiled from the top six global yard crane manufacturers: ZPMC, Kone Cranes, Kalmar, Reggianne, FELS Cranes, and Liebherr (Cargo Systems, 2007[b]; 2008[b])

System features	**Tractor chassis systems (wheeled operations)**	**Straddle carrier (SC) systems**		**Yard gantry systems**	
		Direct	Relay	RTG	Rail-Mounted Gantry (RMG)
Equipment	Tractor-chassis sets throughout the terminal	Straddle carriers (Quay transfer + yard operations + gate)	Tractor-trailer sets (quay transfer) + Straddle carriers (yard) + combination at gate	Tractor-trailer sets (quay transfer) + RTG (yard) + lift truck at gate	Tractor-trailer or SC sets (quay transfer) + RMG (yard) + lift truck at gate. RMG may be used for rail gate operations
Average stacking height[*]	1	1over 2 (up to 1 over 3)	1over 2 (up to 1 over 3)	1 over 6 (up to 1 over 7)	1 over 6 (up to 1 over 7)
Average width (by number of container rows)	N/A	1 to 2 wide	1 to 2 wide	6 to 7 wide	9 to 11 wide
Practical storage capacity (TEU/Hectare)	250	500 (based on 1 over 2) 750 (based on 1 over 3)	500 (based on 1 over 2) 750 (based on 1 over 3)	1000 (based on 1 over 4)	1100 (based on 1 over 4)
Land utilisation	Very low	High	High	Very High	Very High
Operating factor[#]	• Good accessibility • Low damage • Labour intensive, but no requirement for skilled labour • Scope for full automation possible	• High flexibility, • Good stacking features • Low labour usage • Suits smaller or odd shaped terminal yards	• High flexibility • Good stacking features • Low labour usage • Less investment needed than direct system	• Good flexibility – can move between stacks • Low labour usage but requires highly skilled labour • Scope for partial automation	• Limited flexibility – cannot move between stacks • Low labour usage but requires highly skilled labour • Scope for partial automation
Terminal development costs	Very low	Medium	Medium	High	High
Equipment cost	Low	Medium	Low to Medium	High	Very High

[*] :Excludes staking height for empties, which can be up to 1 over 8 depending on the equipment used.

[#] : Some modern RTG and RMG cranes offer tandem/twin lifting capabilities. They can also be automated, either partly or fully.

IV.1.4 Factors beyond the Control of Terminal Operators

Productivity benchmarks of container terminal operations depend on factors that are both within and beyond the control of terminal operators. An illustration of controllable and uncontrollable factors in container terminal operations is provided in Table 12.

Table 12: Examples of controllable and uncontrollable factors in terminal operations and management (Source: Author)

Controllable Factors	**Uncontrollable Factors**
• Service and port time / vessel queuing & waiting • Dedicated / priority berthing arrangements • Capacity development and expansion • Terminal layout and configuration • Terminal procedures (including safety & security) • Working hours, shifts and labour arrangements • Handling and storage charges • Type, size and maintenance of equipment • Routing and stacking of containers • Equipment allocation/ vehicle deployment • Berth and yard management systems • ICT and management supporting systems • Customer service / quality of services provided	•Tidal and weather restrictions • Trade pattern, traffic type and mix • Vessel size and type • Pattern and frequency of shipping and inland transport services • Pattern of arrivals of vessels, trucks and trains • Stowage plan and pattern • Container status, type, and dimensions • Landside logistics patterns and arrangements • Customs and trade related procedures • Environmental, safety and security regulations • Other regulatory requirements

An important part of the judgement of variable selection in port benchmarking studies lies in the understanding of the interplay between controllable and uncontrollable factors. On the one hand, only variables derived from controllable factors should be included in the benchmarking analysis. On the other hand, the extent to which uncontrollable factors influence port efficiency should also be considered. Even though, the definition of what constitutes a controllable variable and what constitutes an uncontrollable variable is not always consistent between studies on port efficiency.

Take for instance terminal configuration and capacity expansion factors, which are considered as controllable factors by most port researchers, but this assumption must depend on the nature and objectives of the benchmarking exercise. If the focus is on long-term planning and strategy, then most decisions on terminal configuration and capacity expansion will lie under the control of terminal management including such aspects as the reconfiguration of terminal layout and the development of additional terminal capacity. If, on the other hand, the focus is on short-term planning and operations, then container terminals will only be able to control operational factors such as in terms of new planning procedures and/or investment in short-term superstructure capacity, e.g. equipment and warehouses as opposed to terminal infrastructure.

Another instance of the interplay between controllable and uncontrollable factors occurs when terminal operators are able to exercise some degree of control over uncontrollable factors. This is the case for port operators who also operate logistics centres and related intermodal facilities. Shipping lines that own and/or operate container terminals are also able to influence trade patterns and service frequency in ways that favour a port or another. Therefore, the definition and selection of model variables should rely on a thorough understanding of the interplay between controllable and uncontrollable factors within the context and objectives the port benchmarking exercise.

IV.1.5 Formulating Operational Hypotheses

From the above discussion, we demonstrate that the prescribed need to link theory and container port practice conforms to the theme and objectives of this research in terms of investigating both procedural security and operational efficiency. In this context, we formulate a number of operational hypotheses for further testing and validation:

- There is a positive correlation between the size of container terminals and their operational efficiency,
- There is a positive correlation between incremental investment in port capacity and the decline in productive efficiency,
- There is a positive relationship between container terminal efficiency and the rate of transhipment incidence
- There is a positive relationship between container terminal efficiency and the proportion of cargo mix (FEU vs. TEU sizes, empty vs. full containers, LCL vs. FCL containers, etc.)
- There is a positive relationship between container terminal efficiency and the type of handling and configuration system
- There is a positive relationship between container terminal efficiency and the nature of operating policies and work procedures
- The operation of container terminals exhibits disproportionate performance levels between terminal sub-systems and operating sites

IV.2 Potential Methods for the Research Problem

This research attempts to assess and analyse the ex-post security impacts on the operational efficiency and performance benchmarking of container terminals. The research problem can be formulated as follows: '*what is the impact of procedural security on the efficiency of container port and terminal operations?*'

To direct the problem more precisely, three research questions are used:

- *Q1: What is the operational and procedural scope of port security programmes?*
- *Q2: How can container-port operational efficiency be measured and benchmarked?*
- *Q3: How can we measure and quantify the impact of procedural security?*

Answering these questions offers grounds for selecting applicable research tools and techniques of analysis. Based on the above discussion about the need to understand port practice, security procedures must be captured in terms that fit container-port configurations, operating sites, and handling systems. This could be then linked to the measurement of operational efficiency, providing comparative benchmarks of productivity changes before and after the introduction of port security measures. Security impacts can therefore be assessed in terms of efficiency gains or losses, both over time and across container terminals. To conform to this approach, three analytical techniques are required, namely:

(1) Prescriptive modelling for mapping terminal processes and security procedures,
(2) Analytical benchmarking for measuring and comparing container-port efficiency,
(3) Productivity change analysis for assessing the impacts of security regulations.

IV.2.1 Process Description and Function Modelling: IDEF0

Process modelling uses a variety of tools such as systems engineering, functional economic analysis, Petri-nets, and IDEF (Integration Definition) techniques. The IDEF methodology was derived from a well-established graphical language known as the structured analysis and design technique (SADT). In the late 1980s, the US Air Force launched the Integrated Computer Aided Manufacturing (ICAM) project to develop a modelling method to help with designing and managing its process of supplier development and evaluation. The IDEF family includes several tools each for modelling a particular perspective, with IDEF0 for function modelling being the most suitable for prescriptive mapping of terminal operating processes and security procedures. Function and process modelling provide the framework required to analyse and redesign workflows and business processes of actual container-port operations and achieve improvements in system’s performance both at individual and aggregate operating processes.

IDEF0 models are composed of three types of information: graphic diagrams, text, and glossary. The graphic diagram is the major component of an IDEF0 model, containing boxes, arrows, box/arrow interconnections, and associated relationships. In its original form, IDEF0 includes both a definition of a graphical modelling language (syntax and semantics) and a description of a comprehensive methodology for developing models. The two primary modelling components are functions represented on a diagram by boxes, and the data and objects linking those functions and represented by Inputs, Controls, Outputs, and Mechanisms (ICOM) arrows. The semantics of IDEF0 boxes and arrows is shown in Figure 13 below.

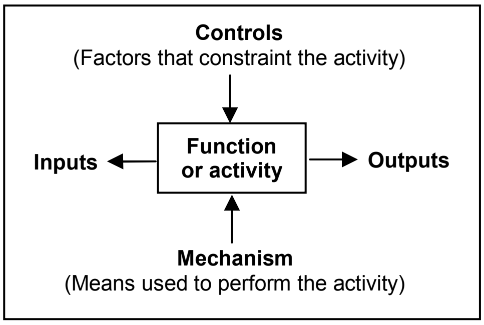


Figure 13: Semantics of IDEF0 box and arrows (Source: Author)

The result of applying IDEF0 to a system is a model that consists of hierarchical cross-referenced series of diagrams, text and glossary. Boxes or functions are decomposed into diagrams that are more detailed until the subject is described at a level necessary to support the goals of a particular project. As illustrated in Figure 14, the top-level diagram of the model provides the most general or abstract description of the subject. It is then followed by a series of child diagrams providing more details about the subject. For a detailed description of the IDEF0 method, the reader is referred to Mayer (1992), Colquhoun et al. (1993), and Jorgensen (1995).

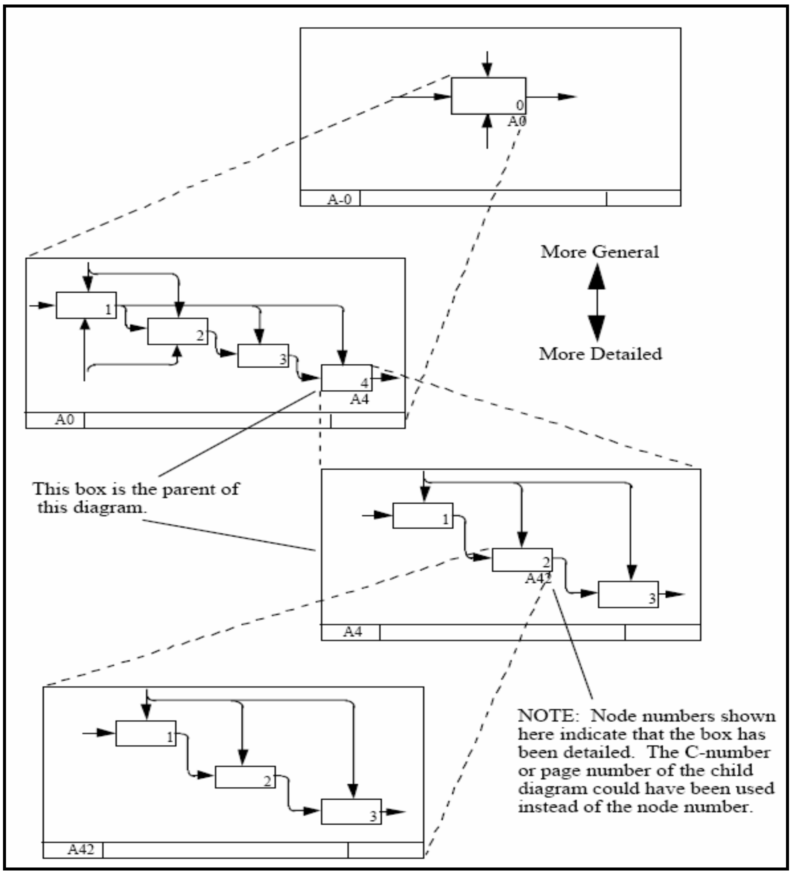


Figure 14: IDEF0 decomposition structure
(Source: Barletta and Bichou, 2007)

Over the years, a series of standard IDEF0 functional modelling diagrams were developed for different system enterprises such as manufacturing, production, and logistics systems (Slats et al., 1995). There is indeed an extensive literature on various applications of the IDEF0 technique in the logistics industry, but with only a few applications in ports - see for instance Paik and Bagchi (2000), and Barletta and Bichou (2007).

IV.2.2 Analytical Benchmarking: DEA Models and Site-Specific Datasets

The objective of benchmarking is to compare the efficiency of carrying out a particular activity or group of activities either at a point in time or over time. In Chapter III, we reviewed benchmarking methods applicable to port operations and demonstrated that any benchmarking analysis should be defined relative to an assessment of best practice, in other words the level of efficiency should be measured relative to an efficiency frontier. We also showed that several benchmarking techniques can be used to estimate the efficiency frontier and these are classified into two main categories: econometric (parametric) techniques versus programming (non-parametric) techniques. Econometric models require an assumption about the relationship between inputs and outputs and estimate the parameters of a cost or a production function. Programming models, in contrast, relate outputs to inputs without recourse to econometric estimation and the efficiency is estimated directly from the data.

Further discussions on the advantages and disadvantages of each technique as well as on the features of port operating systems have shown that programming techniques are most suited to benchmarking operational efficiency for assessing the ex-post impacts of procedural security. In particular, the structure of container port production depicts different handling configurations and operating systems, which makes the estimation of a functional form under SFA very difficult to apply in the context of international port benchmarking. Programming techniques are less restricted to sample size than econometric models, and can estimate technical efficiency for both individual inputs and the overall production process. Moreover, both the multi-output nature of port production and the lack of detailed data are likely to limit the practicality and reliability of econometric methods. On such grounds, we advocate the use of programming techniques namely in the form of a series of data envelopment analysis (DEA) models.

In order to estimate and compare efficiency scores under a stationary frontier over time, we conduct contemporaneous and inter-temporal DEA analyses using cross-sectional and panel data, respectively. In the context of cross-sectional data, the contemporaneous approach compares observation units within the same time-period, e.g. a year. In the context of panel data, the inter-temporal approach pools all data over the total time observed, e.g. total number of years. By using both approaches, a DMU is benchmarked against varying sample sizes while still assuming constant technology over time.

In addition to estimating the efficiency of DMUs within the aggregate dataset, contemporaneous and inter-temporal approaches are also used to analyse the efficiency of observation units relative to alternative DEA models and site-specific datasets. The utilisation of different DEA models and datasets conforms to the objectives of this research in terms of analysing the interplay between terminal sites and operating configurations. On the one hand, container terminal systems portray different operating configurations that require alternative DEA models capable of capturing the variations in handling and production technologies between and within terminals. On the other hand, the structure of container terminal production depicts a network-type operating process that necessitates detailed analysis by site-specific and network-related efficiency. The specification and operationalisation of relevant DEA models and site-specific datasets are provided in Chapter V.

IV.2.3 Productivity Change Analysis: TFP Malmquist DEA

Although contemporaneous and inter-temporal analyses are useful for estimating and comparing technical efficiency, they can be misleading in a dynamic context because neither approach accounts for possible shifts of the frontier over time. Furthermore, there is no means of checking whether the frontier is moving or stationary over time.

To ensure a DMU's efficiency is tracked over time while allowing for shifts in the efficiency frontier, several time-dependent versions of DEA have been developed, notably DEA window analysis. Under DEA window analysis, also referred to as window DEA, DMUs in selected time-periods are included simultaneously in the benchmarking analysis. Depending on the width of the window, the technique may be conducted in terms of contemporaneous, inter-temporal and locally inter-temporal analyses (Charnes, 1985; Asmild et al., 2004). Contemporaneous and inter-temporal analyses correspond to the basic DEA approaches described above where the window width is equal to 1 (one) and T (total time or number of years observed), respectively. The locally inter-temporal analysis compares subset DMU observations at different but successive time windows where each DMU-observation is only compared with the alternative subset in the single window, assuming a constant frontier during each window. Under this approach, the window width is larger than one and less than all periods combined, but it is usually set for a three-year period. Cullinane et al. (2004) used this approach when they applied DEA windows analysis to track the productive efficiency of 25 major container ports between 1992 and 1999.

Although the locally inter-temporal window analysis seems an attractive technique for tracking changes in efficiency over time, it has many limitations. First, the technique is akin to a moving average procedure where the technology remains constant in each window. Second, a DMU under window DEA is only compared with a subset of data and not with the whole data set. Indeed, the width of the window is usually defined arbitrarily given that no underlying theory or analytical evidence that validates the choice of a particular window size exists. In the context of benchmarking container-port efficiency, the overlapping subsets derived from successive windows wrongly imply that the container port production is somehow discontinuous over the study period. Last, but not least, because the efficiency of a DMU observation in a particular window is calculated more than once and hence included in several windows, it is not obvious how to define the frontier in the same window-period. This issue hinders the application of total factor productivity (TFP) analysis such as through the Malmquist productivity index (MPI). For instance, Asmild et al. (2004) recommended that it is not appropriate to decompose Malmquist indices based on window DEA into standard frontier shift and catching up effects.

In view of the above, we advocate the use of Malmquist DEA in favour of window DEA. The Malmquist TFP index, or Malmquist Productivity Index (MPI), requires the estimation of a distance function but the latter can be directly specified under DEA. The approach adopted in this thesis is to apply a stepwise Malmquist DEA analysis, both on a year-by-year basis and on a regulatory-period basis.

In applying the stepwise Malmquist DEA, we can exploit panel data for both efficiency measurement and analysis of TFP growth. This approach provides a sound basis for benchmarking container-terminal efficiency with a view to tracking the shifts in frontier technology over time. The calculation of the MPI should also indicate whether any convergence in port productivity rates has taken place over time, especially in the aftermath of the new security regulations. Another advantage of the MPI is the ability to decompose total factor productivity into various sources of efficiency, mainly into a measure of total technical efficiency change (TEC) representing the catching up effect and a measure of technological change (TC), which represents the shift in frontier technology. TEC can be further decomposed into a measure of pure technical efficiency change (PEC) and a measure of scale efficiency change (SEC). This can shed further light on the interplay between the impacts of procedural security and the sources of changes in TFP over time and between container terminals.

IV.3 Research Design and Procedure

From the above discussion, it appears that there is a methodological difficulty in linking procedural security with port efficiency and benchmarking. On the one hand, benchmarking port's operational efficiency necessitates an analytical framework that (i) captures terminal sub-systems and operating procedures, (ii) incorporates technology and performance variations across container port handling systems, and (iii) seeks to identify best-class operational performance. On the other hand, assessing the ex-post impacts of security requires (iv) a full understanding of security systems' design and operations, (v) a detailed analysis of the spatial and operational scope of security regulations, and (vi) appropriate techniques for analysing the impact of procedural security. An integrative approach is therefore required. To achieve this, we design a research procedure that links and integrates the above components through a logical chain of influence and relationships (see Figure 15):

- Starting from exploring the range and scope of port security regulations, we identify their spatial scope of influence with respect to container-terminal operating sites (quay, yard and gate). The prescribed operating sites and sub-systems are the result of (i) a structured categorization of port configurations and (ii) a detailed IDEF0 modelling of port processes. For the former, we disintegrate container-port operations into three intersecting sets of configurations: the spatial configuration (terminal operating sites), the process configuration (process flows and operating procedures), and the physical configuration (terminal handling systems). For the latter, we develop an abstract top-level IDEF0 model for container-port operations, which we disaggregate later into various IDEF0 sub-models, each corresponding to a particular container flow process (inbound, outbound, and transhipment) across various sites and configurations.

- In the next phase, we use the outcome of port configurations and IDEF0 modelling to identify parameter standards and key performance indicators for variable definition and selection. This is then contrasted against the available information from the container-port sample to make up the final dataset of input and output variables. Both the dataset and the sampling frame are designed in terms that fit the analytical framework and methods used for this study.

- In the final phase, we start by applying inter-temporal and contemporaneous analyses to estimate and compare operational efficiency under constant technology, and then apply the stepwise Malmquist DEA in order to assess total productivity growth while allowing for shifts in frontier technology. Both approaches are modelled and adjusted in order to conform to the objectives of this research in terms of analysing the interplay between operational efficiency and procedural security. On the one hand, we specify a number of alternative DEA models in order to analyse both site-specific and network efficiencies, and test the impacts of operational and exogenous factors on container port productivity. On the other hand, we apply the stepwise Malmquist DEA on both multi-year periods and regulatory runs, and decompose the MPI into various efficiency components in order to track different sources of productivity growth over time, including before and after the introduction of security regulations.

IV.4 Chapter Conclusion

We started this Chapter by reviewing container-port practice, focusing in particular on operating systems, equipment technology, handling configurations, and working procedures as well as on the exogenous factors that are outside the control of terminal operations and management. From this review, it seemed that the existing literature on procedural security and operational efficiency does not proceed deeply enough to disaggregate container-port systems into terminal operating sites and processes, or to incorporate technology and performance variations in terminal equipment, handling systems, and operating procedures.

Following further discussions on the need to understand port practice and security procedures, we formulated a number of operational hypotheses for further testing and analysis. We then proposed an integrative research approach with the objective of linking operational efficiency with procedural security. In particular, we selected and justified the relevant techniques of analysis, namely IDEF0 for prescriptive modelling and mapping of container-port processes, DEA for the measurement and benchmarking of terminal efficiency, and MPI for analysing productivity change an assessment of security impact.

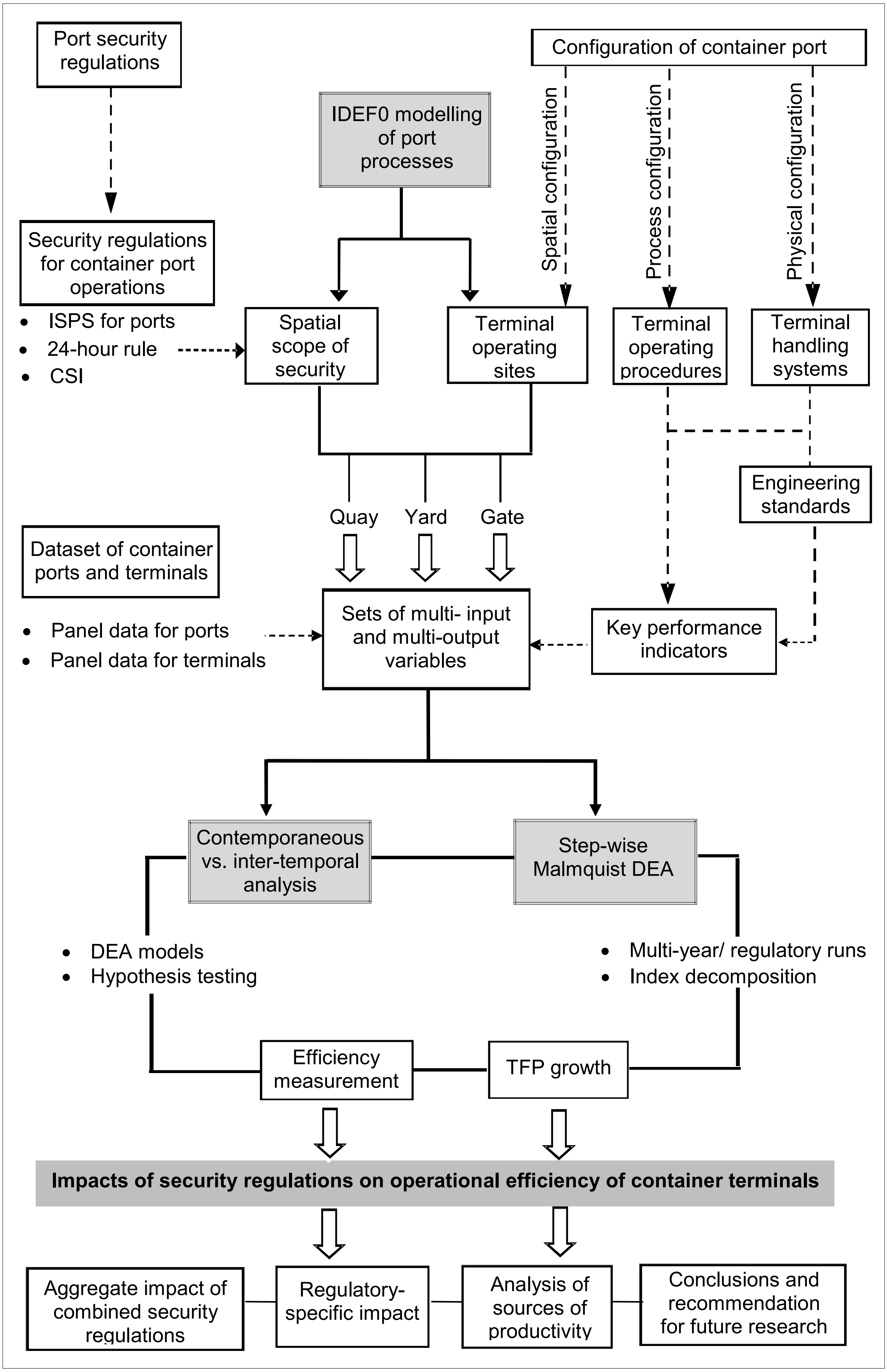


Figure 15: Research design and process followed in this study (Source: Author)

CHAPTER V: OPERATIONALISATION

This Chapter deals with the operationalisation and application of the approach and methodology selected for this study. This is done in three phases:

- First, we build IDEF0 models and diagrams for container terminal operations and their sub-processes. The IDEF0 modelling of container terminals' operating processes is a pre-requisite to analysing the spatial scope of security regulations and identifying relevant key performance indicators (KPIs) and variables for efficiency measurement and performance benchmarking.

- Next, we formalise the analytical models and techniques of analysis. Based on the results of the IDEF0 modelling, we specify several DEA formulations and decompose the Malmquist Productivity Index (MPI) with a view to assessing both operational efficiency and productivity change analysis.

- Finally, we define the sampling frame and variable selection, and describe the methods and sources of data collection. We then present both the aggregate and specific datasets, and validate their definition and selection in view of DEA and MPI analyses.

V.1 IDEF0 Modelling

Unlike simulation languages that build predictive mathematical models, IDEF0 modelling is a reliable and effective technique for describing and analysing process components and the interactions between them, providing a logical and structured functional model. IDEF0 modelling has a dual advantage in the context of analysing both procedural security and container-port efficiency. On the one hand, its decomposition structure allows the analysis of security regulations in terms of their spatial scope and procedural requirements. On the other hand, the ICOM (Input, Output, Control and Mechanism) structure can be used for evaluating functional and system's performance based on an input-output analysis, hence providing a basis for DEA model definition and variable selection.

Note that IDEF0 modelling does not incorporate the time dimension of prescribed processes and relationships such as crane cycle time or container inspection time. Such analysis may be performed by another IDEF methodology, for instance the IDEF3 for process description capture. However, the latter requires detailed time-based information on the behaviour of each terminal in the sample, and therefore it cannot yield generic descriptions applicable to standard container terminal operating processes. Moreover, the information required under IDEF3 modelling is hardly available since it is considered too confidential by terminal operators. However, certain standard control-time variables such as terminal opening hours and gate cut-off times are published by most terminals or by shipping lines using them. We use these variables in our dataset as they can also be captured by the IDEF0 structure.

In designing IDEF0 models, we follow a two-step approach. First, we design the top-level IDEF0 model for the function '*Operate Container Terminal*' based on a general abstraction of the subject as viewed from the perspective of the terminal operator (IDEF0 viewpoint). We then decompose this top-level function into detailed and interlinked sub-functions in order to record operational and flow processes at the level of individual operating sites. Further analysis of container flows and of the variations in the scope of security shows that several IDEF0 models are needed for analysing container flows and security measures within and across terminal sites.

V.1.1 Building the Top-Level IDEF0 Diagram

The starting step in IDEF0 modelling is to design the top-level diagram of the model by defining the most general description (parent function) of the subject, its ICOM semantics, and the objects that should fit into those categories. Following the selection of container terminals as the main decision making units (DMUs) for this research, we specify the function A0 '*Operate Container Terminal*' as the high level abstraction of the subject under study and define its ICOM elements as shown in Figure 16. Note that in line with the features of IDEF0 structure and the objectives of this modelling exercise, we do not incorporate exogenous factors that either fall outside the scope of container-terminal operations or are beyond the control of the terminal operator. Also, note that due to data unavailability, we exclude from the modelling exercise financial flows associated with handling operations and cargo movements.

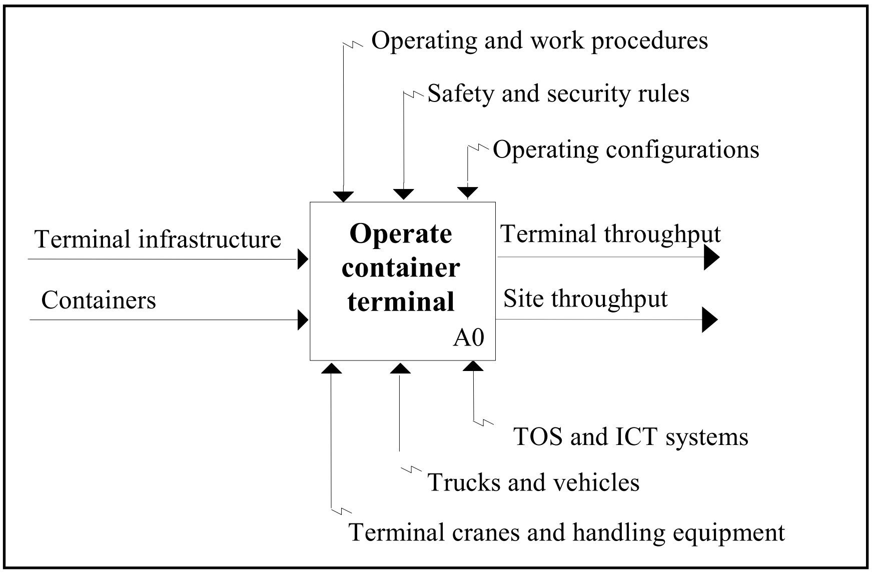


Figure 16: IDEF0 top-level diagram for container terminal operations (Source: Author)

- Inputs describe items that trigger the activity, which in production and logistics systems include station and material's information a manager or operator needs to have in order to perform an activity. For the top-level A0 function 'Operate container terminal', we define the two input elements as terminal infrastructure and containers. Information on the first input encompasses the infrastructure of both the terminal and its sub-systems (quay, yard and gate). For the second input, we include information on categories (type, size and status) of containers that pass through the terminal. Input elements under the IDEF0/ICOM structure must not be confused with the input set for production frontiers; the latter can also include Controls and Mechanisms.

- Controls are the constraints of the system that guide or regulate the activity. In container-port operations, controls correspond to operating and procedural constraints translated in our top-level function into operating and work procedures, safety and security rules, and operating configurations. An important feature of IDEF0 modelling and ICOM syntax is that Controls must also include constraints determined by the function taking place earlier in the production process.

- Outputs describe the output of the transformation process. It can be expressed in different production or measurement units such as time, quantity, or quality. For port production, this process is usually specified in terms of physical outputs mainly terminal's throughput. We use the latter for the abstract function but also include site (quay, yard and gate) throughput as we decompose further the top-level diagram.

- Mechanisms comprise people, equipment and systems used to perform the activity. In the terminology of port operations and management, mechanisms correspond to port superstructure and operating systems. In our case, mechanisms for operating container terminals are identified as terminal cranes and handling equipment, trucks and vehicles, TOS and ICT systems. The latter include EDI and port community systems, planning modules, scanning and identification systems, and positioning and routing devices. Note that we have not included information on labour as a resource mechanism since such information is incorporated in handling and operating configurations.

V.1.2 Decomposing the Parent Diagram

Available process and enterprise models for container port systems often depict terminal operations in a network of sequenced planning, execution and monitoring tasks, which do not capture port spatial components and the interactions between them, particularly in the context of performance measurement and assessment.

In view of the need to disaggregate container-terminal operations into various operating sites and sub-systems, we decompose the parent function in Figure 16 into three linked sub-functions reflecting the operations of terminal sites and the interactions between them. Because in real-world terminal operations container flows across different sites are multi-directional (i.e. from quay to gate and vice versa), we use multiple IDEF0 models to accommodate these flows.

Table 13: ICOM syntax for the IDEF0 decomposed model (Source: Author)

ICOM	Terminal level description	Site-level description	Spatial scope
Inputs	I1: Infrastructure	I11: Terminal area	Terminal
		I12: Terminal capacity	Terminal
		I13: Quay length	Quay site
		I14: Number of berths	Quay site
		I15: Berth draft	Quay site
		I16: Yard stacking capacity	Yard
		I17: Number of gates/ rail tracks	Gate
		I18: Number of gate lanes	Gate
	I2: Containers	I21: Inbound containers	Terminal
		I22: Outbound containers	Terminal
		I23: Transhipment containers	Quay and yard
Controls	C1: Operating and work procedures	C11: berth working hours	Quay site
		C12: Work shifts	Terminal
		C13: Yard storage policy	Yard
		C14: Gate working hours	Gate
		C15: Gate closing time	Gate
	C2: Safety and security rules	C21: Driving and safety rules	Terminal
		C22: ISPS code	Terminal
		C23: CSI	Quay and yard
		C24: 24-hour rule	Gate and yard
	C3: Operating configurations	C31: Quay crane configuration	Quay site
		C32: Yard crane configuration	Yard
		C33: Yard handling system	Yard
Outputs	O1: Terminal throughput		Terminal
	O2: Site throughput	O21: Loaded containers	Quay site
		O22: Discharged containers	Quay site
		O23: Transferred containers	Quay and yard
		O24: Stacked containers	Yard
		O25: Gate-in processed containers	Gate
		O26: Gate-out processed containers	Gate
Mechanisms	M1: Terminal cranes & handling equipment	M11: Quay cranes	Quay site
		M12: Yard cranes and handling equipment	Yard
	M2: Trucks and vehicles	M13: Internal trucks and vehicles	Terminal
		M14: External trucks	Gate
	M3: TOS and ICT systems	M31: EDI and port community systems	Terminal
		M32: Identification technology	Gate and yard
		M33: Routing and positioning	Terminal
		M34: Ship-by plan	Quay site
		M35: Berth plan	Quay site
		M36: Yard plan	Yard

To achieve this, we segregate container flows into inbound (import), outbound (export) and transhipment flows; each with a different site affiliation and ICOM structure as shown in Table 13. This decomposition is central to modelling container-port operations because otherwise terminals may be shown as being exclusively dedicated to import, export, or transhipment operations. Once the detailed ICOM structure is defined, we then link the ICOM arrows to various operating sites at the level of each operational and process flow, resulting into three IDEF0 models as shown in Figures 17 to 19. The iGraphs Product Suite 2007 (iGraphs, 2008) for IDEF0 modelling was used as the main software for creating fully compliant IDEF0 diagrams.

Note that in Figures 17 to 19, some arrows representing the ICOM syntax are '*tunnelled'* either at the connected or at unconnected end from/to the box. Tunnelled arrows that connect to the box indicate that the data conveyed is not necessary at the next level of decomposition and does not have to show at all levels of the model. On the other hand, tunnelled arrows at the unconnected end indicate that the data conveyed is not relevant to or supplied by the parent diagram. In IDEF0 detailed diagrams, tunnelled arrows may be either detached from the activity box or simply deleted from the child diagram, the latter option has been followed in our detailed IDEF0 models.

V.1.2.1 Import flow

For the import flow, inbound containers are discharged at quay using data and information from the ship's by-plan profile, which is also used for yard planning and staking assignments. The unloaded containers are then transferred via internal trucks and vehicles to the yard where they are stacked before being dispatched through the gate by external trucks. To support and manage the container import flow, TOS and ICT systems are used throughout the process, mainly in the form of EDI, port community and information management systems (IMS), identification technology (e.g. RFID, GPRS, Wireless-Lan), and positioning and routing assignments. The processing of data exchange (cargo tracking, work schedule documents, (un)loading sequence sheets, etc.) and billing information (electronic manifests, bills of lading, etc.) is treated both here and for other terminal flows as part of EDI and port community systems despite many ports worldwide still operating through a paper-based documentation system.

In addition to operational constraints such as work shifts, berth and gate working hours, and driving and safety rules, the configuration typology for both quay and yard sites is a key factor in the operations of both sites and in the management of the container terminal as a whole. For yard operations, the free storage policy (number of days during which containers can be stored free of charge), the status (FCL, LCL, empty) and size (TEU, FEU, non-standard) of containers are key elements in yard operations. However, the status of containers is being categorised here in terms of empties and non-empties only. This is because container freight stations (CFS) in modern ports are usually located outside the container terminal area, which eliminates the need to disaggregate containers by their LCL or FCL status.

An important control variable for container terminal operations is the security framework being put in place. In the context of the new security regime, not only the new regulations directly affect the design and implementation of cargo inspection and release process, but the variations in security threats and compliance levels (e.g. ISPS MARSEC levels) also affect procedural planning and execution of terminal operations. In the import-flow IDEF0 model, only the ISPS code is included as a control variable since both the CSI and the 24-hour rule are targeted exclusively at export and transhipment operations.

V.1.2.2 Export flow

For the export flow, external trucks and vehicles carrying outbound containers enter to the terminal through the gate and may either proceed directly to the yard or go to an interchange area where they exchange the containers with internal trucks. Following a waiting period in the yard, outbound containers are transferred to quay where the loading operation takes place. Two major features in container's export flows must be considered. First, the cut-off time informs about the gate closing time for outbound containers before ship's departure. Second, yard planning and staking arrangements are executed in generic assignments until detailed information about vessel loading list and profile are received and confirmed.

Another important aspect is the spatial scope of export-oriented security measures, namely the CSI and the 24-hour rule. For the CSI, the pre-screening and inspection of export containers by CBP officials in non-US ports (or their counterparts in US ports) may take place either in the yard or in the interchange area between the yard and the quay site. As for the 24-hour rule, the regulation does not primarily target ports but its application has a direct impact on container terminal operations because containers whose details have not been reported according to the Rule are denied loading on board the ship and may have to wait in the yard until the next ship's schedule. To avoid this, some shippers prefer expediting their containers several days in advance of ship's schedule, especially in cases where a container terminal displays a generous free yard storage policy. Conversely, shippers may decide to send their export cargo at the last moment, especially when gate cut-off times before ship's departure are reduced to the minimum; which may result in potential congestion problems at terminal gates.

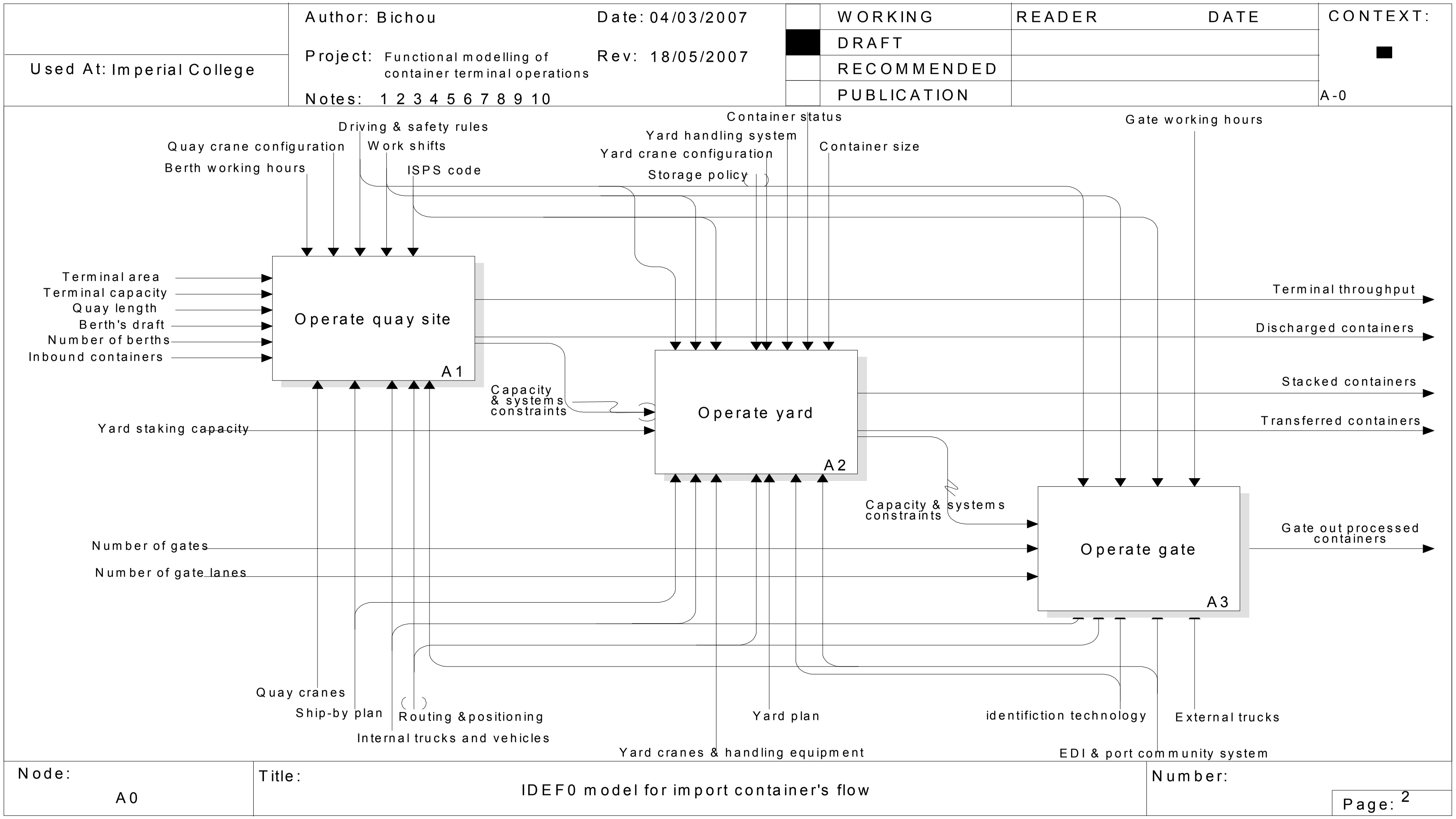


Figure 17: IDEF0 model for import container's flow (Source: Author)

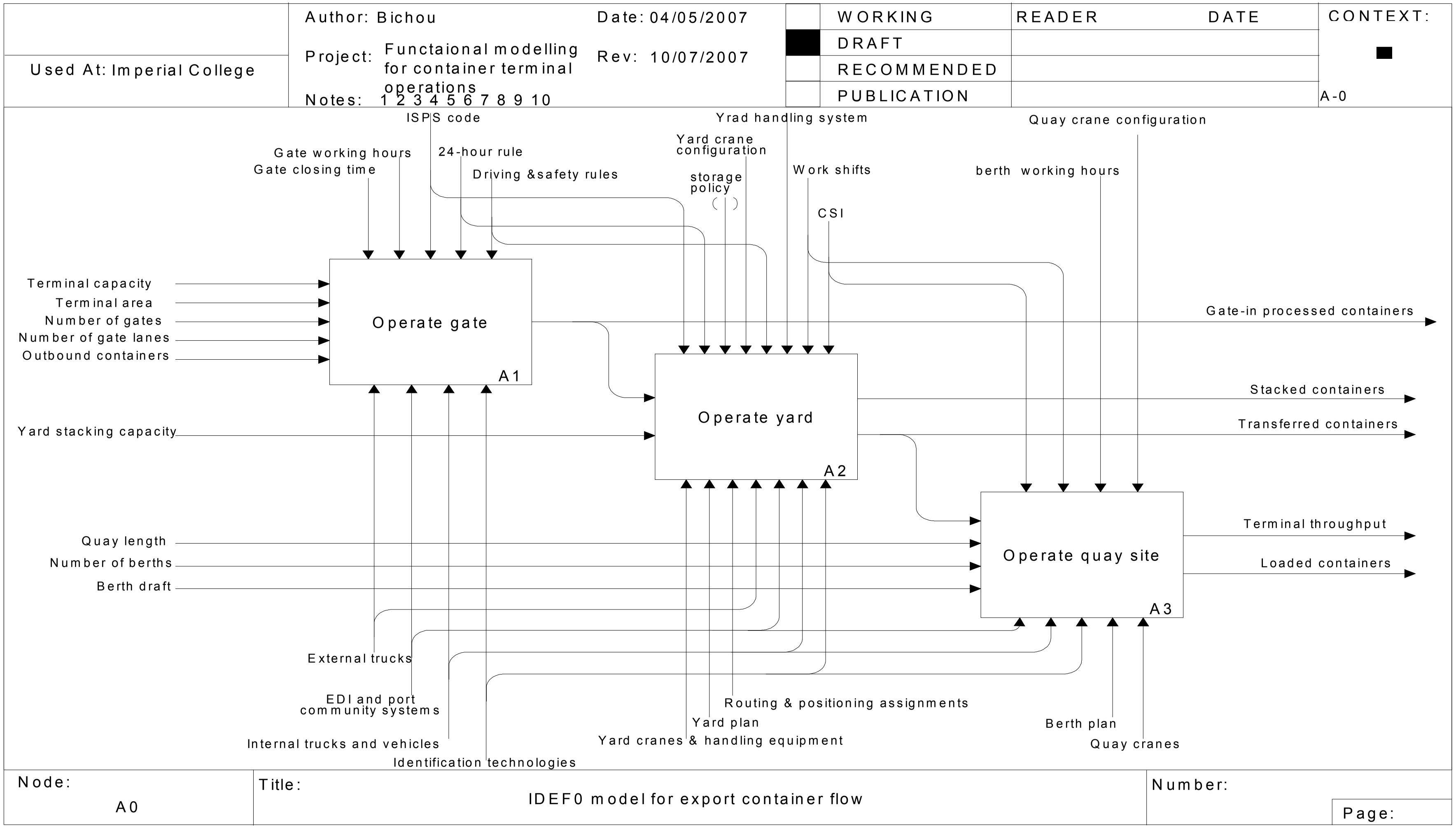


Figure 18: IDEF0 model for export container's flow (Source: Author)

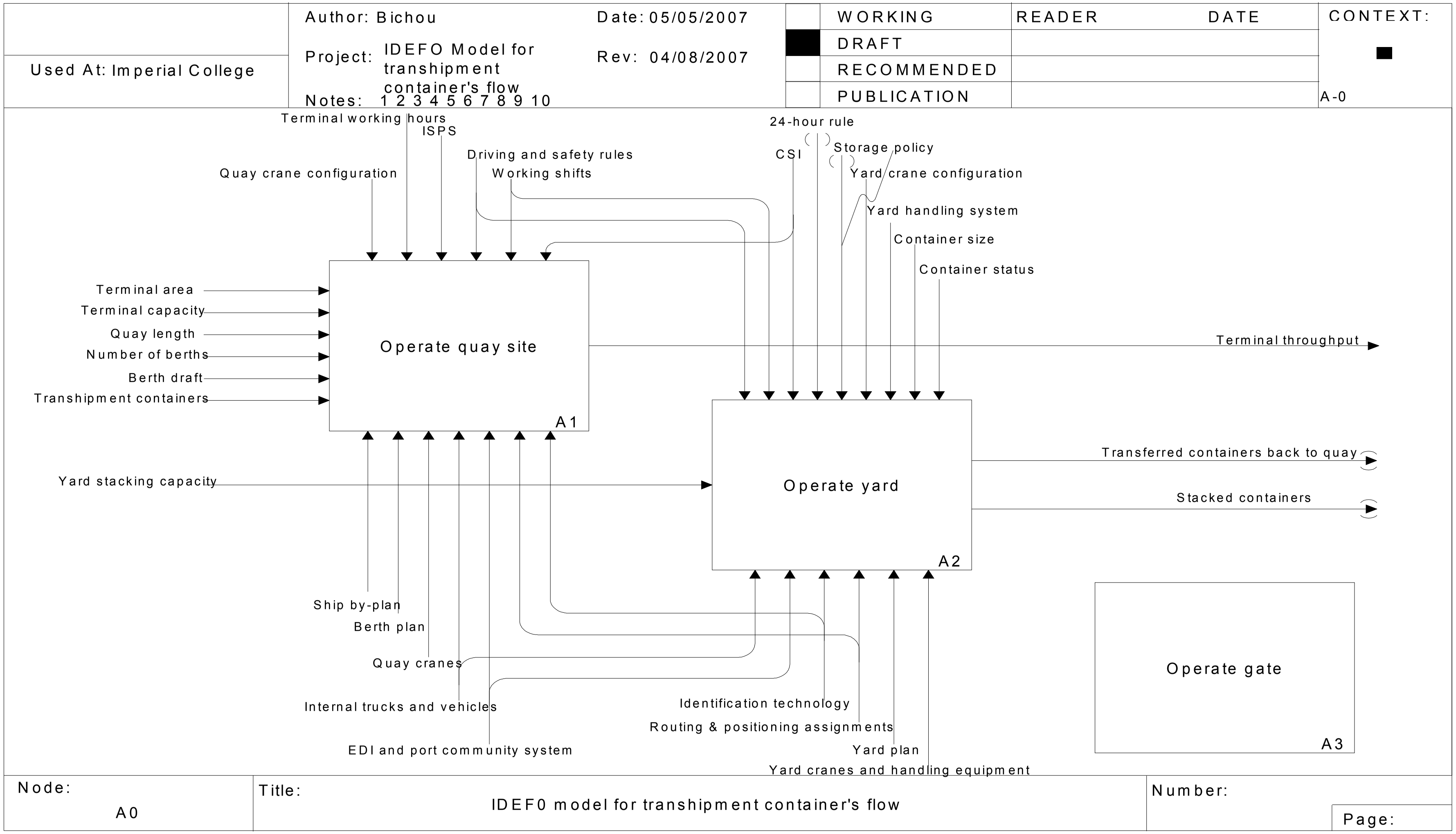


Figure 19: IDEF0 model for transhipment container's flow (Source: Author)

V.1.2.3 Transhipment flow

For the transhipment flow, containers follow a sequence combining export and import flows without using or passing through the gate site. Note the corresponding changes in the ICOM syntax and data objects, including the adjustment in the spatial scope of security regulations.

V.2 Formalising the Methodology

In this section, we formalise the analytical techniques selected for efficiency benchmarking and productivity change analysis. On the one hand, we specify several DEA formulations in terms that capture both the network structure of container-terminal operations and the exogenous factors affecting terminal's productivity. On the other hand, we decompose the Malmquist TFP index into various sources of efficiency in order to both assess the impacts of procedural security and track the shifts in frontier technology.

V.2.1 DEA Models

V.2.1.1 Measure specific DEA

The slack-based DEA model specified in equation (12) is primarily used to benchmark the efficiency of container-terminal DMUs and assess the joint influence of the three regulations (ISPS, CSI, and 24-hour rule) under consideration in this study. However, we also want to assess the individual impact of each security measure and this can be achievable by excluding the operating sites (and their corresponding input and output variables) that fall outside the spatial scope of the security measure under study. Measure specific DEA models allow this assessment. They can also be used to model uncontrollable inputs and outputs. Note that because of the network structure of container-terminal operations, this approach is not without bias. Excluding one operating site or another in order to assess the impact of a specific security regulation may distort this network structure. However, a refined analysis necessitates detailed terminal operational data, the latter being hardly reported or made available by world container ports and terminals.

Let $I \subseteq \{1,2,3,...m\}$ and $O \subseteq \{1,2,3,...s\}$ represent the set of specific inputs and outputs of interest (controllable variables), respectively. We can then obtain a set of measure-specific models where only the inputs associated with I or the outputs associated with O are optimised:

$$
\begin{aligned}
& Min\ \ \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\
\text{s.t.}\quad & \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{ik} \qquad i \in I \\
& \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{ik} \qquad i \notin I \qquad i = 1,2,3 \ldots,\ m \\
& \sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rk} \qquad\qquad r = 1,2,3 \ldots,\ s \\
& \sum_{j=1}^{n} \lambda_j = 1 \qquad\qquad\qquad j = 1, \ldots, n \\
& \lambda_j \geq 0
\end{aligned}
\tag{13}
$$

V.2.1.2 Supply chain DEA

In view of the IDEF0 description of the structure of container-terminal operations, a container terminal would be best modelled as a network of interrelated sub-processes. However, the complexity of the container-flow process and the unavailability of relevant data usually act against developing an applicable network DEA model.

DEA models that have attempted to model the internal structure of DMUs have been developed and applied successfully in sectors other than ports and shipping. Färe and Grosskopf (1996) have pioneered a line of research, coined network DEA, aimed at modelling general multi-stage processes with intermediate inputs and outputs. Their representation of the flow of product is consistent with the engineering and industrial economics literature on multi-stage systems where each internal stage's technology is modelled using a single stage DEA model. Another line of research that is worth mentioning has been initiated by Zhu (2003; 2005) and Zhu et al. (2006) and aims at developing DEA-based supply chain models to measure the aggregate efficiency of a supply chain and calculate the set of optimal values for intermediate performance measures that establish an efficient supply chain. Further literature on the specifications and applications of those types of models can be found in Färe and Grosskopf (2000), Chen and Zhu (2004), Liang et al. (2006), and Biehl et al. (2006).

In ports, DEA applications to-date have not yet modelled the internal structure of the port system, and we are not aware of any published work having developed a DEA-model aimed at capturing the transformation process within the container-terminal and across its sub-systems. There exist indeed a number of methodological difficulties against developing a DEA benchmarking model capable of capturing the complex network structure of container terminal operations as illustrated in Figure 20 below.

- The internal structure of container terminals depicts neither a serial multi-stage flow nor a hierarchical supply chain process through which the product passes forward, but is composed instead of several operating sites linked to each other multi-directional and by simultaneous container flows and processes.

- The linkages of inputs and outputs between the stages are not always evident to define, in particular when one subsystem's efficiency must be improved at the expense of efficiency deterioration in another subsystem.

- The typology of container terminal operations and procedures is not identical across world ports to allow a global benchmarking analysis based on network modelling. In particular, the planning, execution and co-ordination of work schedules across different terminal sites largely depend on the details of operational constraints, cargo mix, and planning strategy at the level of each container port or terminal.

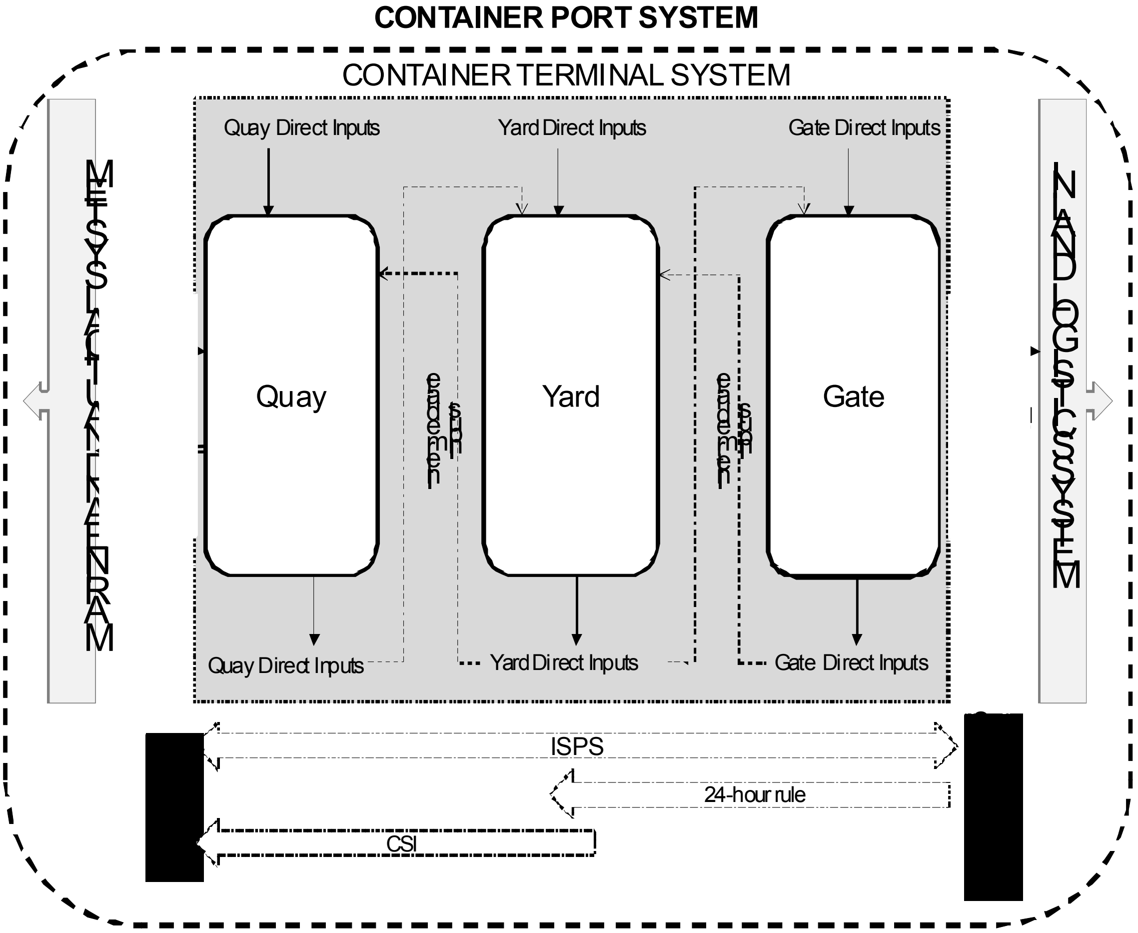


Figure 20: Configurations of terminal structure and security flow process for a possible network or supply chain DEA benchmarking application (Source: Author)

While it is not practical to model the network structure of aggregate terminal operations, it is still possible to model the network technology for either import or export related processes subject to detailed data being available at both terminal and site levels. Because both the CSI and the 24-hour rule target exclusively export containers, it is possible to model their network technology subject to data availability. In our case, this was made feasible because 10 terminals in the sample (GCT, HBCT, HGCT, WPCT, PTP, T37, SAGT, JSCT, SPCT, and KCT) provide detailed operational export data.

As shown in Figure 20, we present the container-terminal export flow in terms of a two-stage process where container terminals are benchmarked as supply chains. In Figure 21, X_A is the input vector and Y_A is the output vector of Stage A. Y_A is also an input vector of stage B, along with X_B; while Y_B is the stage B output vector. Each stage corresponds to one or a combination of terminal operating sites. Stages have been defined in ways that capture the spatial and operational scope of the CSI and the 24-hour rule, respectively.

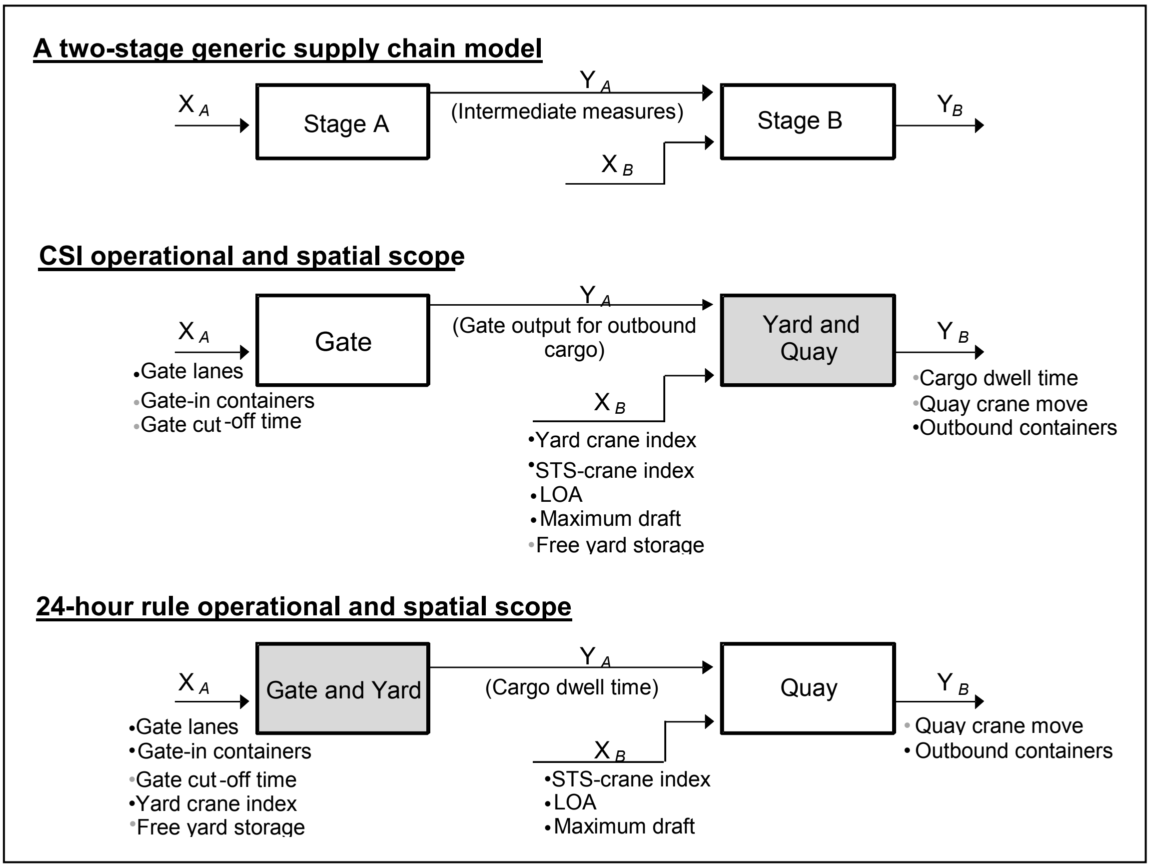


Figure 21: A two-stage supply chain model for the container export flow relative to the CSI and the 24-hour rule security programmes (Source: Author)

Under a supply chain system, input and output measures are defined either as direct or intermediate measures. Direct measures are those associated with a specific stage while intermediate measures are associated with two or more stages. For instance, in the 24-

hour rule network site the cargo dwell time (DwT) is an output of the gate-yard site but is also an input to the quay site. Because of the presence of intermediate measures, performance improvement of one stage (or site) affects the efficiency status of the other. Consequently, the values of intermediate measures must be determined through coordination among related stages and operating sites. The two-stage supply-chain terminal process for DMU_k can be modelled in DEA as the average efficiency of both stages as shown in equation (14).

$$
\begin{aligned}
& Max \;\; \frac{1}{2}\left[\frac{c_A^T y_{A_k}}{v_A^T x_{A_k}} + \frac{u^T y_{A_k}}{c_{B\,A_k}^T + v_B^T x_{B_k}}\right] \\
& \text{s.t.} \;\; \frac{c_A^T y_{A_j}}{v_A^T x_{A_j}} \le 1 \qquad j = 1,2,....,\ n \\
& \qquad \frac{u^T y_{Bj}}{c_B^T y_{A_j} + v_B^T x_{B_j}} \le 1 \qquad j = 1,2,....,\ n
\end{aligned}
\tag{14}
$$

Equation (14) can be expressed in a primal form as in (15):

$$
\begin{aligned}
& \underset{c_A, u, v_A, v_B, c_B}{Max} \;\; c_A^T y_{A_k} + u^T y_{B_k} \\
& \text{s.t.} \;\; v_A^T x_{A_k} = 1 \\
& \qquad c_A^T y_{A_k} + v_B^T x_{B_k} = 1 \\
& \qquad c_A^T y_{A_j} - v_A^T x_{A_j} \le 0 \qquad j = 1,2,....,\ n \\
& \qquad u^T y_{Bj} - c_B^T y_{A_j} - v_B^T x_{B_j} \le 0 \qquad j = 1,2,....,\ n
\end{aligned}
\tag{15}
$$

Where v and u are weights for direct inputs and outputs, and c is the weight for intermediate input /output. DMU_0 is defined supply chain efficient when it maximises both stage A and stage B efficiency.

The dual formulation can be specified as in (16):

$$
\begin{aligned}
&\underset{\theta,\phi,\eta,\mu}{Min} \quad \theta + \phi \\
&\text{s.t.} \quad -\theta x_{A_k} + \sum_j \eta_j x_{Aj} \leq 0 \\
&\quad y_{A_k} - \sum_j \eta_j x_{Aj} \leq 0 \\
&\quad -\phi x_{B_k} + \sum_j \mu_j x_{Bj} \leq 0 \qquad (16) \\
&\quad y_{B_k} - \sum_j \mu_j y_{Bj} \leq 0 \\
&\quad -\phi y_{A_k} + \sum_j \mu_j y_{Aj} \leq 0
\end{aligned}
$$

V.2.2 Malmquist Index Decomposition

Recall the formulation of the Malmquist input-oriented index as shown in equation (7):

$$M_i(y_t, x_t, y_{t+1}, x_{t+1}) = \left[\frac{d_i^{t+1}(y_t, x_t)}{d_i^{t+1}(y_{t+1}, x_{t+1})} \frac{d_i^t(y_t, x_t)}{d_i^t(y_{t+1}, x_{t+1})} \right]^{1/2}$$

The Malmquist productivity index (MPI) is the geometric mean between two indices, the first evaluated against period $t+1$ technology and the second evaluated against period t technology. Two of the four distance functions, $d_i^t(y_t, x_t)$ and $d_i^{t+1}(y_{t+1}, x_{t+1})$, are technical efficiency measures while the other two, $d_i^t(y_{t+1}, x_{t+1})$ and $d_i^{t+1}(y_t, x_t)$, depict cross-period distance functions showing efficiencies which use observations at periods $t + 1$ and t relative to the frontier technology at periods t and $t + 1$, respectively. A value of MPI greater than 1 indicates an improvement in TFP while a value lower than 1 indicates a deterioration in TFP.

Equation (7) can also be expressed as (17) whereby the left-hand part measures the change in technical efficiency (TEC), representing the catching up effect, while the right-hand part measures technological change (TC), representing the frontier shift effects[1]. Färe et al. (1992) use DEA distance functions to calculate the CRS Malmquist index in Equation (17).

$$M_i(y_t, x_t, y_{t+1}, x_{t+1}) = \frac{d_i^t(y_t, x_t)}{d_i^{t+1}(y_{t+1}, x_{t+1})} \left[\frac{d_i^{t+1}(y_t, x_t)}{d_i^t(y_t, x_t)} \frac{d_i^{t+1}(y_{t+1}, x_{t+1})}{d_i^t(y_{t+1}, x_{t+1})} \right]^{1/2} \qquad (17)$$

In order to measure TFP using the above MPI expression, CRS distance functions are required. This is because the technical efficiency change (TEC) entails changes in both scale efficiency (SE) and non-scale technical efficiency (pure technical efficiency:

PEC). Since the DEA VRS model does not capture the impact of production scale on efficiency, the MPI under VRS distance functions is not able to measure changes in scale efficiency. Hence, it may be misleading as to the extent of frontier shift effects.

Färe and Lovell (1994) and Färe et al. (1994) suggest an enhanced TFP decomposition that relaxes the CRS assumption while allowing for the measurement of scale efficiency change. By introducing some VRS distance functions, technical efficiency change (TEC) can be decomposed into a pure technical efficiency change (PEC) component and a scale-efficiency change (SEC) component. Equation (17) can therefore write as (18) where superscripts V and C refer to VRS and CRS technology, respectively.

$$\boldsymbol{TPFC = PEC * SEC * TC}$$

$$M_i = \frac{d_i^{t(V)}(y_t, x_t)}{d_i^{t+1(V)}(y_{t+1}, x_{t+1})} \left[\frac{d_i^{t+1(V)}(y_{t+1}, x_{t+1})}{d_i^{t(V)}(y_t, x_t)} \frac{d_i^{t(C)}(y_t, x_t)}{d_i^{t+1(C)}(y_{t+1}, x_{t+1})} \right] \left[\frac{d_i^{t+1(C)}(y_t, x_t)}{d_i^{t(C)}(y_t, x_t)} \frac{d_i^{t+1(C)}(y_{t+1}, x_{t+1})}{d_i^{t(C)}(y_{t+1}, x_{t+1})} \right]^{1/2} \quad (18)$$

Equation (18) decomposes the TFP change (TFPC) into various sources of efficiency change, and is expressed as follows

This property makes the Malmquist index a particularly attractive technique for measuring and decomposing changes in productivity. In the dynamic security context, the MPI can track productivity change before and after the implementation of security regulations. The decomposition of the Malmquist index also helps to single out the impacts of security from the effects of other operational factors. Finally, a clustering of reference sets (DMUs) by compliance criteria will shed further light on both the individual and the aggregate impacts of security regulations.

V.2.3 Model Assumption and Orientation

Despite the requirement of consistency between the selection of DEA orientation and the objective of the benchmarking exercise (input conservation versus output augmentation); port researchers often reduce port objectives to general targets such as profit or throughput maximisation, but these goals are not always consistent with modern container port operating and management systems. An instance of flawed selection of model orientation is the application of an output orientation to short-range cross-sectional data using output variables such as terminal throughput. However, the latter may be considered as an exogenous variable in the short run because terminal operators have little control over fluctuations in throughput volumes and demand for port capacity over short-term periods. In the context of container-port operations, one could argue conceptually for one orientation or the other but given the emphasis of this research on operational efficiency, the input oriented specification seems the most appealing because output levels in the short-run tend to be exogenously determined by the volume of demand and other locational factors.

Analytically, despite both orientations estimating the same frontier, the efficiency scores of inefficient DMUs (terminals) may differ under VRS. This aspect is central to the objectives of this research because, as demonstrated by the variations in terminal configurations and handling equipment, container terminals clearly depict a VRS production technology. Even though, any misrepresentation of the ranking scores of inefficient terminals may influence the results of the benchmarking analysis and the interpretation of security impacts. Therefore, we express most DEA models and the associated Malmquist TFP indices in terms of both CRS and VRS technologies.

V.3 Sampling Frame, Dataset and Variable Selection

As pointed out earlier, the selection of container terminals rather than container ports as homogenous units or DMUs is consistent with the objective of this research. Similarly, the emphasis on operational efficiency rather than other performance attributes is consistent with the analysis of security impacts since it reduces the effects of exogenous factors such as port location, ownership features, and organisational arrangements.

V.3.1 Sampling Frame

Due to the scope of research and time limitations, we purposely limited the original sample size to ports featuring an annual container throughput of more than 2 Million TEU in the year 2000, leading to an original sample of 113 container terminals from 26 ports. To this, we added the smaller CSI ports that were not selected in the original sample and ended up with an initial sample of 43 ports and 127 container terminals.

Container terminals, or DMUs, have been defined in this study according to their operational features rather than their institutional or organisational arrangements. This is because container terminals are often operated and managed as operational units. On the one hand, several terminals operate as a single operational unit when they share similar yard and gate facilities within the same port, for example, Northport terminals of CT1/CT2 in port Kelang (NPCT). On the other hand, a single terminal may be shared by several operators, for instance the APM Terminals and Eurogate Med-Centre Container Terminal (MCT) in Gioia Tauro and the COSCO/HIT terminal Eight-East (TE8) in Hong Kong. Whether operated as a single unit or by several operators, these terminal clusters are defined as a single DMU in the context of this research.

For the purpose of homogeneity and data cleaning, we excluded from the sampling frame terminals with multipurpose facilities and those that also handle non-container cargo. We also excluded ports and terminals that either have a shorter history than the study period, i.e. having started operations after the year 2000, or lack complete or reliable data. As a result, we ended up with a final sample of 60 container terminals belonging to 39 ports, the details of which are provided in Appendix 12.

It is worth noting that despite having sent on-line questionnaires (primary data) requesting further information from sampled terminals for which data was missing, several terminal operators have declined our request either because of company policy (e.g. Handico terminal in Rotterdam) or because detailed terminal data are not recorded at aggregate port management levels (e.g. the ports of Singapore and Kaohsiung).

V.3.2 Data and Variables

In this study, the choice of variables is based on a high-level aggregation of container-terminal operations with a view to utilizing available and reliable data on operational performance and ensuring homogeneity between observation units. Where relevant, a second set of key performance indicators, namely the STS-crane move per hour, the free yard storage time, the cargo dwell time, and the gate cut-off time, is added to the dataset. Micro-performance indicators such as those related to scheduling, allocation, routing, and stacking policies are too detailed and terminal-specific for inclusion in a benchmarking exercise of productive efficiency. Furthermore, such data are hardly available outside terminal management.

Earlier in Chapters III and IV, we pointed out the shortcomings of the port benchmarking literature in incorporating the operating typologies and configurations of container ports and terminals. A typical manifestation of the gap between container-port practice and theory is the rather subjective definition and selection of input and output variables. For instance, most researchers include the number of quay and yard cranes as input variables but each crane category depicts a different production technology and operating configuration. To incorporate these differences, we define structured sets of input variables that account for the variations in crane technology and cargo handling operation:

A. As shown from the discussion in the previous chapter, STS cranes depict different operating configurations such as the gauge, the outreach, the back-reach, the lift capacity and the height. These parameters are usually proportional to the type and size of vessels serviced but they operate on speedier cycle times (hoist and trolley speed) so that standard operational benchmarks of crane move per hour can be achieved. Because large vessels have an extended outreach, the average cycle time of STS cranes operating them must be increased substantially in order to achieve comparable productivity levels to those of STS cranes handing smaller vessels (see tables 14 and 15). In addition to the cycle time parameter, the lifting capability is another key performance indicator for STS cranes. Modern cranes have a higher load capacity and are equipped with several extendable spreaders, which allow them to handle multi-container picks (e.g. twin and tandem lifts) in a single move. Therefore, performance data on both cycle time and lifting capability must be included in the crane input variable in order to capture the productive technology of STS cranes.

For the cycle time, one can capture its performance directly from the rate of crane move per hour, the latter being an additional output variable used in this study. For the lifting capability, we use industry data provided by terminal operators. When such information is unavailable, we use data from industry surveys on STS-crane delivery (see for instance Cargo systems, 2007[a]; 2008[a]) as well as data on crane engineering standards as compiled from global crane manufacturers. Our index for capturing STS-crane input is therefore expressed as follows:

STS Crane's index = Number of cranes * Lifting capacity

Lifting Capability index (in TEU):

- Conventional Technology 20ft = 1
- Twin 20ft = 2
- Tandem 40ft = 2
- Two tandem = Two Twin 20ft = 4
- Triple 40ft = 6

Table 14: Relationship between STS-crane speed and productivity -data based on average productivity of 25-30 moves per hour- (Source: Bhimani and Sisson, 2002)

Crane Generation	**Outreach (meter)**	**Lift Height (meter)**	**Hoist speed**		**Trolley speed**	
			MPM	Ratio	MPM	Ratio
Panamax	35	24	48	1	150	1
Post-Panamax	44	29	55	1.15	180	1.2
Super-post Panamax	50	33	61	1.14	245	1.35
Malacca-max (22 wide)	65	40	90	1.88	300	2

Table 15: Relationship between STS-crane productivity and vessel turnaround time (Source: Bhimani and Sisson, 2002)

Crane productivity (move per hour)	**Turnaround time in hours per vessel size**			
	6000 TEU	8000 TEU	10000 TEU	12000 TEU
25-30	60	64	72	85
35-40	45	48	52	66
50	35	38	44	51
60	30	32	36	45

B. For yard handling equipment, we refer to the handling configurations described in Chapter IV and construct an index for yard stacking equipment based on two operational features namely the ground storage capacity (in TEU) and the staking height. These are the main performance data used by industry for container yard stacking equipment (Cargo systems, 2007[b]; 2008[b]). Information on yard equipment operational features is usually provided by the websites of terminal operators but can also be sourced from trade journals or from the manufacturers' reference list of yard crane deliveries.

Stacking equipment index = Yard equipment * Ground storage capacity * Stacking capacity

The definition and selection of other variables follow the same reasoning. Variables should be practical and consistent with both the objectives of this research and the results of IDEF0 modelling. Variables selected for benchmarking container terminal operations consist of seven inputs and one output. The input variables are terminal area, maximum draft, length overall (LOA), STS-crane index, yard-stacking index, internal trucks and vehicles, and number of gates (or gate lanes). The output variable is terminal throughput in TEU. Additional variables used for benchmarking site and network efficiency are the free yard storage time and the gate cut-off time as inputs, and the STS-crane move per hour and the cargo dwell time as outputs.

Table 16: Input and output variables for container terminal operations

Variables	**Descriptions**	**Units of measurement**	**Site**
INPUTS			
Terminal area	Total terminal area in square meters	1000 m^2	Terminal
Maximum draft	Maximum draft in the terminal	Meter	Quay
Length overall (LOA)	Total quay length in meter	Meter	Quay
Quay crane index	STS crane index = Lifting Capability * STS Cranes	TEU	Quay
Yard stacking index	Yard equipment stacking index = staking height *storage capacity *Yard Equipment	TEU /1000 m^2	Yard
Trucks & Vehicles	Internal trucks, tractors and other supporting vehicles	Number of vehicles	Terminal
Number of gates	Number of gates, gate lanes, and/or railway tracks at the gate	Number	Gate
OUTPUT			
Terminal Throughput	Annual total throughput	1000 TEU	Terminal

The dataset consists of annual observations of sampled container terminals and spans the period from 2000 to 2006. This is because many container terminals have started implementing the new security regulations as early as 2004 and we wanted to select a reasonable observation period that would allow us assess productivity changes before and after the introduction of security measures. The collection of data observations over a 7-year time-span resulted in a panel data of 420 terminal-*years*. In a dynamic context, panel data prevail over times-series and cross-sectional data. On the one hand, because a DMU is observed only once in either the times-series or the cross-sectional analysis, its efficiency estimate would be subjected to a higher degree of randomness and, therefore, may be misleading. On the other hand, the increase of the sample size under panel data analysis (from 60 to 420) would reinforce analytical reliability and reduce statistical error. In a panel data analysis, a DMU is defined as a container terminal-*year*, for instance HIT-*2003*.

Regarding the data collection methods, we used both primary and secondary data sources, mainly the latter source:

- Primary data is sourced directly from the terminals under study using a standard on-line questionnaire as shown in Appendix 13. However, only 15 responses were received, and secondary data was used for the rest of terminals in the sample.

- Secondary data was sourced from the websites and annual reports of port and terminal operators in the sample as well as from subscribed databases of trade journals namely Containerisation International yearbooks for the period 2000-2006, Containerisation International On-line website, Cargo World, World Port Focus, and the Fairplay database of container ports and terminals.

- We also relied on the information reported on the websites of global carriers and shipping lines, particularly the information on free-time demurrage and detention at the yard, and gate procedures and cut-off time. We verified and crosschecked information from all these sources. Where inconsistency arises, we record information from primary sources if data is available, otherwise from the website of sampled ports and terminals.

The combination of 60 terminals, 8 variables, and a 7-year (2000-2006) timeframe has resulted into a container-terminal panel dataset of 420 DMUs and 3360 data points. Table 17 depicts a summary of descriptive statistics relative to the aggregate container terminal dataset.

Table 17: Descriptive statistics of the aggregate container terminal dataset

Variable	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
Terminal area (1000 m^2)	105	2650	730	505
Maximum Draft	10	18	14	2
LOA	305	4875	1515	993
STS-crane index	2	390	55	57
Yard stacking index	6	212	35	35
Internal trucks and vehicles	2	390	55	57
Gates	3	37	10	7
Terminal throughput (1000 TEU)	123	8865	1526	1465

V.3.3 Validation of Data and Variable Selection in the Context of DEA

In this section, we justify and validate the definition and selection of the dataset and variables for carrying out performance benchmarking by means of DEA.

V.3.3.1 Data accuracy

Inaccurate data regarding a DMU can have an impact on efficiency scores depending on whether it makes incorrectly the DMU in question efficient or inefficient. Collected data for all DMUs must therefore be as accurate as possible. This is why we used various data sources and crosschecked information provided by each of them. In case of conflicting information, we recorded data from primary sources. We also relied on our expert understanding of container terminal operations to review and correct reported data that looked inconsistent with the size and operational arrangements of the container terminals in the sample.

We also checked data and variable selection against congestion. In economics, congestion takes place when reductions (increases) in one or more inputs generate an increase (decrease) in one or more outputs, for instance when an increase of the number of stevedores and other port labour is associated with lower throughput and production levels. Much of the problems associated with congestion are attributable to the choice of input and output variables. The DEA literature provides several models for measuring congestion (see for instance Brocket et al., 1984 and Cooper et al., 2004) but in this study, none of these models was needed since both input and output variables have been selected in ways that avoid the occurrence of congestion.

V.3.3.2 Homogeneity

As discussed in Chapter III, the variations in traffic and operational arrangements between world container ports and terminals may breach the requirement of homogeneity across sampled terminals. To reduce the lack of homogeneity, we defined and selected terminal DMUs according to their operational and technology features as specified in the previous sections. Even though, instances of non-homogeneity may occur in the dataset. For instance, looking at the summary statistics in Table 17, the standard deviation for the yard-stacking index is higher than the mean, implying that the sample is not very homogenous. This is simply because there are large terminals in the sample alongside small ones, each with a different set of crane equipment and handling configuration. In either case, we additionally apply returns-to-scale (DEA-BCC) and sensitivity (e.g. measure-specific DEA) models in order to identify different scale properties and performance layers of the production frontier.

V.3.3.3 Number of DMUs

In DEA, the number of units in the dataset should be greater than the number of inputs and outputs combined to ensure sufficient degrees of freedom (see for instance Dyson et al. (1990) and Bowlin (1998) for a review of this aspect). A general rule of thumb is that three (3) DMUs are needed for each input and output variable. In our case, the use of composite indicators such as the STS-crane index and the yard-stacking index helped reducing the number of the input/output set. When DEA cross-sectional analysis is applied, the ratio of DMUs (60) to the number of inputs and outputs (8) is 7.5 (>3), which ensures sufficient degrees of freedom. When DEA panel data analysis is applied, the number of DMUs is increased to 420 ($60\ terminals \times 7 yeras$) which increases the ratio of DMUs to the number of variables to 52.5 (>3).

V.3.3.4 Data scaling

Whenever possible, data should be scaled down so that input-output levels do not take excessively large values and reduce potential round-off errors in solving DEA models. This is why we recorded both terminal throughput and area in 1000 TEUs and 1000 m^2, respectively.

V.3.3.5 Exclusivity and exhaustiveness

The property of exclusivity and exclusiveness requires, subject to the exogeneity of the variables under consideration, that only the inputs selected should influence the output levels and that this influence should only be limited to the selected output variables. It is important to recognise this property because in many instances the output produced or the input utilised may be an assigned task that is exogenously determined.

To establish exclusivity and exhaustiveness between variables, we first narrow down input and output variables of the model by identifying the type of performance being assed (operational efficiency) and the spatial and operational scope of the DMU under study (container-terminal). We then draw from expert analysis and the results of IDEF0 modelling to include the input variables that capture all container terminal operational resources and the output variables that account for all the outcome of terminal operations.

V.3.3.6 Positivity

Generally, the DEA formulation requires that the input and output variables be positive or greater than zero. In Chapter III, we discussed the problems related to zero values under DEA and in the context of container-port operations. In our case, all input and output values are positive and no further treatment is necessary.

V.3.3.7 Isotonicity

To satisfy the isotonicity premise, we carried out a Pearson correlation test. The correlation coefficients (r^2) in table 18 show a p-value of less than 0.05 ($p < 0.05$) across all inter-correlations, which satisfies the isotonicity requirement. When relevant, some variables are reported in ways that satisfy the isotonicity requirement. For instance, the output variable cargo dwell time, which is used later in the analysis, is reported as a reciprocal of the average number of days during which containers remain in the yard.

Table 18: Correlation coefficients between input and output variables

Variable	Terminal throughput
Terminal area	r^2=0.486 (p =0.0001)
Maximum draft	r^2=0.9678 (p =0.0001)
Length overall	r^2=0.7361 (p =0.0001)
STS crane index	r^2=0.9199 (p=0.0001)
Yard stacking index	r^2=0.9372 (p =0.0001)
Internal trucks	r^2=0.9124 (p =0.0001)
Gates	r^2=0.4225 (p =0.0001)
Throughput	r^2=0.4897 (p =0.0001)

V.4 Chapter Conclusion

Following the design of the research approach in the previous chapter, this chapter deals with the operationalisation and formalisation of the analytical methods and techniques selected for this study; as well as the sampling frame, data collection, and variable selection.

We started first by mapping container terminals' flow processes through IDEF0 modelling. Following the specification of a top-level diagram for container terminal operations and its corresponding ICOM semantics, the parent function is decomposed into three linked sub-functions, each reflecting the operations of a terminal site or sub-system. Further decomposition by operational and process flow arrangements resulted into three IDEF0 models corresponding to import, export, and transhipment flows, respectively. The results of IDEF0 modelling were later used to identify the spatial scope of security regulations and define the relevant variables for benchmarking and productivity change analyses.

Regarding the formalisation of the analytical models, we formulated several DEA models, namely the conventional slack-based model, the measure specific model, and the supply chain model; and justified the benefit of applying both contemporaneous and inter-temporal analyses. We then specified the Malmquist Productivity Index (MPI) and decompose it into three sources of efficiency; technical efficiency, scale efficiency, and technological change. In order to measure productivity change before and after security implementation, we applied a step-wise MPI in terms of multi-year and regulatory-run assessments.

Starting with an original sample of 127 terminals from 43 ports and ending up with a final sample of 60 container terminals belonging to 39 ports, we defined the sampling frame and procedures with the objective of achieving homogeneity and operational consistency. We then relied on the results of IDEF0 modelling and previous discussion on container-port operations and security regulations to define the relevant variables (8 primary variables and 3 additional variables) and the time frame (the period from 2000 till 2006) for the study, the combination of which has resulted into a panel dataset of 420 terminal-*years* or DMUs. We described the methods and sources of data collection and methodology. We then validated variable selection in view of DEA analysis, including such aspects as number of DMUs, data scaling, homogeneity, exclusivity and exhaustiveness, positivity, and isotonicity.

CHAPTER VI: RESULTS AND INTERPRETATION

This chapter sets out to analyse and compare the efficiency estimates and results from both the benchmarking exercise and the productivity change analysis. The aggregate container terminal dataset has been divided into several datasets, each with a corresponding set of DMUs and input and output variables. For each dataset, we apply a series of benchmarking and productivity-change models as formalised in the previous chapter. Furthermore, we explore a range of hypotheses in order to test the assumptions presented in Chapter IV and investigate the theoretical discussion and findings from previous port literature. The approach adopted in this Chapter is to present and interpret the empirical results by type of analysis and research problem. In so doing, we analyse and validate the empirical results in ways that allow us understand the nature of the container-port production and emphasise both the joint and individual impacts of security regulations. The software DEA-Frontier for Excel 2003 (Zhu, 2003) is used throughout this study to derive solutions to the both the benchmarking and productivity change analyses.

VI.1 Empirical Results under Constant Technology

In this section, we present the results of both contemporaneous and inter-temporal DEA. Both approaches assume constant technology over time, but each of them has its own advantage. Under contemporaneous DEA, the frontier is constructed at a single point in time (e.g. a year) from cross-sectional data. Consequently, a DMU is benchmarked against a small sample of observations and therefore has a greater chance to be classified as more efficient. Under inter-temporal DEA, a single frontier is constructed from panel data by pooling all observations made throughout the time-periods under consideration so that each DMU-*year* is treated as a separate DMU. As a result, a DMU is benchmarked against a large sample of observations and therefore has a greater chance of being dominated or classified as less efficient. Both analyses provide a snapshot of productive efficiency and are useful for testing operational hypotheses as well as for analysing the efficiency of site-specific and network-related operations.

VI.1.1 Estimating Efficiency under Alternative DEA Models

With no prior empirical evidence on scale properties of container-port production, we use alternative DEA models to examine the effects of model choice on efficiency estimates. DEA-CCR and DEA-BCC models have been chosen to analyse terminal efficiency under constant and variable returns to scale, respectively. We also use both output and input orientations despite the latter being the selected orientation in the context of this research. Appendices 14 to 21 report the estimates of technical and scale efficiencies for different DEA models and type of data used.

For the DEA panel analysis (inter-temporal DEA), the results show that 44 DMU-*years* out of 420 in the sample are identified as efficient (efficiency score of 1 or 100%) under the DEA-CCR model compared with 93 units identified as efficient under the DEA-BCC model. For the DEA cross-sectional analysis (contemporaneous DEA), the results show that a total of 63 and 161 terminals, all years included, are identified as efficient when the DEA-CCR and the DEA-BCC models are applied, respectively. These results confirm that while the same set of DMUs are identified as efficient under both input and output orientations, the DEA-CCR models are more restrictive and yield lower efficiency scores than the DEA-BCC models, with respective average efficiency scores of 67% and 78.3% in the inter-temporal (input-oriented) analysis and 65.1% and 90.8% in the contemporaneous (input-oriented) analysis. The Spearman's rank order correlation coefficient between the efficiency rankings derived from DEA-CCR and DEA-BCC analyses is 0.67 and 0.92 when input and output orientations are applied, respectively. This indicates that the efficiency estimates yielded by the two approaches follow the same pattern across sampled terminals.

Despite the general trend of relatively high operational efficiency, some terminals depict extremely low efficiency scores. JNCT-*2000* has scored the lowest efficiency rating in the sample, with a value of 0.068 in both the DEA-CCR-I contemporaneous and DEA-CCR-I inter-temporal analyses. In addition to JNCT, 29 DMUs have scored lower than 30% efficiency rating in the DEA-CCR-I contemporaneous model and 19 DMUs in the CCR-I inter-temporal model. Of these low scores, twelve (12) have been recorded in the first year of the study (2000) under the CCR-I contemporaneous model against nine (9) in the CCR-I inter-temporal model. Further investigations show that the latter 9 terminals (MDCT, TOCT, NP, JNCT, MPE, TT, ASCT, SACT, and CCT) have either started operations in the year 2000 or undergone extensive expansion in that year.

Other noticeable cases include CT3, which has experienced a significant drop in its efficiency in 2005 due to a period of slow activity following the transfer of ownership from CSX World Terminals to DP World (CT3 efficiency scores in 2005 are 32.8% in the CCR-I contemporaneous model and 17.9% in the CCR-I inter-temporal model). Such findings support the argument that DEA and other benchmarking techniques tend to favour small or fully ‘utilised’ terminals against newly operated terminals and those expanding or investing in new facilities. Further discussion on the impact of incremental investment on container terminal efficiency is presented in subsequent sections.

To confirm that the above terminal DMUs are mere outliers and are not likely to affect the general results, we run a sensitivity analysis through excluding these DMUs from the sample. An outlier is an observation that does not follow the general behaviour of the analysed units but can cause significant problems especially in extreme point methods such as DEA. The results of the sensitivity analysis show no major change in average efficiency estimates or in the rankings of DMUs in the sample, which indicates that the above outliers have no influence on the position or stability of the frontier.

Turning to the comparison of efficiency estimates yielded from alternative DEA models, Figure 22 depicts the year-by-year evolution of average terminal efficiency under both contemporaneous and inter-temporal analyses. It shows a general upward trend for average efficiency estimates until 2003, followed by an almost flat trend in 2004, a sharp downward trend in 2005, and a return to the ascendant trend in 2006. Since most security measures have been introduced in late 2004, the results from Figure 22 may suggest a possible negative impact of procedural security on port efficiency, but a definitive conclusion requires the estimation of a TFP index for assessing productivity change before and after the implementation of the new security regulations.

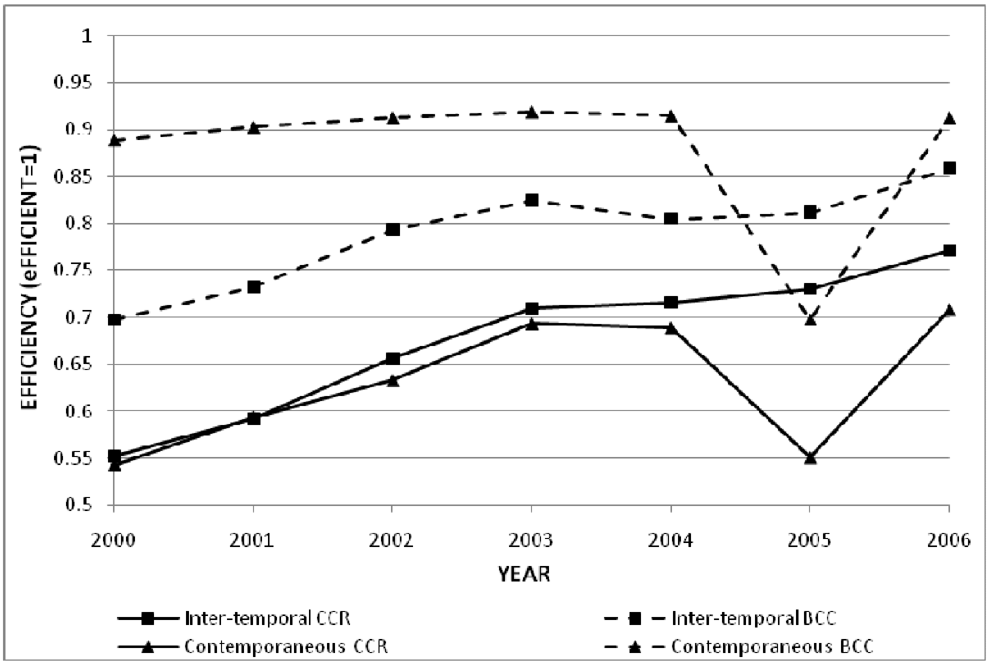


Figure 22: Year-by-year (2000-06) evolution of average terminal efficiency (Based on input-oriented efficiency ratings)

Figure 23 shows the relationship between mean terminal efficiency scores and their standard deviations and indicates low negative correlation coefficients of $r = -0.10$ for DEA-CCR contemporaneous analysis, $r = -0.24$ for DEA-BCC contemporaneous analysis, $r = -0.21$ for DEA-CCR-I inter-temporal analysis, and $r = -0.23$ for DEA-BCC-I inter-temporal analysis. A two-sided test of significance reveals that the correlation coefficients are statistically significant at the 5% confidence level, implying that the efficiency of container terminals in the sample does not exhibit similar levels of variation over time. This means that the more efficient terminals tend to have less relative variability over time compared with the less efficient terminals. These findings are in contrast with the results of previous port literature (e.g. Valentine and Gray, 2001; Song et al., 2003; Cullinane et al., 2001) which have found similar levels of fluctuation over time between the efficiency of sampled terminals irrespective of their level of average efficiency. This may be due to the sampling procedure used in most port benchmarking studies where DMUs are usually selected from top-ranked ports in terms of throughput or from ports located within the same country or region.

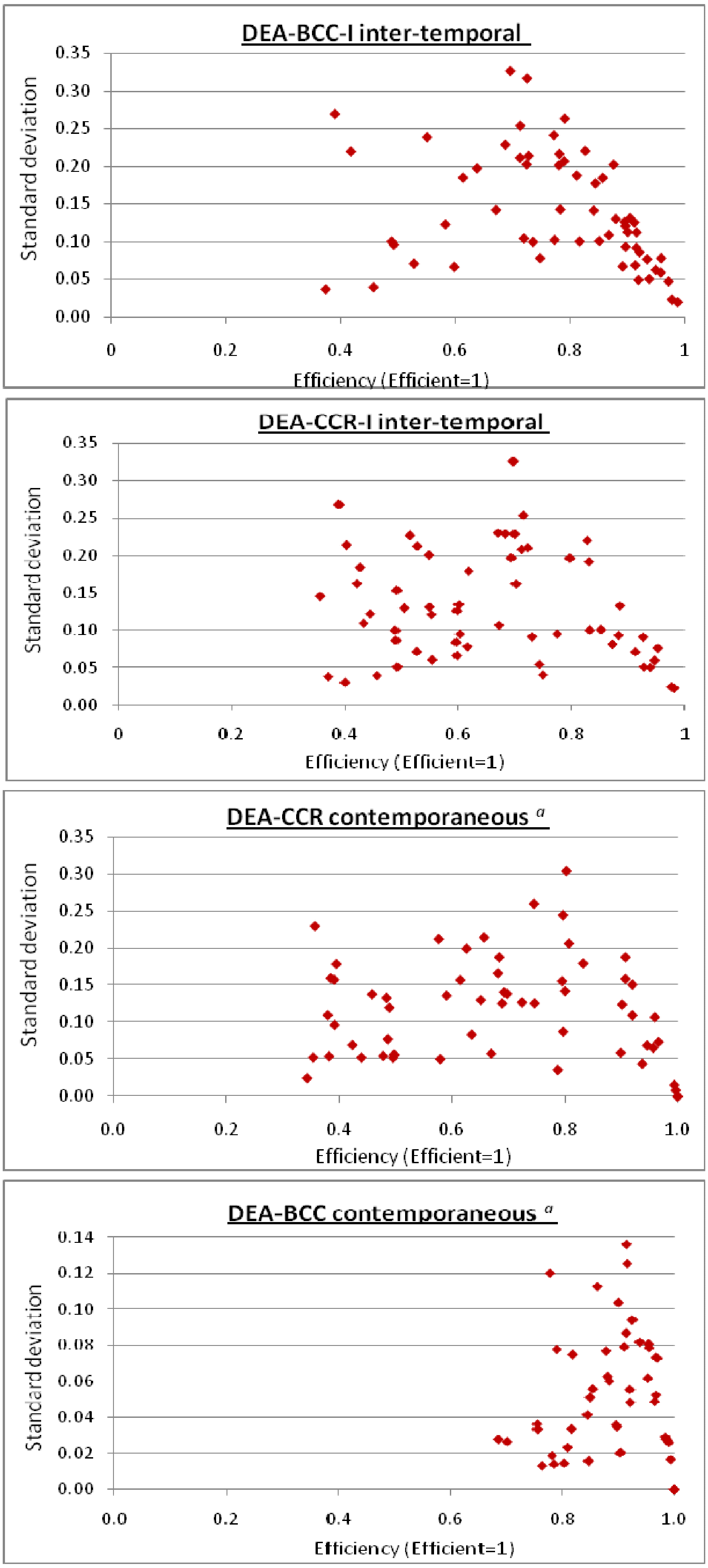


Figure 23: Relationship between mean efficiency and standard deviation (Input-oriented efficiency ratings)

VI.1.2 Testing Operational Hypotheses

In this section, we use the results of both contemporaneous and inter-temporal DEA in order to test certain hypotheses implied from the operational assumptions previously discussed in Chapters III and IV. In so doing, further light can be shed on the structure and mechanisms underpinning the operations of container ports and terminals.

VI.1.2.1 Analysis of scale efficiency and the impact of incremental investments

The relationship between scale of production and operational efficiency can be inferred directly from Appendices 14 to 21. The results from applying input orientation show that of the total number of 420 DMUs in the sample 44 and 63 exhibit constant returns to scale, and 376 and 357 exhibit increasing returns to scale when contemporaneous, all years combined, and inter-temporal models are applied, respectively. In the output orientation, 105 and 65 are found to exhibit constant returns to scale, 267 and 296 exhibit increasing returns to scale, and 48 and 59 exhibit decreasing returns to scale, when contemporaneous and input-oriented models are applied, respectively. These empirical results assert once again that container terminals clearly depict a VRS production technology. Therefore, subsequent analysis will be mainly conducted, unless specified otherwise, under the assumption of VRS technology.

Among terminals found to be scale-inefficient, those depicting decreasing returns to scale have all an annual throughput of more than 2 million TEU except for one terminal that shows a throughput of 1.3 million TEU per year. Conversely, 85% of scale-inefficient terminals with an annual throughput of less than 0.5 million TEU are found to exhibit increasing-returns to scale. These results suggest a strong association between large terminals and decreasing returns to scale and between small terminals and increasing returns to scale.

Further analysis on the relationship between throughput and efficiency shows positive coefficients relative to both the Pearson correlation and the Spearman’s rank order correlation, which indicates that the size of port production in terms of container throughput (not to be confused with terminal size or area) is positively correlated with efficiency scores (Table 19). However, the small values of both coefficients seem to indicate that this positive correlation is not highly significant. Further tests reveal a weak correlation between the standard deviation of efficiency scores and the scale of production (Table 20).

Table 19: Relationship between throughput size and productive efficiency (Based on input orientation)

DEA model	*Type of data*	*Correlation between throughput and efficiency*	
		Pearson Correlation	Spearman's rank order correlation
CCR	*Panel data*	0.557	0.193
	Cross-sectional data	0.569	0.228
BCC	*Panel data*	0288	0.216
	Cross-sectional data	0.284	0.189

Table 20: Relationship between variations in efficiency scores and scale of production

DEA model	*Type of data*	*Correlation between throughput and efficiency fluctuations*	
		Pearson Correlation	Spearman's rank order correlation
CCR	*Panel data*	-0.231	-0.198
BCC	*Panel data*	-0.262	-0.177

The apparent inefficiency of large container terminals may be explained by the incremental nature of port investment, especially for large-scale capacity expansion projects. Because of the competitive dynamics of the port industry, additional port capacity is usually associated with strategic and long-term planning. In their quest to cater for future traffic while maintaining or increasing productivity levels, container ports and terminals incrementally expand their capacity (infrastructure, superstructure, or both) ahead of anticipated increases in container traffic, which creates a short-term over-capacity and yields lower efficiency ratings during periods of expansion.

Although well documented in the frontier applications on various sectors of the economy, the relationship between incremental increases in port investment and the variations in productive efficiency over time has not been yet thoroughly investigated in the frontier literature. Against the general trend of container terminals depicting a VRS production technology, several port researchers have found that small sized ports achieve relatively high scores in their productive efficiencies vis-à-vis their large-scale counterparts (Kim and Sachish, 1986; Martinez-Budria, 1996; Coto-Millan et. al, 2000; Jara-Diaz et al, 2002; Cullinane et. al, 2006). However, little explanation or empirical evidence was provided as to the possible causes and implications of such relationship.

To illustrate the relationship between incremental investments in port capacity and subsequent reductions in productive efficiency, Figure 24 shows how LCB1 and LCIT terminals in the port of Laem Chabang in Thailand have experienced a significant decrease in their relative efficiencies following major expansion programmes in 2004 and 2005, respectively. The lagging-time or catching up effect between supply and demand of port services is depicted in Figure 24 by a sudden and significant decline in relative efficiency, indicative of short-term over-capacity, followed by a gradual return to normal productivity levels once anticipated increases in demand (traffic) start taking place. Newly built and operated terminals also depict a similar catching up effect, see for instance the evolution of the productive efficiency of ASCT, MDCT, JNCT, PTP, MPE and TT which have all started operations in the year 2000.

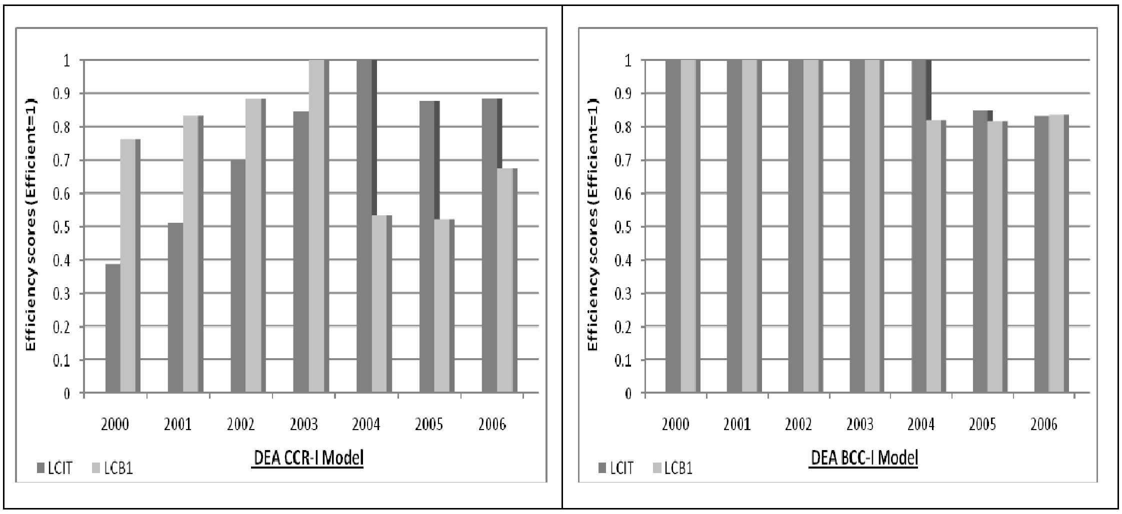


Figure 24: Decline in productive efficiency of LCB1 and LCIT following the expansion of terminal capacity (Based on DEA cross-sectional data analysis)

The above trend contrasts with the steadily high efficiency scores associated with terminals that have not invested heavily in capacity expansion, in particular small-size container terminals. However as evidenced by a series of empirical research on berth occupancy ratio and cargo dwell time, higher utilisation is usually associated with longer queues and congestion which ultimately yields poor levels of productive efficiency. In fact, port practitioners and experts believe that a full utilisation of port capacity is detrimental to port efficiency in the medium and long runs (Fourgeaud, 2000; Bichou, 2005b, Cochrane, 2007). Additional port capacity is also desirable in the context of operational port planning because of the seasonal nature (e.g. peak seasons) of container-port production.

VI.1.2.2 Impact of exogenous factors on terminal efficiency

In order to ensure appropriate selection of input and output variables for this study, we excluded non-discretionary and exogenous variables that are outside the control of terminal DMUs under analysis. Even though, some DMUs may still appear efficient simply because of the trade patterns and/or the variations in traffic mix relative to their terminal operations. For instance, terminals with a significant ratio of transhipment (T/S) traffic and/or FEU containers are likely to yield higher productive efficiency. This is because transhipment and FEU containers are counted twice in terms of handling activity and unit of measurement, respectively. In addition, a transhipment container requires less input use because of the relatively simple rules for cargo handling and yard stacking. A higher proportion of transhipment traffic also implies additional calls from feeder vessels, which would increase berth utilisation and operational efficiency.

The relationship between terminals' efficiency and proportion of transhipment cargo is shown in Figure 25. Because of the unavailability of detailed data at terminal level, information on the rate of transhipment incidence was mostly sourced from annual port statistics under the assumption that the proportion of transhipment traffic at a given port also applies to terminals belonging to the same port. The results from Figure 25 show that terminals with higher transhipment incidence tend to yield higher productive efficiency scores. Similar results are found for terminals with a high proportion of FEU containers although the analysis was conducted for 25 terminals only because of unavailability of data across all terminals in the sample (Figure 26).

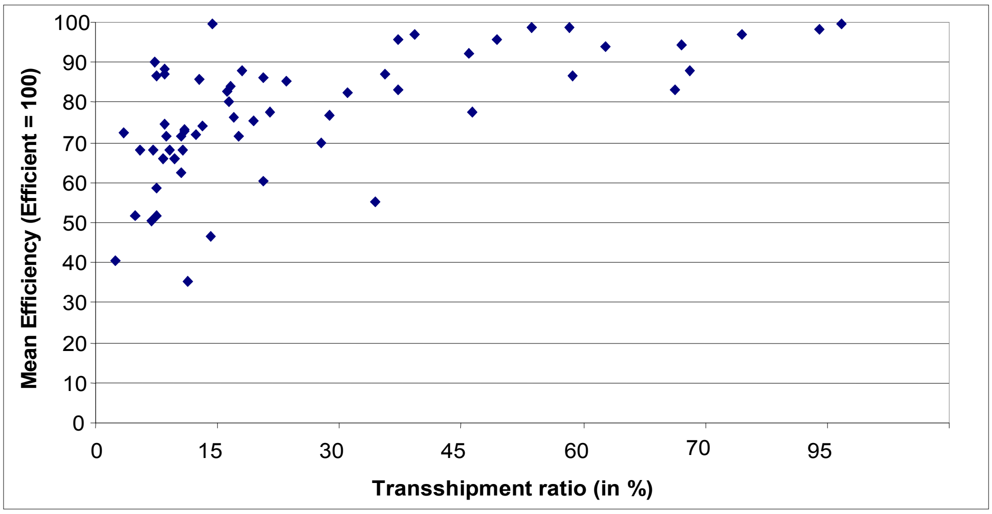


Figure 25: Relationship between average efficiency and ratio of transhipment traffic (Efficiency estimates based on input-oriented DEA-BCC cross-sectional analysis)

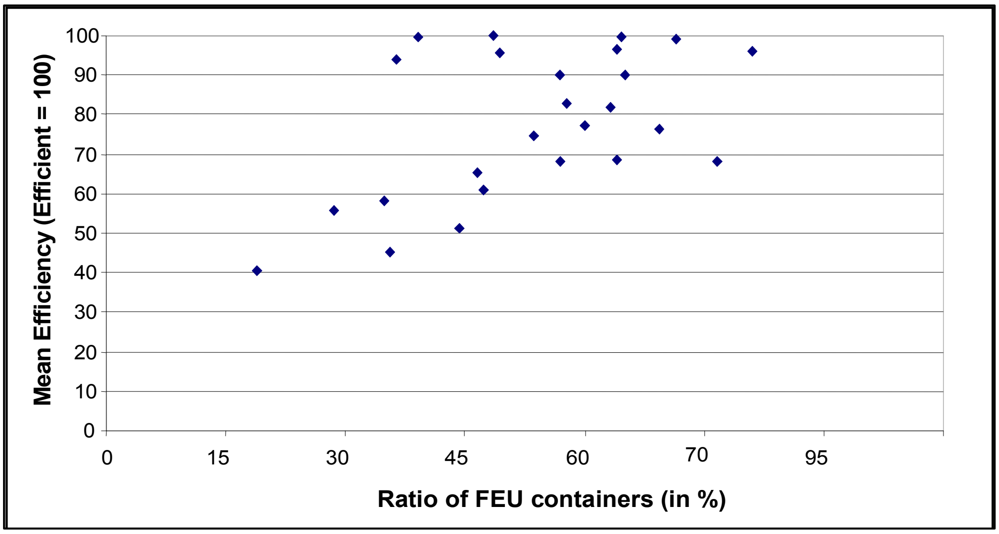


Figure 26: Relationship between average efficiency and proportion of FEU containers (Efficiency estimates based on input-oriented DEA-BCC cross-sectional analysis)

Transhipment containers are the direct product of modern logistics patterns of maritime transportation, e.g. hub-and-spoke arrangements, but the latter may influence in several other ways a port's efficiency. Factors underlying this influence include the number, characteristics (size, technology, etc.) and type of service (frequency, rotation, number of stops or port calls, etc.) of ships deployed within a particular trade route or shipping string. From an operational perspective, these factors translate into efficient port operations through improved ship's stowage plans, minimal re-stow and re-shuffling, and greater simplicity for berth and yard planning and operations. However, except few publications (Angeloudis et. al, 2007; Bell and Bichou, 2008; Bichou, 2008) on the subject, the port literature provides little empirical analysis on the extent of influence of these factors on port performance benchmarking or on how they vary from a shipping trade to another. Although the impact of shipping network and service characteristics on port efficiency is beyond the scope of this research, a case-study discussion on such impact is provided in the second part of this Chapter.

In addition to transhipment incidence, the proportions of container mix can also influence port efficiency. Because terminal throughput is an activity measure rather than a traffic measure, factors such as container size (FEU, TEU), type (outbound, inbound, T/S), and operational status (LCL, FCL, empties) would have an impact on port efficiency. To examine the relationship between those exogenous factors and productive efficiency, we classify terminal DMUs in three (3) groups according to the category of container mix (size, type and status) and analyse the variations of their efficiency scores. Because of missing values, different groups have different dataset sizes.

Table 21: Terminal groups by container mix

Group	Description	*Attributes*		
		Proportion	*Container mix*	*Data size* [a,b]
Group 1	Terminals with high proportion of Inbound containers	*≥50%*	*Type*	*105*
Group 2	Terminals with high proportion of Outbound containers	*≥50%*	*Type*	*175*
Group 3	Terminals with high proportion of T/S	*≥50%*	*Type*	*220*
Group 4	Terminals with high proportion of FEUs	*≥50%*	*Size*	*175*
Group 5	Terminals with low proportion of FEUs	*≤50%*	*Size*	*207*
Group 6	Terminals with high proportion of Empties	*≥50%*	*Status*	*126*
Group 7	Terminals with high proportion of Full containers (FCL & LCL)	*≥50%*	*Status*	*91*

[a]: Number of DMU-*year*

[b]: Information on container mix proportions is not available throughout the study period. Moreover, container terminals usually depict different proportions of container mix in each year.

Although the 50% cut-off proportion is a rather arbitrary classification, the results from Figure 27 suggest an association between exogenous factors and productive efficiency. It shows for instance container terminals with high proportions of transhipment, FEU or empty containers depicting higher efficiency ratings that those with high proportions of direct and full containers. In Figure 27, the grey box represents the inter-quartile range of efficiency scores where the median is indicated by the black centre line and the lower and upper edges of the box are the first and third quartiles, respectively. The extreme values (minimum and maximum efficiency scores) are represented by the squares at both ends of the lines which extend beyond the grey box.

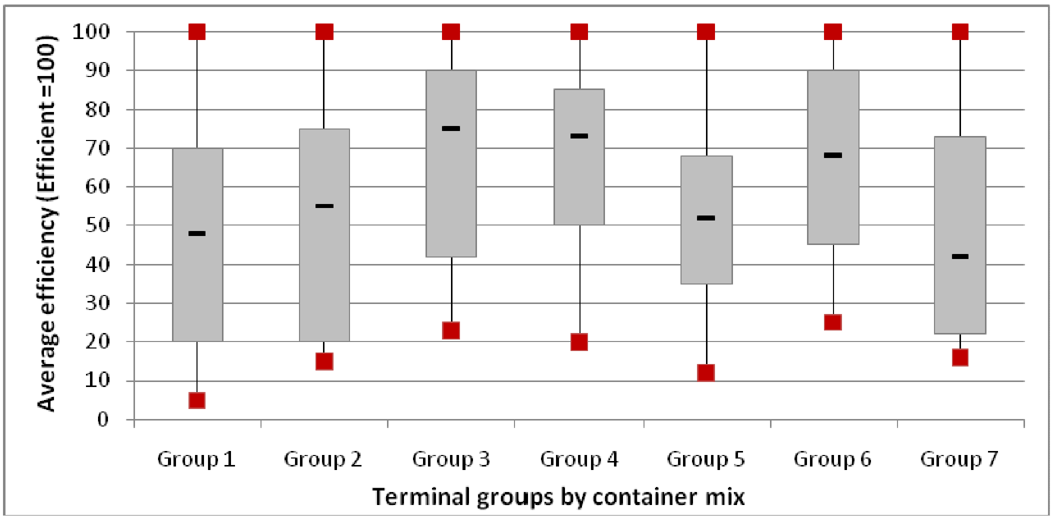


Figure 27: Variation of productive efficiency across container terminal groups (Based on DEA-BCC-I panel data analysis)

VI.1.2.3 Analysis of terminal efficiency by operating configuration

Earlier in Chapter IV, we described the various operating configurations of container terminal equipment and handling systems and justified the need to benchmark container-terminal efficiency in terms of generic operating typologies. In the subsequent Chapter, we used the configuration approach to define some input variables in particular for quay crane and yard carne indices. In order to investigate the assumption that each operating configuration depicts a different production technology, we group terminal DMUs in terms of distinctive yard handling configurations and analyse potential differences in their productive efficiencies.

Out of a panel data of 420 DMU-*years*, 33 terminals (231 DMUs) have operated on a yard gantry system (RTG and/or RMG), 13 terminals (91 DMUs) on a straddle carrier system (SC), 2 terminals (14 DMUs) on a wheeled system (tractor-chassis), 6 terminals (42 DMUs) on a hybrid system, and 4 terminals (28 DMUs) on a fully or partially automated system. The remaining two terminals (14 DMUs) have changed their yard-stacking configurations during the period of study (alternating system). Table 22 shows the average efficiency scores for terminal clusters by handling configuration.

Table 22: Average efficiency by yard handling configuration

Yard handling configuration	2000	2001	2002	2003	2004	2005	2006	Average Efficiency*
Yard gantry system	0.548	0.576	0.674	0.731	0.751	0.770	0.802	0.693
Straddle-Carrier system	0.539	0.564	0.619	0.728	0.738	0.757	0.763	0.673
Wheeled system	0.398	0.415	0.425	0.457	0.537	0.593	0.674	0.500
Automated system	0.646	0.780	0.785	0.666	0.705	0.692	0.728	0.715
Hybrid system	0.461	0.551	0.650	0.731	0.772	0.754	0.799	0.674
Alternating systems	0.685	0.659	0.641	0.599	0.492	0.299	0.377	0.536

*: Based on input-oriented DEA-CCR panel data, as we wanted to exclude the effects of scale production.

As shown in table 22, terminals operating on automated systems depict the highest average efficiency score of 71.5%. Second in the ranking are terminals operating on yard gantry systems with an average efficiency rating of 69.3%. Terminals operating on hybrid systems (e.g. RTG/SC system) and those using the straddle carrier system come next with a similar average rating of 67.3-67.4%. Alternating systems score an average efficiency rating of only 53.6% while terminals operating on a wheeled (tractor-chassis) system achieve the lowest average efficiency with a score of 50%.

The box-plot diagram shown in Figure 28 below provides further information on the dispersion, skewness and potential outliers of efficiency scores yielded by terminal DMUs of each yard-handling configuration. The results confirm the variations in production technology between different yard handling configurations and the need to consider such variations when measuring or benchmarking port performance and efficiency.

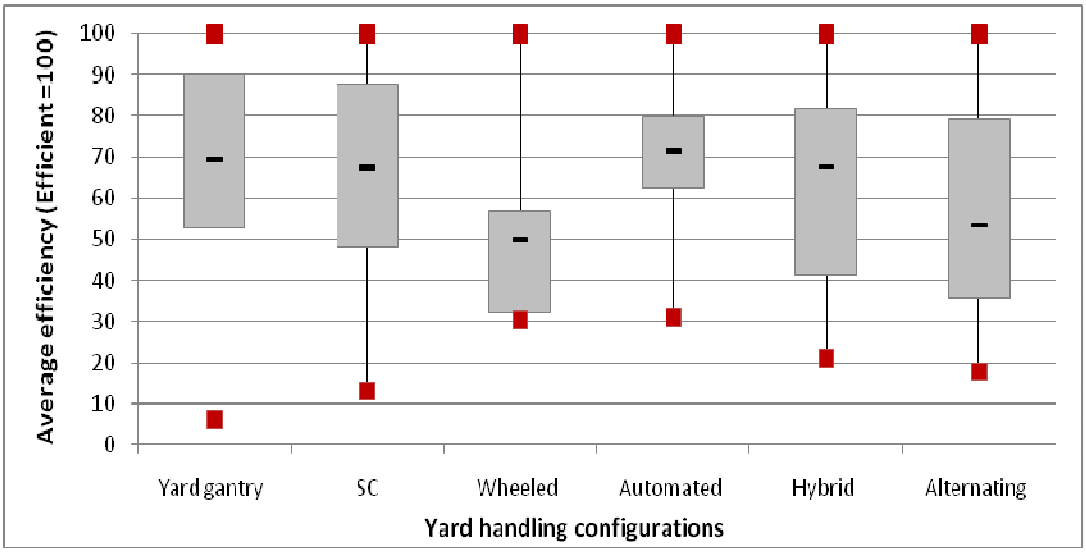


Figure 28: Comparison of efficiency scores by yard handling configuration

To analyse further the variations in productive efficiency between terminals of different yard handling configurations, we group terminal DMUs into more distinctive yard stacking systems namely: the tractor-chassis based system, the RTG based system, the RMG based system, the straddle carrier-direct (SCD) system, and the straddle carrier-relay (SCR) system. In this grouping, automated, hybrid and alternating configurations are being categorised according to their dominant yard stacking systems. We use the paired-sample *t*-test to compare the mean efficiency of any two yard-stacking systems at a time. Ten independent comparisons are carried out and the results are listed in Table 23. The results show six pairs of means with differences at the significance level of 1% and one more at a level of 5%. This implies that the RTG and the SCD systems yield higher efficiency levels than the SCR and the RMG systems, with the RTG system depicting the highest productive efficiency.

Table 23: Paired-sample tests

Paired configurations		***Paired Differences***					*t*	*Degree of freedom*
		Mean	Standard deviation	Std. Error Mean	99% Confidence Interval of the difference			
					Lower	Upper		
Pair 1	RTG-RMG	0.336	0.288	.0366	0.251	0.452	*7.216*	*59*
Pair 2	RTG-Chassis	0.355	0.251	0.334	-0.576	0.125	*0.942*	*59*
Pair 3	RTG-SCD	0.886	0.231	0.038	-0.167	0.194	*2.289*	*35*
Pair 4	RTG-SCR	0.243	0.251	0.343	0.159	0.361	*7.809*	*47*
Pair 5	RMG-Chassis	-0.306	0.418	0.581	-0.317	-0.818	*-5.934*	*59*
Pair 6	RMG-SCD	-0.210	0.257	0.432	-0.317	-.0848	*-4.60*	*35*
Pair 7	RMG-SCR	-0.729	0.274	0.393	-0.178	0.327	*-1.879*	*47*
Pair 8	Chassis-SCD	0.986	0.369	0.601	-.0661	0.216	*1.626*	*35*
Pair 9	Chassis-SCR	0.270	0.274	0.408	0.126	0.419	*5.808*	*47*
Pair 10	SCD-SCR	0.143	0.206	0.339	0.039	0.2113	*3.898*	*35*

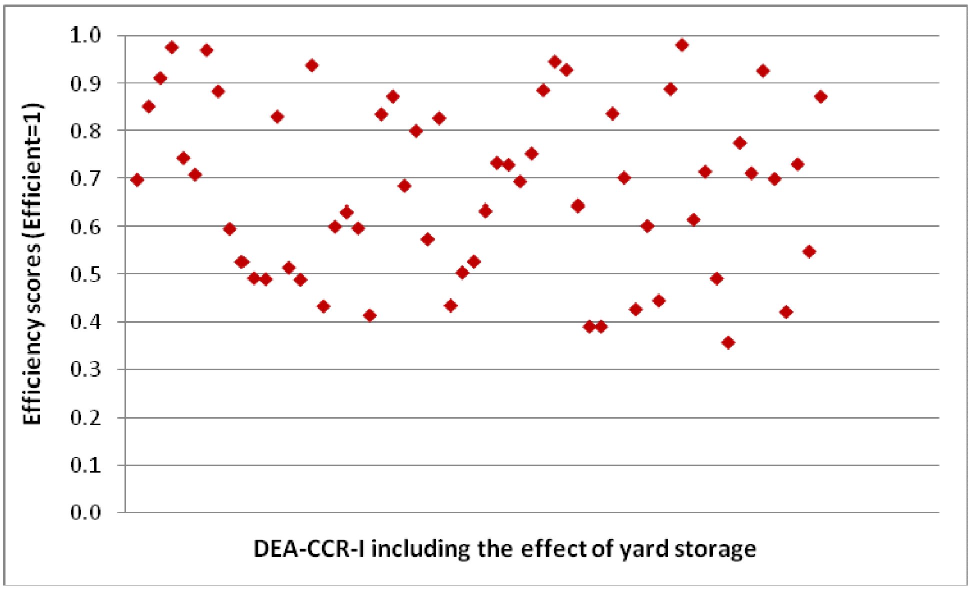
VI.1.2.4 Analysis of terminal efficiency by operating procedures

Both operating policies and work procedures were not included in the initial benchmarking analysis because they are closely associated with administrative efficiency and therefore may be considered as micro-indicators for terminal operational efficiency. Nonetheless, several empirical studies have shown that poor administrative, procedural, and customs efficiency have a negative impact on port operational efficiency, which could in turn influence the level of security impacts. This section is intended for the examination of the relationship between the scope of terminal operating procedures and possible shifts in productive efficiency. In the second part of this Chapter, further tests will be undertaken to analyse the relationship between procedural security and terminal efficiency.

In view of the results of the IDEF0 modelling exercise, several control factors relative to container-port operating procedures may be expressed in terms of key performance indicators (KPIs) that fit the benchmarking structure of DEA. For instance, the factors free yard storage time, gate cut-off time, and number of working hours can all be used as proxies for the yard storage policy, the gate closing time, and the work shift procedure, respectively. In this section, we focus on the first two factors since all terminals in the sample operate on a 24-hour working pattern. We also exclude operating rules and procedures derived from security regulations since the impact of these factors will be analysed separately in the subsequent sections.

In order to examine the relationship between yard storage policy and terminal efficiency, we run a further model as a replica of the initial DEA panel data (inter-temporal) model, with the difference that the variable ‘number of free storage days in the yard’ features now as an input variable. Since the yard storage policy is believed to be an explanatory factor, we want to test whether the results are sensitive to it, in other words whether the inclusion (or exclusion) of this variable is likely to affect efficiency scores of terminal DMUs. The comparative results of this analysis are depicted in Figure 29. Full results are reported in Appendix 22.

From Figure 29, similar trend pattern can be detected in both cases, but there is a minor change in efficiency scores. As compared with the results of the initial DEA model reported in Appendix 21, the inclusion of the input variable ‘free storage time in the yard’ leads to a generalised increase of technical efficiency scores for 86 terminal DMUs, 77 of which have experienced an increase in their efficiency rating by less than 10%. This means that on average, the use of storage policy as an additional input resource seems to boost operational efficiency but only slightly. Even though, terminals that adopt a good yard policy seem to benefit the most from efficiency improvement. For instance, the DMUs SKCT-*2003*, YICT-*2002* and YICT-*2005* have all scored the maximum efficiency rating of 100% when the input variable ‘free storage time in the yard’ is included, in contrast with respective efficiency scores of 77.7%, 94.5% and 92.6% when the same variable is excluded from the analysis. Further investigations show that as part of the storage policy in the port of Shenzhen, SKCT and YICT terminals offer only 12 hours (0.5 days) of free yard storage for both inbound and outbound containers, the shortest free storage time among all sampled terminals.



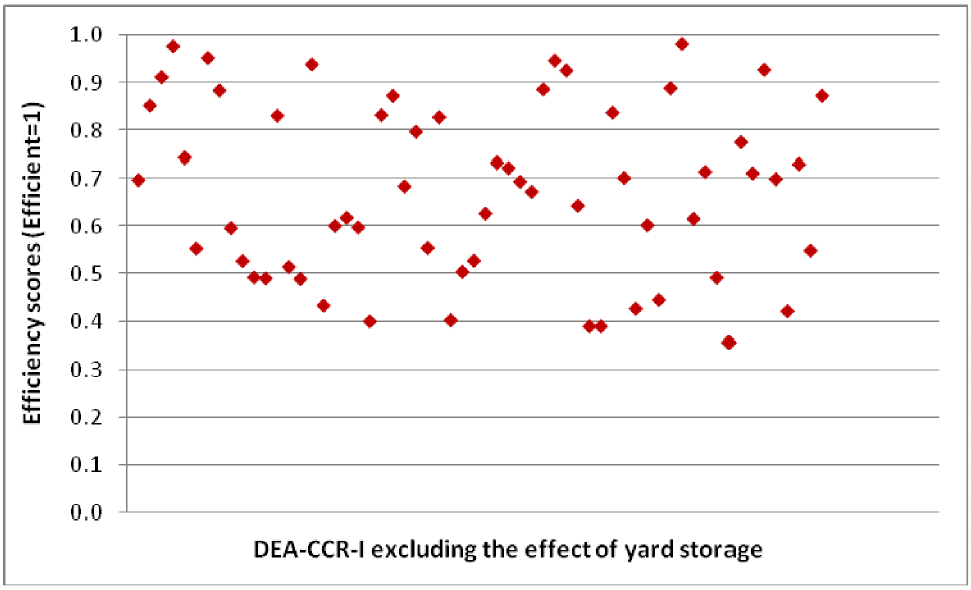


Figure 29: Comparison of average terminal efficiency with and without the input variable 'free storage time in the yard' (Based on CCR-I panel data analysis)

As with yard storage policy, we conduct a similar analysis for gate operating procedures by running a replica DEA model that includes the variable 'gate cut-off time before closing'. Detailed efficiency ratings are listed in Appendix 23 and summarised in Figure 30. The results depict similar trend pattern but there has been a generalised increase of technical efficiency scores for 65 terminal DMUs after including the input variable 'gate cut-off time'. This increase is even less significant (9% on average) than the one observed when the yard storage policy was included. However, there exist significant differences between terminals in the sample.

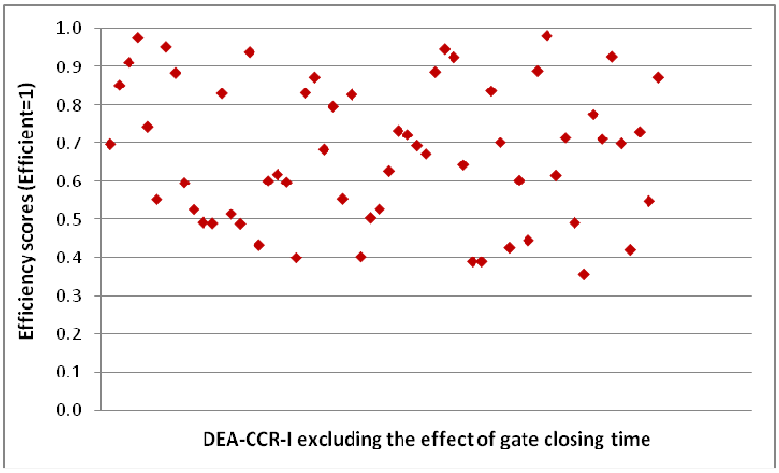


Figure 30: Average terminal efficiency including the input variable 'gate cut-off time' (Based on CCR-I panel data analysis)

An instance of the impacts of operating procedures on terminal efficiency occurs when gate procedures (gate working hours, cut-off times, etc.) are redefined following a policy change or a new regulatory requirement. Take for instance Assembly Bill 2650, a legislation passed by the state of California in the USA in 2002 and enforced in 2003 with the objective of reducing the congestion at US West-coast ports. Assembly Bill (AB) 2650 imposes a penalty of $250 on container terminals where trucks wait for more than 30 minutes to enter the gate. To avoid fines, terminals have responded by either extending gate hours, e.g. to weekend hours, and/or reducing gate closing time by introducing automated appointment system for truck and railroad companies (Giuliano and O'Brien, 2007).

Looking at the results in Appendix 23, all sampled terminals belonging to the California ports (LBPF, LBPT, and YCT) show a general increase of technical efficiency after the introduction of the new appointment system. Both LBPF and LBCT show a significant improvement in productive efficiency due to AB 2650, which has followed a period of low productivity caused by long queues and congestion. A particularly remarkable upward shift of operational efficiency has been experienced by YCT which has increased its relative efficiency rating from just above 50% in 2003 to 100% in 2006 (see Figure 31). This leap in productive efficiency has been achieved with no additional investment in terminal infrastructure or equipment and there is little evidence to suggest that exogenous factors have caused such a substantial efficiency change. With everything else being equal, the increase of terminal efficiency can be largely attributable to procedural changes such as in terms of reducing the gate closing time following the introduction of the AB 2650 regulation. In fact, YCT has responded to AB 2650 by changing operating procedures through extending gate working hours and, in particular, providing a free, automated and same day appointment system. YCT was indeed the only terminal in the three ports that provided a no-fee appointment system (Yusen Terminal, 2007).

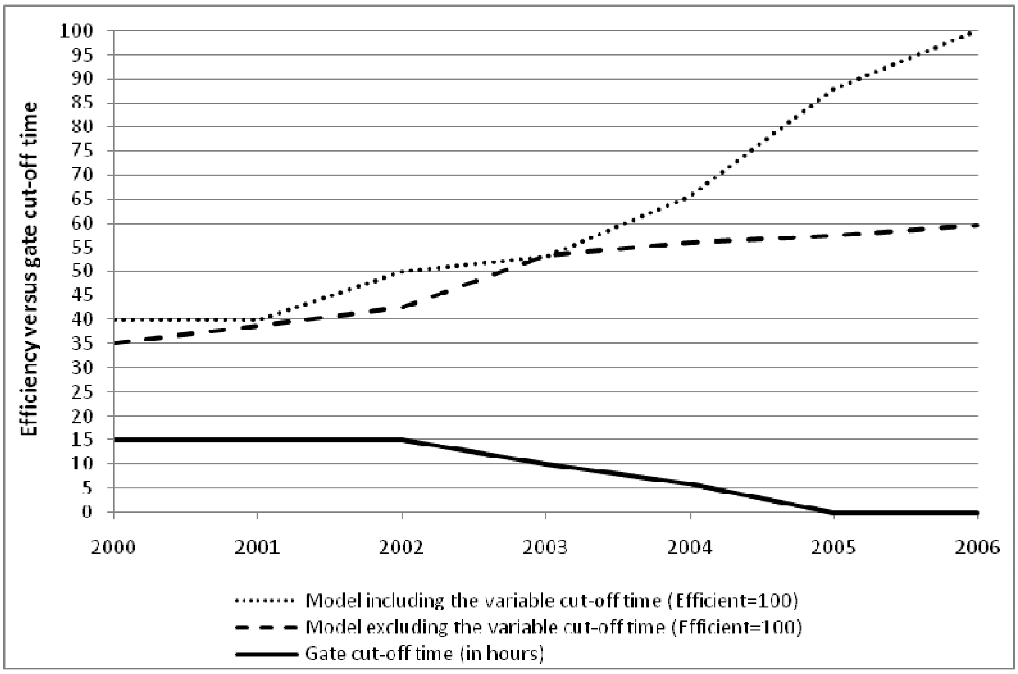


Figure 31: Variations in productive efficiency of YCT following changes in gate closing time policy (Based on CCR-I panel data analysis)

VI.1.3 Analysis of Site-Specific and Network Efficiency

VI.1.3.1 Analysis of site-specific efficiency

Earlier in Chapter IV, we described the configuration of container terminal systems and the relationship between different operating sites. In particular, we emphasised existing disproportionate performance and capacity constraints at the level of each terminal site and the need to integrate them with a view of achieving overall terminal productivity.

Table 24: Site-specific datasets and their corresponding analytical models

Site	Data nature	DMUs	Variables	Estimation model
Quay site	Panel	420	Inputs: Quay site inputs (maximum draft, LOA, STS crane index), terminal area, internal trucks and vehicles Output: STS crane move/hour	CCR-I / BCC-I Measure-specific DEA
Yard site	Panel	70	Inputs: Yard site input (yard stacking index, yard free storage time), terminal area, internal trucks and vehicles Output: Cargo dwell time	CCR-I / BCC-I Measure-specific DEA

To test the assumption of whether disproportionate performance levels exists or not between terminal sub-systems, efficiency estimates for different terminal sites are calculated and compared with the efficiency of overall terminal operations. Table 24 depicts the datasets and analytical models used for estimating the efficiency scores for the quay and yard terminal sites, respectively. We could not however estimate technical efficiency for the gate site because of prevalent data unavailability on gate input.

The dataset for the quay and yard sites includes input and output variables relative to each site only, including micro-variables, as well as the input variables associated with aggregate terminal operations, namely 'terminal area' and ' internal trucks and vehicles'. Unlike for the quay site, technical efficiency for the yard is estimated for 10 terminals only due to missing output data, namely the cargo dwell time. Those terminals are GCT, HBCT, HGCT, WPCT, PTP, T37, SAGT, JSCT, SPCT, and KCT. Cargo or container dwell time denotes the average time a container remains in the yard before being loaded on board a ship (for outbound containers) or dispatched through the gate (for inbound containers). The datasets for quay and yard sites have both been tested and validated in the context of DEA. For instance, we use panel data to ensure sufficient degrees of freedom and report information on dwell time in reciprocal figures to satisfy the isotonicity requirement. The results for both datasets are reported in Appendices 24 and 25, respectively.

For quay-site operations, the results show that the latter clearly exhibit higher performance levels than those derived from overall terminal operations with mean efficiency scores of 75.8% and 67.6%, respectively. However, the analysis of berth efficiency yielded only 35 efficient units against 45 units found to be efficient when terminal efficiency is analysed. The comparative results of efficiency estimates for the terminal and the berth are consecutively depicted in Figure 32.

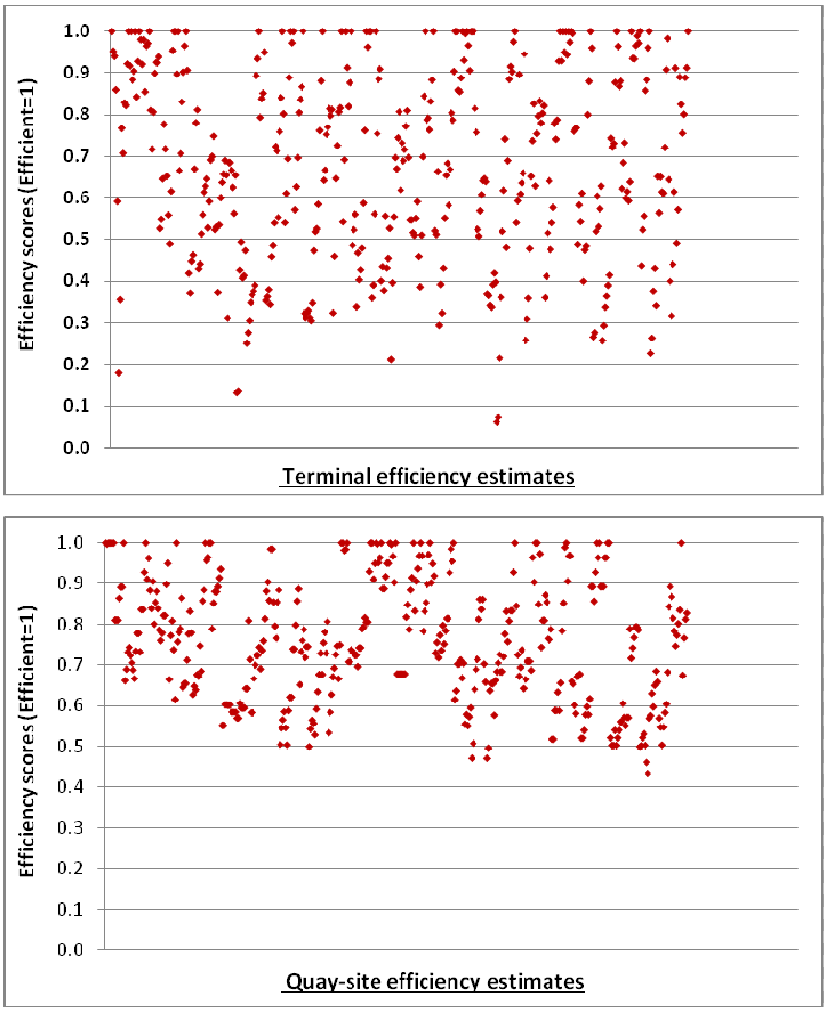


Figure 32: Comparison of terminal and quay-site efficiency estimates
(Based on CCR-I panel data analysis of 420 DMUs)

Further analysis shows a low positive correlation coefficient ($r = 0.1$) between the efficiency estimates yielded from the two sites. These results, which might be surprising in their clarity, even hold true in operational and management perspectives. Take for instance the case of the Hong Kong terminals CT3 and MTL. As shown in Figure 333 below, CT3 has seen its terminal efficiency decreased dramatically despite high levels of berth productivity. This is because the period following the transfer of ownership from CSX World Terminals to DP World has been marked by low activity, therefore resulting in low container throughput. However, this decrease in throughput had no direct negative impact on STS-crane productivity. For MTL, quay-site operations constantly record lower efficiency ratings than those of terminal operations but do not follow the same efficiency trend over time. In particular, berth efficiency tends to decrease when terminal's efficiency (and throughput) increases, which may be indicative of congestion problems during times of high demand.

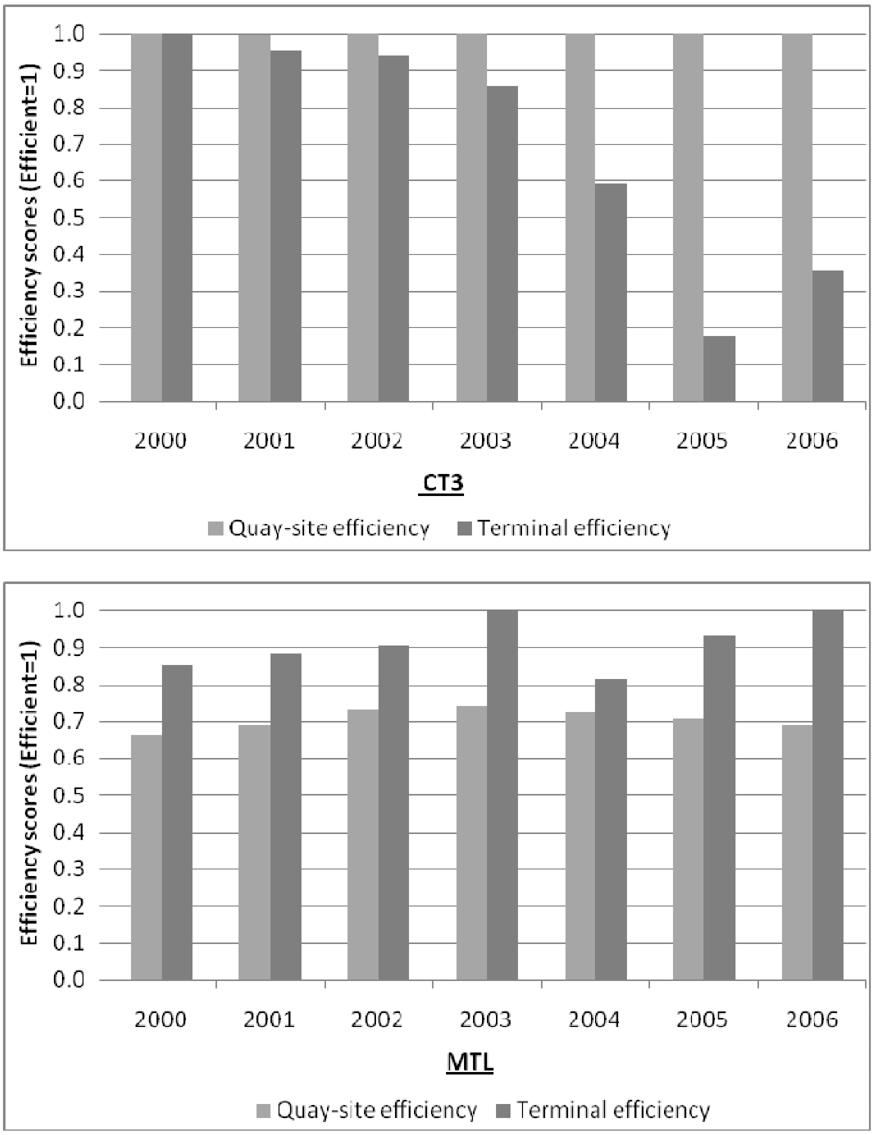
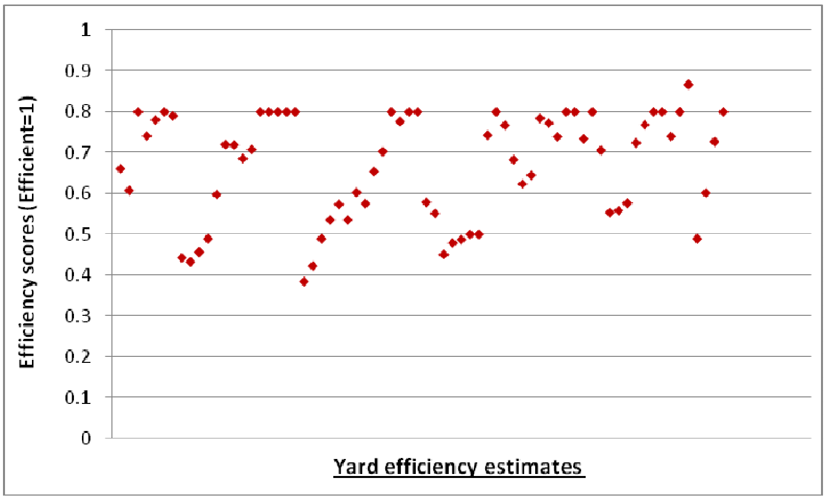


Figure 33: Comparison of terminal and berth efficiency estimates for CT3 and MTL (Based on CCR-I panel data analysis of 420 DMUs)

The examples of CT3 and MTL summarise the findings from the comparative analysis of berth efficiency against terminal efficiency. Each efficiency/productivity may be an explanatory factor to the other, but is neither the exhaustive factor nor a sufficient one.

For yard operations, efficiency estimates of yard sites in 10 terminals (70 DMUs) generally exhibit lower performance levels than those of aggregate terminal operations, with average efficiency scores of 66.9% and 87% for the former against 68.5% and 91.6% for the latter when DEA-CCR-I and DEA-BCC-I models are applied, respectively. The comparative results of efficiency scores are depicted in Figures 34. Note that none of the DMUs has achieved a 100% efficiency score for yard operations.



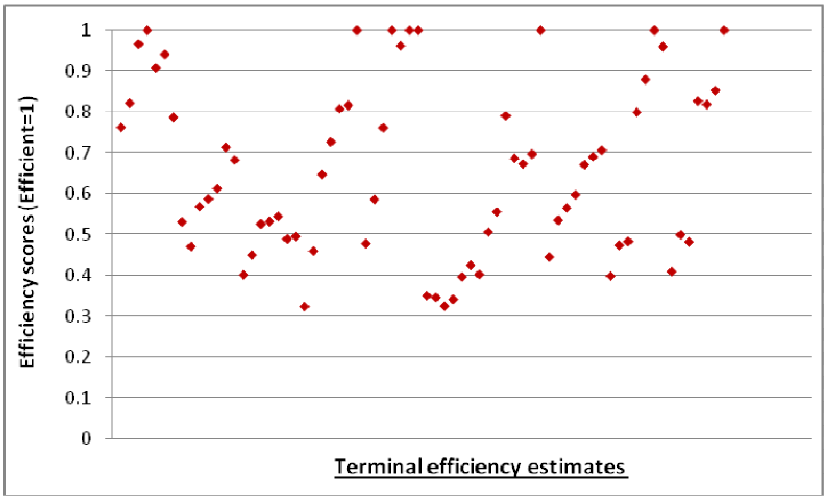


Figure 34: Plotting of efficiency estimates of yard-site operations
(Based on CCR-I panel data analysis of 70 DMUs)

To examine further the impact of sub-system constraints on overall terminal efficiency, we compare the variations of average efficiency scores over time for quay-site, yard-site, and terminal operations relative to the 10 terminals mentioned above and for which detailed and complete data are available. As shown in table 25, yard operations yield lower levels of productive efficiency compared with both quay-site and terminal operations.

Table 25: Variation of average efficiency by operating site
(Based on CCR-I panel data analysis of 70 DMUs)

DMU/ Site	GCT	HBCT	HGCT	WPCT	PTP	JSCT	SAGT	T37	SPCT	KCT
Yard	0.740	0.552	0.771	0.507	0.730	0.508	0.721	0.764	0.683	0.718
Quay	0.815	0.721	0.952	0.586	0.742	0.645	0.871	0.929	0.640	0.774
Terminal	0.952	0.761	0.718	0.734	0.827	0.434	0.729	0.885	0.714	0.809

Further analysis shows that observed increases by proportionally similar increments in quay and yard efficiencies, e.g. a 10% increase in quay crane move *versus* a 10% decrease in yard dwell time, yield positive but different incremental increases in terminal efficiency, with the bigger increments in terminal efficiency being the results of shorter cargo dwell times. These results imply that while several operators advocate greater performance through higher achievements in berth productivity, the latter does not necessarily translate into similar levels of productive efficiency for aggregate terminal operations. In particular, the optimisation and standardisation of quay-site operations is offset by reported yard-site inefficiencies. These findings are consistent with recent empirical studies showing that operational bottlenecks in port operations often occur in the yard (Choi, 2005; Kim et al., 2006; Nang and Hadjiconstantnou, 2008; Le-Griffin, 2008) and that more focus must be placed on yard and land-interface operations (Bichou, 2005a). They are however at variance with much of the conventional port literature, which tends to prioritise quay-site productivity over other aspects of terminal operations (Tongzon, 1995; Liu et al., 2006).

VI.1.3.2 Analysis of network efficiency

The models and tests used in the previous section examined individual efficiencies of site-specific operations and provided evidence of the existence of disproportionate performance levels between various terminal sites. However, it stops short at analysing the efficiency of the network structure resulting from the interplay between these terminal sites and their operational sub-processes. In the previous Chapter, we advocated that container terminals would be best modelled as a network of interrelated sub-systems, but highlighted the difficulty of modelling the network structure of terminal operations in view of efficiency analysis through DEA. A possible way to achieving this in the context of security regulations is to specify a supply-chain DEA model that captures the network technology for either import or export processes. Because both the CSI and the 24-hour rule target export containers only, one could specify a DEA model whereby the network technology of container export flows is modelled as a series of multi-stage supply chain processes (see equation 16 above). In so doing, a process-stage is captured in terms that correspond to one or a combination of terminal operating sites, each reflecting the spatial and operational scope of the CSI and the 24-hour rule, respectively. Due to the limited availability of multi-stage production data, only 10 terminals (GCT, HBCT, HGCT, WPCT, PTP, T37, SAGT, JSCT, SPCT, and KCT) are included in the supply-chain DEA model.

Table 26: Input and output variables for supply chain DEA model

	Gate		**Yard and Quay**		**Network**	
	Input	Output	Input	Output	Input	Output
CSI configuration	Gate lanes Cut-off time	*Gate outbound TEUs*	*Gate outbound TEUs* Yard staking index Yard free storage STS crane index LOA Max draft	Export TEUs Yard dwell time STS crane move/hr	Gate inputs Yard & Quay inputs *Gate outbound TEUs*	Export TEUs Yard dwell time STS crane move/hr
	Gate and Yard		**Quay**		**Network**	
	Input	Output	Input	Output	Input	Output
24-hr rule configuration	Gate lanes Cut-off time Yard stacking index Yard free storage	Gate outbound TEUs *Yard dwell time*	*Yard dwell time* STS crane index LOA Max draft	Export TEUs STS crane move/hr	Gate & Yard inputs Quay site inputs *Yard dwell time*	Export TEUs STS crane move/hr

The supply chain DEA efficiency scores listed in Appendix 26 show that although many observations on site operations (supply chain members) are efficient, only 13 terminal aggregate (supply chain) performances are efficient, i.e. observations for which all sites are efficient. These are DMUs CGT-*2003*, HGCT-*2000*, HGCT-*2003*, HGCT-*2003*, PTP-*2002*, PTP-*2006*, T37-*2006*, and SPCT-*2002* for the CSI network site; and DMUs CGT-*2000*, CGT-*2003*, HGCT-*2006*, PTP-*2001*, and T37-*2002* for the 24-hour network. The DMU CGT-*2003* is efficient in both models meaning that the export-oriented operations at CGT in the year 2003 have been efficiently performed at both site-specific and the export-network levels.

Table 27: Comparative results of average supply chain efficiency scores
(Based on CCR-I panel data analysis of 70 DMUs)

Regulatory Spatial Site		2000	2001	2002	2003	2004	2005	2006
CSI spatial configuration	Gate	0.885	0.848	0.958	0.863	0.987	0.820	0.741
	Yard and Quay	0.920	0.912	0.908	0.780	0.991	0.830	0.780
	Network	*0.793*	*0.787*	*0.871*	*0.713*	*0.956*	*0.788*	*0.754*
24-hr rule spatial configuration	Gate and Yard	0.899	0.912	0.878	0.794	0.938	0.960	0.890
	Quay	0.846	0.823	0.861	0.874	0.998	0.996	0.964
	Network	*0.853*	*0.804*	*0.811*	*0.699*	*0.897*	*0.946*	*0.856*

Table 27 shows the comparative results of average supply-chain efficiency scores for terminal DMUs by regulatory spatial cluster. The analysis of DEA supply chain efficiency provides more insights on the network structure of container terminal operating systems. The results show that in all cases, a terminal's network efficiency is lower than the average efficiency from both sites. For most inefficient terminal DMUs, we observe that the average value of site efficiency scores is greater than the value of terminal efficiency score, which indicates that the multi-stage (supply chain) terminal operating system could achieve more input savings. The scope and extent of input savings depend on efficiency scores of both site and terminal export operations, and on how these can be improved to reach best practices.

Consider for instance the productive efficiency for HGCT, which are reported in Table 28 below. The table shows that the DMU HGCT-*2006* achieves optimum efficiency for the 24-hour network while DMUs HGCT-*2000*, HGCT-*2002* and HGCT-*2003* achieve an equally efficient rating for the CSI network. The result also show that for the same DMU, a process can be efficient while another may be operating inefficiently, which yields inefficient network operations (see for instance HGCT-*2006* under the CSI network and HGCT-*2000* and HGCT-*2001* under the 24-hour rule network). In such cases, operational adjustments must be taken to counterbalance disproportionate performances between sites. For instance, in order to achieve optimal efficiency for HGCT-*2006* under the CSI configuration, the terminal operator may decide either to improve the efficiency of the combined yard-quay operations so that it levels up with that of gate operations; or to slow down the gate-in rate for export containers so that it matches the production level of the yard-quay operations. When either site is inefficient, one can select different input/output operating mix but still achieve optimal efficiency.

Table 28: HGCT supply chain (network) efficiency for outbound container flow

HGCT	**CSI spatial configuration**				**24-hour rule spatial configuration**			
	Gate	*Yard & Quay*	Average efficiency	*Network efficiency*	*Gate*	*Yard & Quay*	Average efficiency	*Network efficiency*
HGCT-*2000*	**1.000**	**1.000**	**1.000**	***1.000***	**1.000**	0.844	0.922	*0.902*
HGCT-*2001*	0.949	1.000	0.975	*0.922*	**1.000**	0.761	0.881	*0.828*
HGCT-*2002*	**1.000**	**1.000**	**1.000**	***1.000***	0.977	0.964	0.971	*0.917*
HGCT-*2003*	**1.000**	**1.000**	**1.000**	***1.000***	0.722	0.815	0.769	*0.645*
HGCT-*2004*	0.893	0.674	0.784	*0.590*	0.690	0.820	0.755	*0.665*
HGCT-*2005*	0.867	0.760	0.814	*0.698*	0.754	0.820	0.787	*0.719*
HGCT-*2006*	**1.000**	0.921	0.961	*0.885*	**1.000**	**1.000**	**1.000**	***1.000***

The analysis in terms of DEA supply chain efficiency has shown that managing terminals as integrated operating sites is the best way to achieving aggregate best-practice performance. In adopting a network approach to container terminal operations, operators may choose to run their operating terminal sites with varying degrees of utilisation and service levels in order to optimise the aggregate terminal efficiency.

VI.2 Productivity Change Analysis

In order to assess efficiency gains or losses stemming from the implementation of the new security regulations, we apply a stepwise DEA-based Malmquist productivity index (MPI). Unlike other total factor productivity (TFP) indices, the MPI does not require the use of input or output price information and, therefore, it can be constructed direct from DEA. The MPI uses panel data to assess whether there has been an increase or a decline in TFP of each container terminal, both across time and vis-à-vis other terminals in the sample. An MPI greater than 1 indicates a positive productivity change while an index less than 1 indicates a negative productivity change.

Another advantage of the MPI is that total factor productivity change (TFPC) can be decomposed into various sources of efficiency change such as in terms of a total technical efficiency change (TEC) component and a technical change (TC) component. The former captures the catching-up in efficiency while the latter represents the shift in the frontier technology. TEC can be decomposed further into a pure technical efficiency change (PEC) component and a scale-efficiency change (SEC) component. This makes the MPI a particularly attractive technique for assessing productivity changes brought about by the new security regulations. For a full description of the background and methodology behind the MPI, see relevant sections in Chapters IV and V.

The approach used in this study is to apply a stepwise Malmquist DEA both on a year-by-year and on a regulatory-period basis. On the one hand, we estimate the MPI on a year-by-year basis in order to benchmark the efficiency of aggregate container-terminal operations between any two successive years and track short-term changes in productive efficiency. On the other hand, the calculation of MPI by regulatory-runs can track productivity change before and after the introduction of security regulations and between terminals that have implemented them and those that have not.

VI.2.1 Multi-Year TFP analysis

The results of the multi-year TFP analysis are presented in Appendix 27. Overall, the results show that on a year-by-year basis, 110 DMUs have achieved a productivity gain, 249 DMUs have experienced a productivity loss, and only one DMU recording no change in total factor productivity. There are five outliers, namely LCB1 in 2003-2004 (MPI=2.94), CT3 in 2004-2005 (MPI=3.77), LCIT in 2004-2005 (MPI=2.27), MCT in 2004-2005 (MPI=2.20), and MIT in 2005-2006 (MPI=2.13). When excluding these outliers, the average total productivity for container terminals in the sample was regressing for all year-pairs but with varying degrees of efficiency change both across pairs and between terminals. Table 29 shows the descriptive statistics of the year-by-year changes in MPI and its sub-categories.

Table 29: Descriptive statistics of the year-by-year MPI and its sub-categories

			Index decomposition		
		MPI	PEC	SEC	TC
Period	N	60	60	60	60
2000-2001	Mean	0.925	0.985	0.916	1.024
	Median	0.920	0.998	0.931	1.029
	Minimum	0.455	0.691	0.550	0.924
	Maximum	1.439	1.006	1.404	1.065
	Std. Deviation	0.149	0.042	0.132	0.034
2001-2002	Mean	0.887	0.988	0.933	0.961
	Median	0.903	1.000	0.968	0.960
	Minimum	0.320	0.860	0.368	0.872
	Maximum	1.305	1.181	1.384	1.084
	Std. Deviation	0.166	0.042	0.168	0.033
2002-2003	Mean	0.944	0.993	0.929	1.011
	Median	0.906	1.000	0.909	0.989
	Minimum	0.399	0.839	0.509	0.842
	Maximum	1.972	1.108	1.604	1.506
	Std. Deviation	0.297	0.041	0.222	0.121
2003-2004	Mean	1.035	1.007	1.011	1.000
	Median	0.937	1.000	0.946	0.983
	Minimum	0.615	0.903	0.644	0.845
	Maximum	2.935	1.288	2.482	1.373
	Std. Deviation	0.385	0.067	0.275	0.088
2004-2005	Mean	1.064	1.006	1.037	1.008
	Median	0.951	1.000	0.951	0.996
	Minimum	0.473	0.869	0.483	0.904
	Maximum	3.769	1.287	3.296	1.186
	Std. Deviation	0.462	0.058	0.368	0.066
2005-2006	Mean	0.943	0.999	0.970	0.968
	Median	0.909	1.000	0.967	0.968
	Minimum	0.488	0.910	0.505	0.875
	Maximum	2.128	1.106	1.945	1.090
	Std. Deviation	0.232	0.037	0.197	0.036

The results from Table 29 shows that on average a productivity loss in MPI has been recorded in all observation periods, except the successive year-pairs of 2003-2004 and 2004-2005 where a slight gain in TFP was recorded. Container terminals in the sample have experienced minor changes in their pure technical efficiency (PEC) with an almost flat efficiency trend in each of the periods under study. On the other hand, there has been a steady improvement in scale efficiency (SEC) from year to year until the period 2005-2006 where a slight decline has been recorded. Finally, the technical change (TEC) component shows varying productivity change levels between different pairs of years, with the periods 2001-2002 and 2005-2006 depicting a decline in productivity, the periods 2000-2001, 2002-2003, and 2004-2005 exhibiting a gain in productivity, and the period 2003-2004 showing no change in productivity.

Combining the MPI results from all pairs of years, the variations in average productivity depicted in Figure 35 suggests that efficiency changes of MPI and its sub-categories do not all follow similar productivity trends. The Figure shows that there has been an almost flat trend in average pure efficiency change (PEC) across all observation periods. On the other hand, both TFP (MPI) and scale efficiency changes seem to follow the same trend throughout the period from 2002 until 2006, but depict opposing trends in the period prior to 2002. Finally, technical change (TC) efficiency shows a different trend against other sources of efficiency.

The results from both Table 29 and Figure 35 confirm the general trend of decreasing container-terminal efficiency as evidenced by recent congestion problems and a persistent shortage of global port capacity but there is a visible trend of average productivity gains after 2004, which was followed by an equally noticeable decline in 2005.

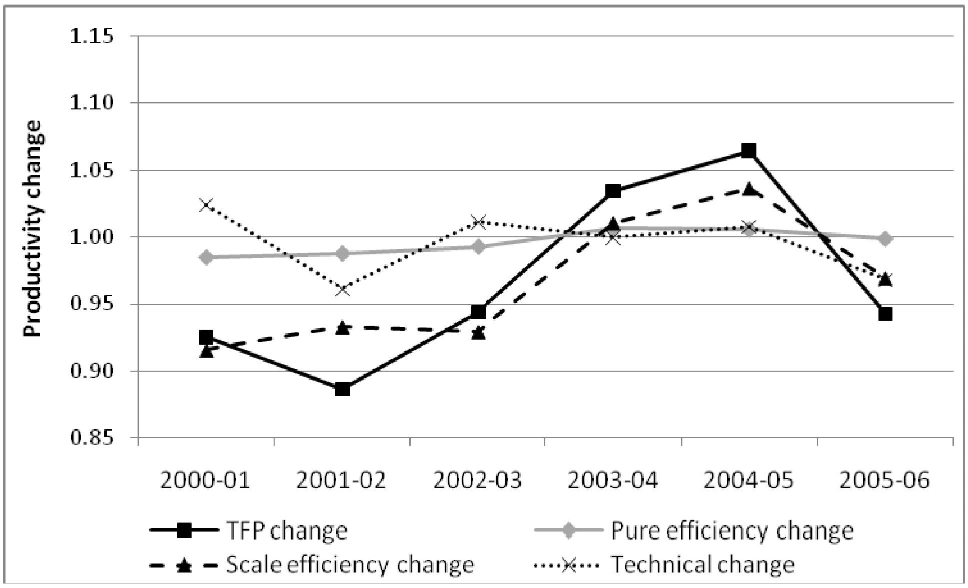


Figure 35: Average values of MPI and its sources of efficiency on a year-by year basis

The analysis of the relationship between the multi-year MPI and its sub-categories provides a statistical ground for explaining the changes in TFP through the various components of efficiency change (see Table 30 and Figure 36 below).

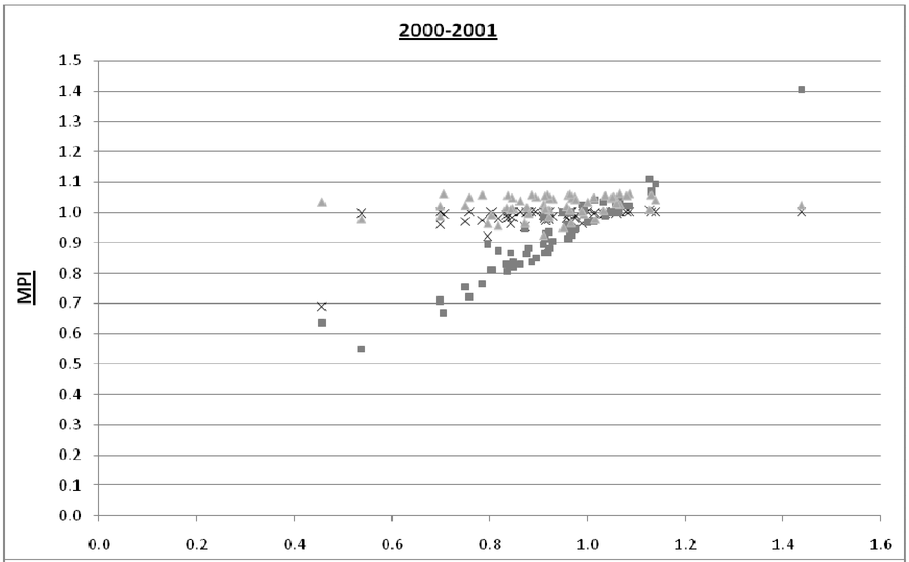
Table 30: Correlation of the multi-year MPI and its sources of efficiency change

Period	MPI Decomposition		
	MPI-PEC	MPI-SEC	MPI-TC
2000-01	0.501	0.957	0.197
2001-02	0.312	0.965	0.123
2002-03	0.491	0.917	0.579
2003-04	0.698	0.972	0.404
2004-05	0.442	0.985	0.330
2005-06	0.707	0.979	0.283

Starting with scale efficiency (SEC), productivity gains achieved from this component have a stronger impact on the improvement of the overall efficiency of container terminals, despite many large terminals operating at the size of decreasing returns to scale (see Appendix 27). The stronger impact of scale efficiency rather than the non-scale (pure) technical efficiency indicates that the focus from the part of terminal operators was on achieving operational efficiency through terminal expansion rather than through the rationalisation of input use. Ports with substantial transhipment traffic and sizeable demand from large hinterland economies also benefit from the production scale effects.

For the impact of technical change (TC), the results also show that shifts in the frontier technology have a statistically meaningful impact on total factor productivity (TFP). However, the size of the impact from technical change is smaller than the one emanating from adjustments in port production scales (SEC) and even lesser than the one from the rationalisation of input factors (PEC). Note that the period prior to the introduction of port security regulations (2002-2003) has been marked by the highest impact of technical change on TFP followed by periods of gradual decline of the impact of technological progress (2003-2004, 2004-2005, and 2005-2006).

Since port security regulations have been introduced in the last two or three years of the study period, the above findings on TC may shed further light on the impact of procedural security on operational efficiency. Technological progress is mainly driven by investment in advanced ICT systems, including tracking and scanning technologies for terminal security, as well as by investment in modern handling equipment. The fact that the frontier shift effects have a smaller variance than other sources of efficiency change indicates that the investment in new technology does not necessarily yield substantial gains in TFP, at least in the short-run. This explains, at least partly, why automated systems are not widely used across global ports and terminals. It also provides further evidence of the compliance culture in the port industry since it suggests that port operators have been compelled rather than willing to adopt new technologies and procedural systems for container-port security.


2000-2001
MPI
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
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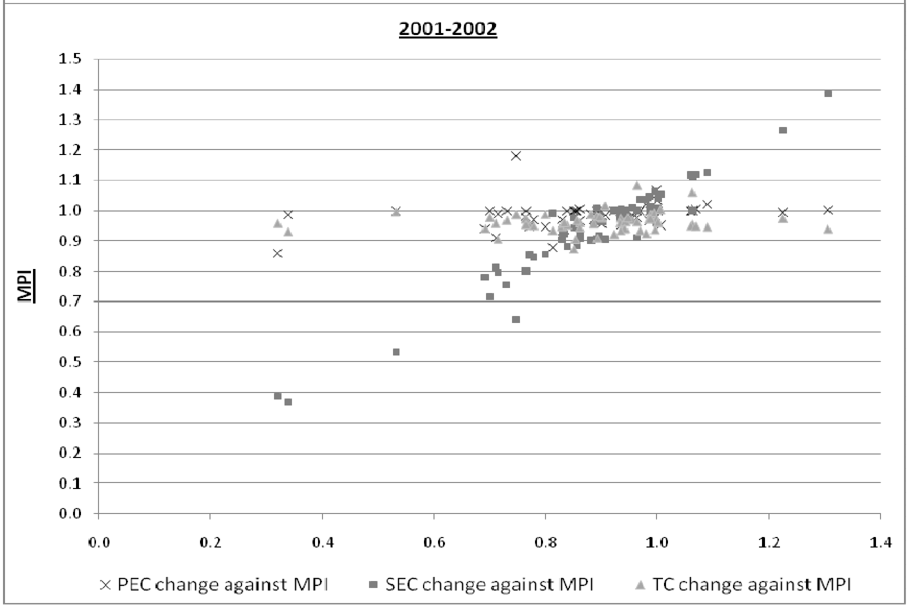
2001-2002
MPI
1.5
1.4
1.3
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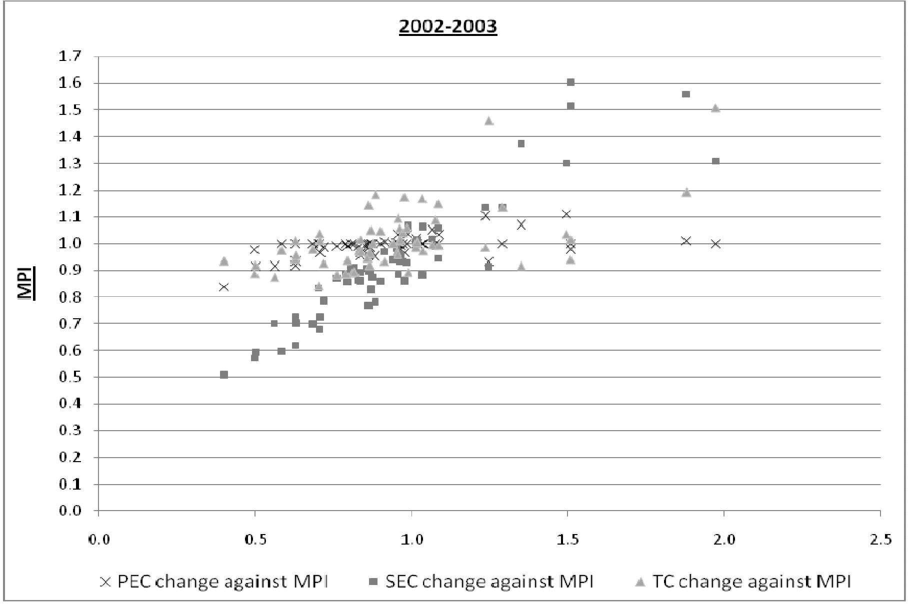
0.4
0.3
0.2
0.1
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
× PEC change against MPI
■ SEC change against MPI
▲ TC change against MPI


2002-2003
MPI
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
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1.0
1.5
2.0
2.5
× PEC change against MPI
■ SEC change against MPI
▲ TC change against MPI

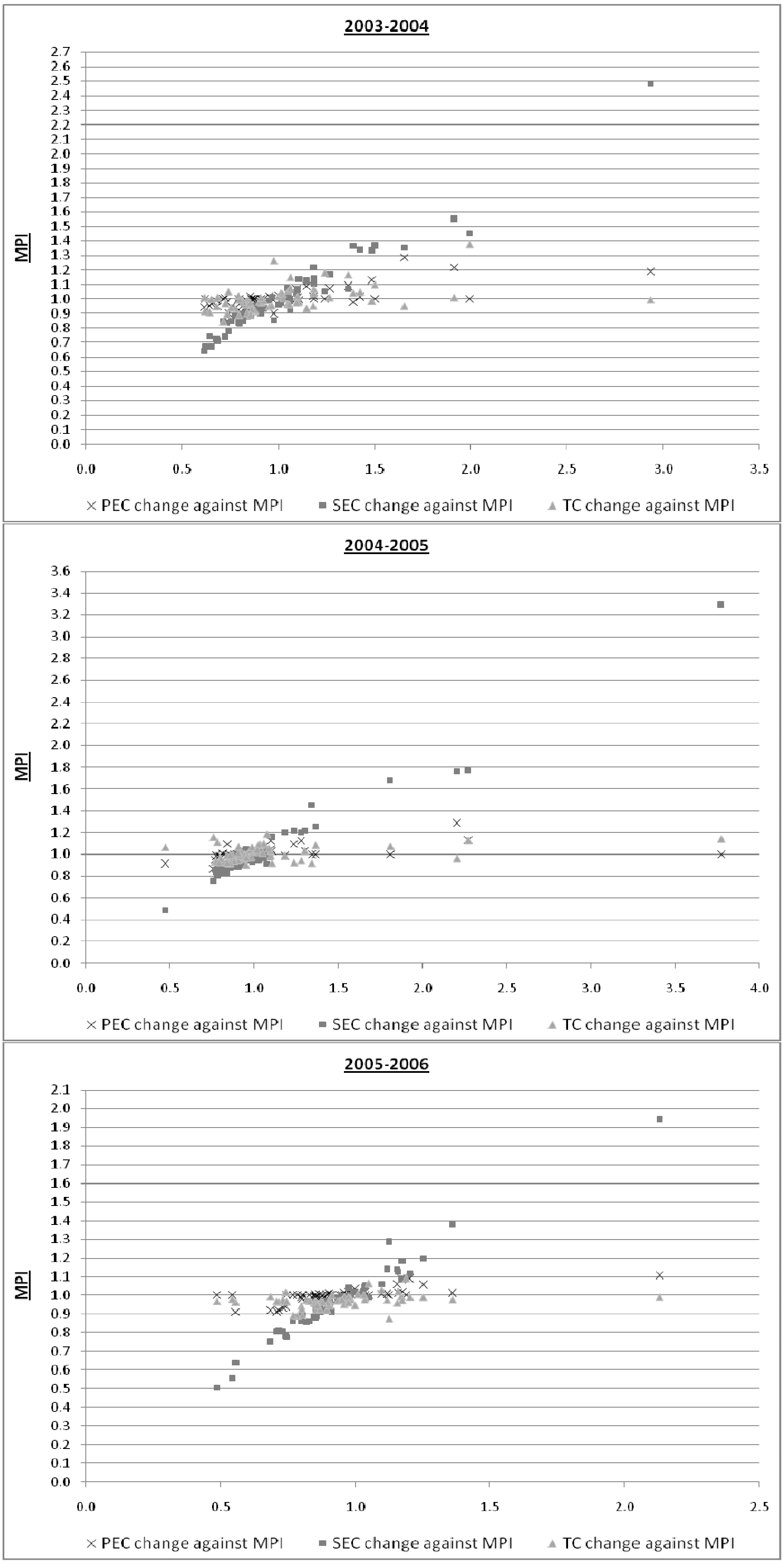

Figure 36: Correlations between multi-year MPIs and components of TFP

VI.2.2 Analysis of MPI by Regulatory Runs

Although the stepwise multi-year MPI is useful for the analysis of short-term changes in productive efficiency, it does not provide a basis for the analysis of the productivity change derived from regulatory and policy decisions because the impacts of these decisions on port operations are likely to take place over the medium and long-term horizons. In order to track TFP growth with a view of investigating the impacts of procedural security, we estimate and compare the MPI and its sources of efficiency by regulatory runs, in other words before and after the introduction of procedural security and between terminals that have implemented security measures and those that have not. This approach is used to assess both individual and joint impacts of security, with the difference that the former focuses on the impact of a specific security measure while the latter tracks the combined impacts from all security regulations under study.

VI.2.2.1 Analysis of the impact of combined regulatory measures

Appendix 28 shows the productivity growth of MPI and its sources of efficiency for the periods of 2000-2006, 2000-2004, and 2004-2006, respectively. Descriptive statistics for each of these regulatory periods are depicted in Table 31 below.

Table 31: Descriptive statistics of the regulatory-run TFP and its sub-categories

			Index decomposition		
		MPI	PEC	SEC	TC
Period	N	60	60	60	60
2000-2006	Mean	0.749	0.976	0.778	0.974
	Median	0.716	1.000	0.772	0.919
	Minimum	0.095	0.730	0.112	0.706
	Maximum	3.293	1.363	1.596	2.064
	Std. Deviation	0.442	0.117	0.311	0.197
2000-2004	Mean	0.769	0.973	0.793	0.996
	Median	0.758	0.994	0.833	0.947
	Minimum	0.119	0.762	0.135	0.706
	Maximum	1.997	1.219	1.386	1.886
	Std. Deviation	0.315	0.098	0.259	0.183
2004-2006	Mean	0.959	0.998	0.974	0.975
	Median	0.897	1.000	0.989	0.919
	Minimum	0.498	0.635	0.493	0.724
	Maximum	3.110	1.363	1.507	2.064
	Std. Deviation	0.367	0.089	0.179	0.196

The results of the regulatory run analysis show that on average total factor productivity change (TFPC) has been regressing for all observation periods, but with varying degrees of productivity losses. CT3 in the period 2000-2006 is the only major observed outlier (MPI=3.29).

Between 2000 and 2006, container terminals in the sample have experienced deterioration of their total factor productivity by an average of 25.1% (MPI=0.749). The decomposition of the index indicates that all sources of efficiency have also decreased with the most noticeable deterioration recorded in average sale efficiency (SEC=0.778). Furthermore, both pure technical efficiency and technical change efficiency have recorded nearly flat productivity growth (PEC=0.976, TC=0.974). This suggests that the decline in TFP in the period 2000-2006 is mainly attributable to the decline in scale efficiency.

To analyse the changes in total productivity before and after the introduction of security regulations, we have estimated two additional Malmquist indices each for a different time-period. The first period spans the years 1 to 5 (between 2000 and 2004) while the second period spans the years 5 to 7 (between 2004 and 2006). The year 2004 is selected as the reference point for both periods because many security regulations have been implemented globally in mid-2004.

The average TFP indexes for both periods show negative productivity changes but only a minor deterioration of TFP has taken place during the period 2004-2006 (MPI=0.959) against a larger deterioration recorded during 2000-2004 (MPI=0.769). Among the sub-categories of the MPI, the average pure technical efficiency varied slightly between the two periods, with average PEC values of 0.973 and 0.998 for the periods of 2000-2004 and 2004-2006, respectively. The same can be said for the technical change (TC) efficiency, with average values of 0.996 and 0.975 for the periods of 2000-2004 and 2004-2006, respectively. Where the difference was most noticeable is in the change in scale efficiency (SEC) for both periods. The average index of scale efficiency (SEC) has shown productivity losses in both periods but was markedly higher during the period following the introduction of security measures (MPI=0.974) compared with the period prior to introducing the new security measures (MPI=0.793).

The analysis of the correlation between the regulatory-run MPI and its sub-categories sheds further light on the trends in productivity change following the introduction of port security measures. The results, which are reported in both Table 32 and Figure 37 below, suggest that TFP change has been driven mainly by adjustments in scale production. For the impact of both pure technical change (PEC) and technical change (TC) efficiencies, the results show that the size of the impact from either efficiency source on TFP is smaller than that emanating from scale efficiency, with the difference that PEC has a lesser impact than TC. Further comparison of the correlation results from the periods before (2000-2004) and after (2004-2006) the introduction of procedural security shows that the impact of technical change has increased dramatically between the two periods at the expense of both pure technical efficiency and scale efficiency changes. These results suggest that container terminals seem to have benefited positively from technological investment in security.

Table 32: Correlation of the regulatory run MPI and its sources of efficiency change

Period	MPI Decomposition		
	MPI-PEC	MPI-SEC	MPI-TC
2000-06	0.356	0.809	0.539
2000-04	0.435	0.805	0.419
2004-06	0.372	0.729	0.758

Compared with the findings from the multi-year TFP analysis, it seems that the effects of technological progress are not noticeable in the short run. As outlined in Chapter II, container ports and terminals have had to invest heavily in technology based security equipment and systems in order to comply with the new security measures. Examples of technology investment in security include such aspects as operational infrastructure (CCTV and surveillance equipment, electrical fences, etc.), network infrastructure (secure IT data platforms, AMS and other electronic data reporting systems); access control (biometric devices, optical scanners, smart readers, etc.), and container integrity (electronic seals, container identity systems, Non-Intrusive Inspection -NNI- technology, etc.). In addition to the benefits of access certification and fast-lane treatment, these technologies and others have proven to be less time-consuming for container handling, inspection, and other ship and cargo processing procedures.

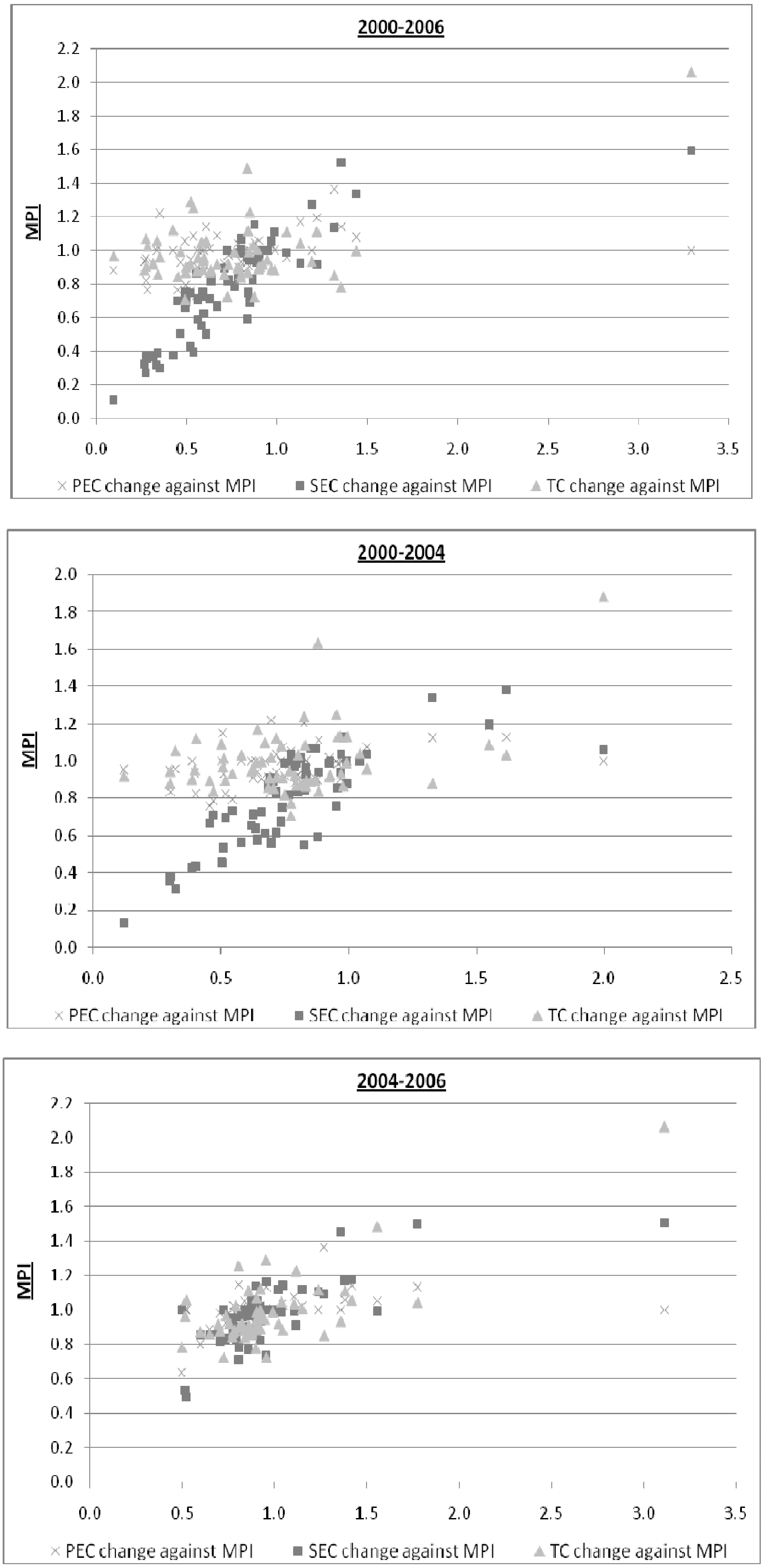

Figure 37: Correlations between regulatory-run MPIs and components of TFP

VI.2.2.2 Analysis of the impact of regulatory-specific measures

The above section reports on TFP change for container terminals in the sample before and after the introduction of security measures. This approach is primarily undertaken to assess the joint influence of relevant port security regulations under study (the ISPS Code, the CSI, and the 24-hour rule). However, not all terminals in the sample are subject to these regulations nor have they introduced and implemented them at the same time. To allow for the assessment of the impact of specific-regulatory measures, the aggregate dataset has been divided into several datasets, each with a corresponding set of terminals. For each security measure, we exclude from the original dataset the terminals for which the selected regulation or combination of regulations do not apply. By comparing the changes in terminal efficiency (MPI) between terminals that have implemented certain security measures and those that have not, it is possible to make inferences on the impacts of specific security regulations. Table 33 depicts the datasets utilised for each regulation or combination of regulations. Note that due to the unavailability of detailed and reliable data, the scope of efficiency analysis for some security regulations is limited to few terminals in the sample.

Table 33: Regulatory-specific datasets for the analysis of productivity change

Groups/ Datasets	**Terminals**
24-hour rule Foreign (non-US) terminals with substantial US export traffic throughout the period 2004-2006	51 terminals: Sample terminals excluding YCT, LBPF, LBPT, PNTC, QQCT, TOCT, XNWT, JSCT, JNCT
Non 24-hour rule Foreign (non-US) terminals with little export traffic to the USA, plus US terminals in the sample.	9 terminals: YCT, LBPF, LBPT, PNTC, QQCT, TOCT, XNWT, JSCT, JNCT
CSI US terminals and CSI foreign (non-US) participant terminals as of 30/12/2004	36 terminals: CT3, TE8, MTL, HIT, GCT, HBCT, PECT, HGCT, UCT, ECTD, MDCT, YCT, BCT, TTC, CTH, LBPF, LBPT, NPCT, WPCT, PNTC, PTP, NP, TP, NCB, LCIT, LCB1, CTB, NSCT, AMCT, MCT, DCT, RSCT, TPCT, VCT, VT, LSCT
Non CSI	24 terminals: SCT, SKCT, YICT, JACT, PRCT, QQCT, TOCT, XNWT, MICT, JSCT, JNCT, NSICT, SAGT, MPE, T37, TT, SPCT, ACT, SACT, KCT, CCT, MIT, PQIT, ACT.
Both 24 hour rule and CSI Terminals which, as of 30/12/04, are subject to both the 24-hr rule and CSI	32 terminals: CSI Cluster excluding US terminals in the sample (YCT, LBPF, LBPT, PNCT)
ISPS only (neither 24 hr rule nor CSI) Terminals which are subject neither to the 24-hour rule nor to the CSI throughout the study period	5 terminals: QQCT, TOCT, XNWT, JSCT, and JNCT

A. Impact of the ISPS Code

Unlike the CSI or the 24-hour rule, the ISPS Code is a compulsory regulation with which all container ports and terminals have had to comply. The ISPS Code entered into force globally in July 2004 but many ports have implemented it several months earlier. Thus, it would be reasonable to consider 2004 as the year of ISPS introduction. As shown in the previous section, the comparative change in terminal efficiency after 2004 shows a slight decline of average TFP by -0.04% (MPI=0.963). This almost flat productivity growth reflects the combined influence of various factors, including those stemming from security regulations other than the ISPS Code.

One way to assess the individual impacts of the ISPS Code is to track TFP change of terminals that have implemented the ISPS Code only, in other words those that have been subject neither to the 24-hour rule nor to the CSI during the observation period. Table 34 reports the scores of MPI and its sub-categories for the five container terminals under this group.

Table 34: MPI and its sources of efficiency for terminals complying with the ISPS only

Terminals	2000-2004				2004-2006			
	MPI	PEC	SEC	TC	MPI	PEC	SEC	TC
QQCT	0.507	1.151	0.454	0.970	0.649	0.888	0.851	0.859
TOCT	0.320	0.957	0.316	1.057	0.902	0.992	0.849	1.070
XNWT	0.671	1.000	0.610	1.100	0.922	1.000	0.965	0.955
JSCT	0.924	1.017	0.990	0.918	0.892	1.040	0.965	0.888
JNCT	0.119	0.956	0.135	0.919	0.737	0.923	0.825	0.968
Average	0.508	1.016	0.501	0.993	0.820	0.969	0.891	0.948

Despite the differences in MPI scores, certain common trends among the sources of efficiency change are worth underlying. First, the pure efficiency (PEC) component in the post-ISPS period shows either a regressing or slightly constant productivity change across the five terminals compared with a general trend of productivity gains in the pre-ISPS period. Second, all the five terminals show a significant improvement in their SEC component during the period following the introduction of the ISPS Code. Note the extremely low SEC score of JNCT in the period 2000-04 due to the over-capacity created during that period. Last, the results of the TC efficiency component show varying levels of technological productivity changes between terminals despite a general downward trend in both periods.

If we exclude the impacts of scale efficiency, which are closely related to production scales and investments in long-term port capacity, the above results confirm the findings from previous studies on the ISPS Code execution and impact. As first pointed out by Bichou (2004) and later confirmed by Bosk (2006) and Kruk & Donner (2008), the ISPS Code provides general provisions on security requirements in ports but does not prescribe detailed instructions on how to comply with them. This situation has led to different interpretations of the Code, including investment requirements in security equipment and technology. For instance, the Port Facility Security Officer (PFSO) provision does not indicate whether it is a sole dedicated position or just an added responsibility to an existing function. Ports and port operators may therefore interpret this requirement differently, hence resulting in variable cost and investment-decision models. Furthermore, many of the provisions of the ISPS Code (fences, CCTV cameras, access control procedures, etc.) have already been put in practice by several global ports and terminals well before 2004. Therefore, it would be difficult to assess the gains or losses in TFP due to the ISPS Code on a global scale given that each port or terminal in the sample may have implemented the Code differently or may have already been in conformity with part or most of the provisions of the Code even before its introduction.

B. Impact of the 24-hour rule

The 24-hour rule requires shipping lines to report detailed information on container-cargo bound to the USA at least 24 hours prior to loading at a foreign port. Therefore, only foreign terminals with substantial direct export traffic to the USA have been included in the 24-hour rule dataset.

Table 35 presents the difference in terminal efficiency (MPI) between the 24-hour rule group terminals and the Non-24-hour rule terminals in the sample. From 2004 to 2006, the 24-hour rule group of terminals have on average a lower MPI than the Non-24-hour rule terminals. The group means are statistically different at 9.5% level based on ANOVA ($F = 02.96,\ p = 0.02$). Both technical and scale efficiencies show lower productivity changes for the 24-hour rule group compared with the Non-24-hour rule group, with pure technical efficiency (PEC) registering positive productivity gains for the latter group of terminals. For technical change, productivity gains have been recorded for both groups with a slightly larger gain for the 24-hour rule group than the TC efficiency gain achieved by the Non 24-hour rule group.

Table 35: MPI and its sources of efficiency for the 24-hour rule and the Non-24 hour rule terminals during the period 2004-2006

Index	Terminal Group	N	Mean	Std. Deviation	Minimum	Maximum
MPI	24-hr rule	9	0.841	0.083	0.762	0.986
	No 24-hr rule	51	0.996	0.244	0.525	1.664
	Total	60	0.974	0.237	0.525	1.664
PEC	24-hr rule	9	0.925	0.107	0.719	1.007
	No 24-hr rule	51	1.010	0.078	0.890	1.386
	Total	60	0.990	0.107	0.512	1.386
SEC	24-hr rule	9	0.794	0.124	0.636	1.048
	No 24-hr rule	51	0.941	0.204	0.394	1.656
	Total	60	0.928	0.203	0.394	1.656
TC	24-hr rule	9	1.169	0.159	0.939	1.348
	No 24-hr rule	51	1.054	0.122	0.838	1.330
	Total	60	1.072	0.130	0.838	1.348

A possible explanation of the above results lies in the requirements and the nature of the new cargo information system introduced by the 24-hour rule:

- First, the requirement under the Rule on ocean carriers to submit detailed cargo information to the US authorities 24 hours prior to loading have resulted in shipping lines declining late shipments and requiring from agents and forwarders to submit details of their US-bound cargo during early booking and well in advance of cargo loading. Shippers had then to adjust their production, logistics and distribution processes accordingly including sending their US bound containers to ports either well in advance of ship arrival or just before gate cut-off time. The first strategy is used for mass-production processes such as assemble-to-order (ATO) and make-to-stock (MTS) whereby cargo shipments are stocked and/or assembled in ports benefiting, inter-alia, from generous policies of yard free-storage and gate closing times. The second strategy is used when exporters operate minimum in-process inventory through just-in-time (JIT) logistics whereby planning processes for cargo shipment are synchronised with the timetable of ship's arrival and departure. The constraints put by shippers and forwarders on the 24-hour rule group of terminals would, in either case, lead to increased congestion and cargo dwell time, which can be assimilated to the recorded productivity losses in pure technical efficiency (PEC).

- Another possible cause of observed productivity losses in pure technical efficiency change is the requirement by the 24-hour rule of detailed cargo descriptions, which can lead to a number of data and operational errors, particularly for LCL (Less than Container Load) and combined cargo shipments. A sample of potential errors that might occur in the course of implementing the 24-hour rule requirement is depicted in Table 36.

Table 36: Potential errors in implementing the 24-hour rule (from Bichou et al., 2007a)

Functional department	Potential errors
Marketing	- Flagging the CSI cargo in business information system - Booking data quality - Booking Confirmation to shipper - CSI cut-off time
Administration (documentation and data handling)	- Manifest data quality - Transmission of manifest data to AMS timely - Handling amendment - Bill of Lading issuance to shipper - Rating the shipment - Billing the CSI fee and amendment fee
Operations	- Release of empty container - Coordination with operators and local customs for cargo inspection - Ship planning

➢ Regarding efficiency gains from technical change (TC), the shift from paper-based to electronic submission of cargo manifests through AMS (Automated Manifest System) have allowed for pre-screening and deliberate targeting of ‘suspected’ containers, hence yielding a more effective cargo clearing procedure than the traditional approach of random physical inspections. The benefits of AMS and advanced cargo information systems under the 24-hour rule can be assimilated to the efficiency gains in technological progress (TC) achieved by the 24-hour rule group of terminals.

➢ Finally, an indirect but adverse consequence of the 24-hour rule is the potential disturbance to ship schedules and stability due to logistics redundancies (cargo delay, increases in dwell-time, congestion problems, etc.) that might be caused by the Rule. Unexpected delays and perturbations often take place in the shipping industry due to various reasons but in the context of liner shipping, i.e. ships plying regular services along a fixed route (or string) of ports; the rate at which containers arrive at and leave the port is a major factor affecting the stability of ship’s schedule. If, because of the 24-hour rule, containers take longer to load say at the first port of call, then one could assume larger extension of ship’s arrival headways to take place at subsequent ports of call. The problem of ship bunching, i.e. ships leaving a port prior to the scheduled time to catch up with the schedule of the next port of call, has been empirically investigated by Bell & Bichou (2008) and Bichou (2008). In the context of the 24-hour rule, ship bunching would occur more frequently because of several redundancies stemming from the implementation of the Rule. For a given port, the extent of the derived impact from ship bunching and delay depends on how tight the schedules are and on the position of the port in the shipping string. If located in a downstream position in the string, the port would bear the accumulation of ship bunching in former ports and must either increase its efficiency to absorb this delay or face the risk of lower traffic volumes and the possibility of footloose relocations from the part of shipping lines.

Kingston Container Terminal (KCT) in Jamaica is a case in point in this regard. Kingston's shipping position as a 'last-out' offshore transhipment terminal bound to US ports makes it particularly vulnerable to ship bunching. In the awake of the 24-hour rule in 2003, the effects of delays caused by other ports in the region (see Figure 39 below) have been particularly detrimental to KCT with immediate effect on ship scheduling and berth occupancy, and far reaching consequences on terminal operations. For the three years following the introduction of the Rule, there has been a 26% average increase of cargo dwell-time and a similar increase (24%) of delays in cargo clearance. The comparative results of TFP change between the periods before and after the introduction of the 24-hour rule confirm the effect of ship bunching on KCT efficiency. As shown in Figure 38, KCT has experienced a further deterioration in its technical efficiency after the introduction of the 24-hour rule despite a productivity improvement in technical change and an almost flat growth in scale productivity.

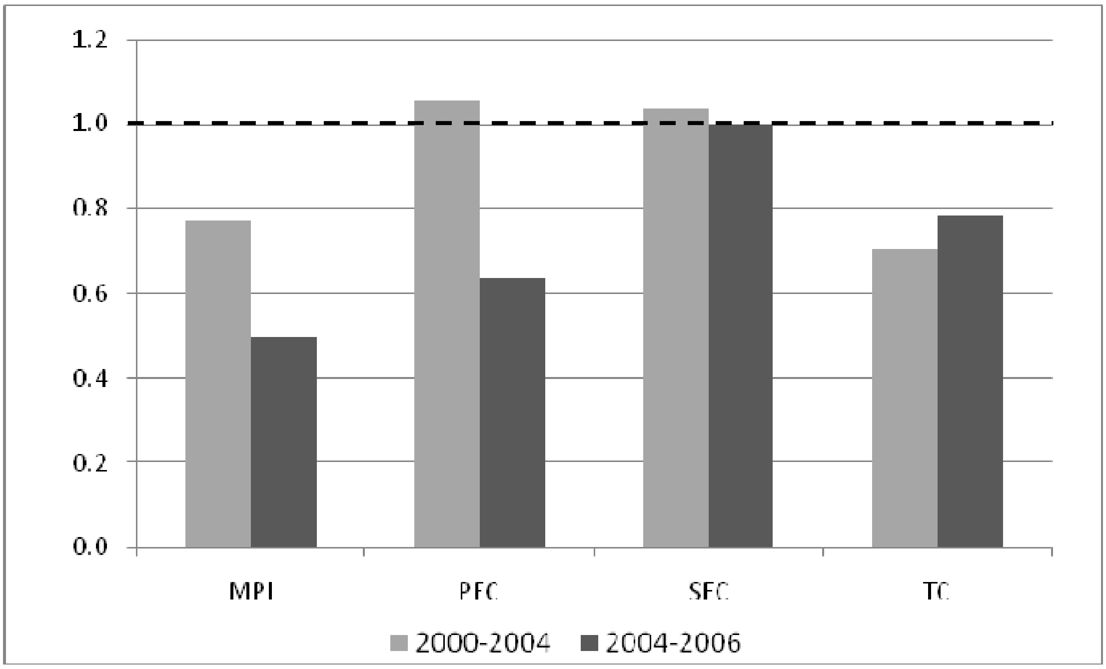

Figure 38: MPI and its sources of efficiency for KCT before and after the introduction of the 24-hour rule

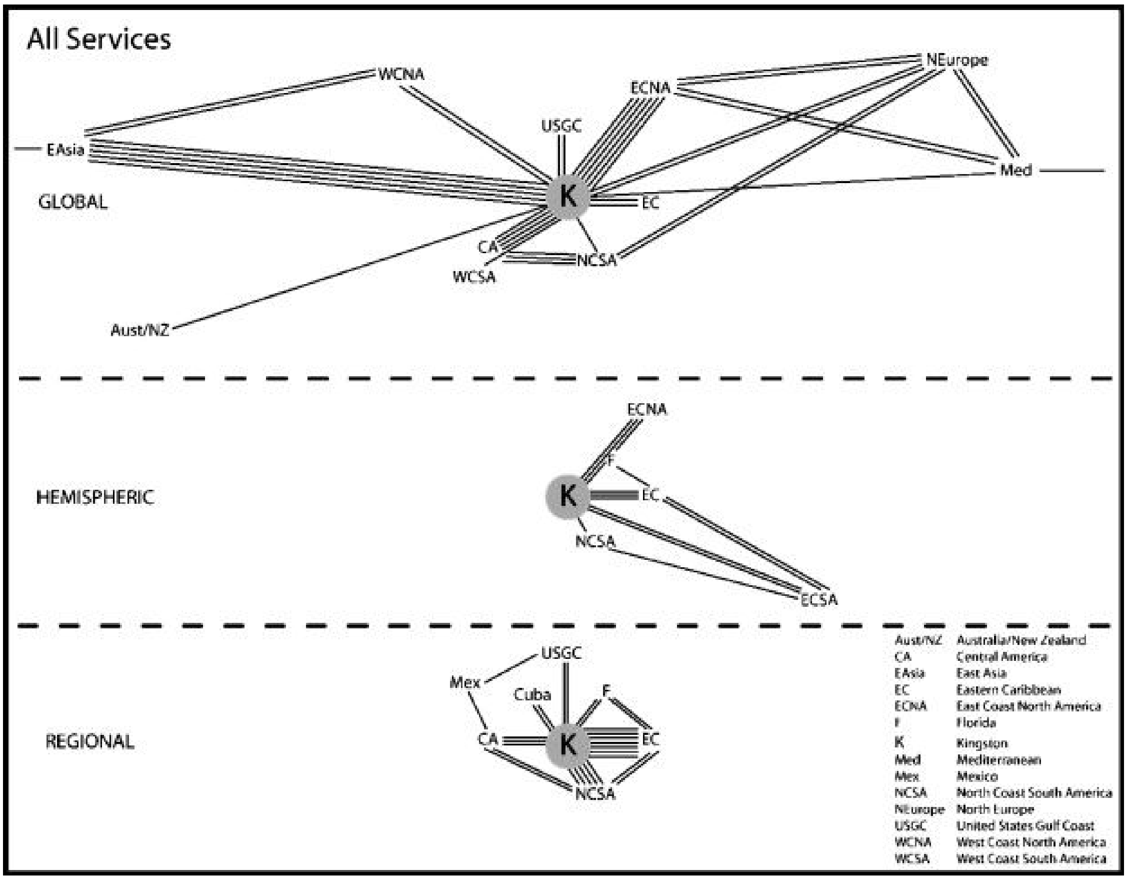

Figure 39: Container shipping routes in the port of Kingston (Jamaica) in 2006 (from McCalla, 2008)

C. Impact of the CSI

As with the 24-hour rule, the CSI only applies to container ports with significant direct export traffic to the USA and with which the US authorities have entered into bilateral agreement allowing the deployment of CBP customs officers in order to screen and inspect high-risk export containers to the USA. However, while the 24-hour rule only influences port operations indirectly, the implementation of the CSI directly results into an increase in the rate of inspection of export containers bound to the USA.

Table 37 compares the changes in terminal efficiency (MPI) between CSI and non-CSI terminals. From 2004 to 2006, the CSI group of terminals have on average experienced a gain in total factor productivity (MPI=1.037) against a loss in TFP experienced by the non-CSI terminals (MPI=0.866). The group means are statistically different at 4.85% level based on ANOVA ($F = 2.62,\ p = 0.05$). In a similar vein, CSI terminals show a gain in pure technical efficiency change (PEC) compared with a productivity loss for the non-CSI terminals. For the scale efficiency change, both groups of terminals show on average a decline in their scale efficiency with the non-CSI terminals depicting the worse results. Finally, both groups have experienced a gain in their technical change component, with the difference that the CSI group has experienced a slightly lower productivity change than the non-CSI group.

Table 37: MPI and its sources of efficiency for the CSI and the non-CSI terminals during the period 2004-2006

Index	Terminal Group	N	Mean	Standard Deviation	Minimum	Maximum
MPI	CSI	38	1.037	0.232	0.698	1.664
	No CSI	19	0.866	0.220	0.525	1.515
	Total	57	0.980	0.241	0.525	1.664
PEC	CSI	38	1.013	0.090	0.890	1.386
	No CSI	19	0.957	0.121	0.512	1.046
	Total	57	0.994	0.104	0.512	1.386
SEC	CSI	38	0.982	0.178	0.687	1.656
	No CSI	19	0.854	0.223	0.394	1.285
	Total	57	0.939	0.201	0.394	1.656
TC	CSI	38	1.044	0.116	0.838	1.307
	No CSI	19	1.084	0.117	0.938	1.330
	Total	57	1.057	0.117	0.838	1.330

A comparative examination of the findings of the TFP analysis relative to the 24-hour rule group against those of the TFP analysis of the CSI group shows contradictory results. Where the 24-hour rule group experiences a decline in efficiency change, namely MPI, PEC and SEC (compared with the Non-24 hour group), the CSI group enjoys gains in productivity change (compared with the Non-CSI group). Even where both groups simultaneously experience a gain in productivity change, namely in TC, the direction of the effect differs from one group to another (an upward trend for the 24-hour rule group versus a downward trend for the CSI group). These results, which might be surprising in their discrepancy, even hold true in an operational perspective as they reflect the functioning of the US system of procedural security for inbound containers.

Figure 40 describes the US CBP screening process for inbound container cargo and provides a basis for understanding the variations of TFP change and its sources of efficiency between the two regulatory groups. In their quest to pre-screen and deliberately target high-risk containers, the US customs authorities use advanced and automated cargo information through the 24-hour rule electronic reporting system in order to identify and later inspect, through the CSI, all suspected cargo in foreign ports before departure to the USA. Therefore, containers that have been pre-screened and approved through the 24-hour rule would enjoy a fast lane treatment from the CSI agents. As a result, one would expect higher levels of operational efficiency during the CSI process of targeting and inspection than during the 24-hour rule process of data processing and risk analysis. In a similar vein, one would expect higher efficiency gains in technological progress (TC) under the 24-hour rule due to better technology and ICT systems (e.g. electronic data submission through AMS) than under the CSI, the latter still relying on traditional but targeted physical inspection.

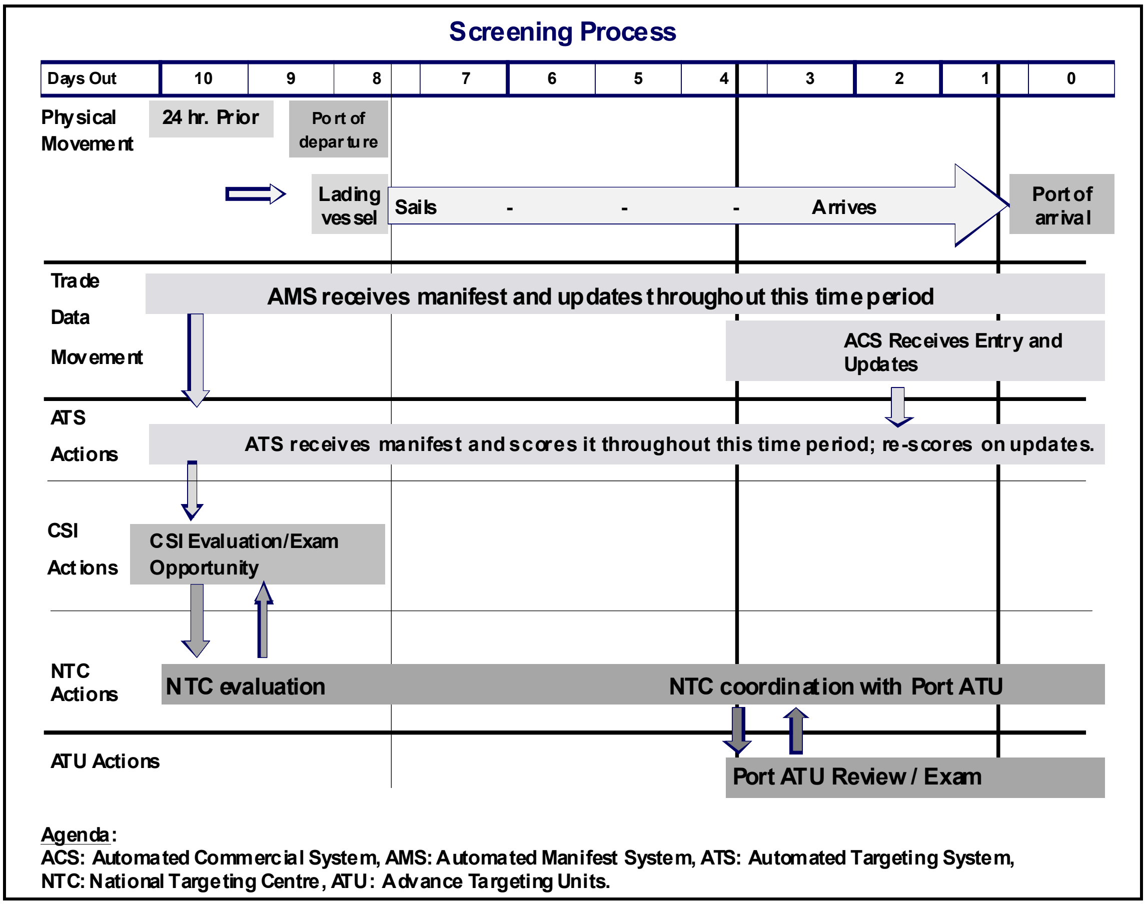

Figure 40: The US screening process combining actions from both the 24-hour rule and the CSI (Adapted by the author from Hercules, 2006)

To examine further the differences between various regulatory groups, a non-parametric test (Mann-Whitney-*U*-test) is used. The method is based on the ranking of data to test whether two samples of observations come from the same distribution (Mann and Whitney, 1947). We refer to the three main regulatory groups used in this study to test three (null) hypotheses:

1. The CSI group exhibits a similar TFP change to that of the non-CSI group,

2. The 24-hour rule group exhibits a similar TFP change to that of the Non-24-hr rule group,

3. Terminals that are subject to the ISPS Code only (i.e. neither CSI nor 24-hour rule Group) depict a similar TFP change to that experienced by terminals complying with both the ISPS Code and other security regulations under study.

Table 38 presents the results on the statistical differences between TFP indices of various regulatory groups. The null hypothesis at a 5% significance level was accepted for both Hypothesis 3 and rejected for hypotheses 1 and 2. The results confirm the findings from previous analysis.

Table 38: Results of the Mann-Whitney *U* test on regulatory groups

	Mean Value		**Non-parametric statistical index**		
ISPS (2004-06)	ISPS only (neither CSI nor 24-hour rule)	All other Terminals	Mann-Whitney *U*	Z	Asymptotic significance (2-tailed)
MPI	0.820	0.986	138	-0.703	0.424
PEC	0.969	0.995	192	-1.68	0.10*
SEC	0.891	0.935	165	-3.219	0.129*
TC	0.948	1.072	129.5	-1.662	0.096*
24-hr rule (2004-06)	24-hour rule terminals	Non-24 hour rule terminals	Mann-Whitney *U*	Z	Asymptotic significance (2-tailed)
MPI	0.841	0.996	213	-0.812	0.493
PEC	0.925	1.010	113.5	-1.65	0.92*
SEC	0.794	0.941	150	-2.30	0.039*
TC	1.169	1.054	183	-1.612	0.103*
CSI (2004-06)	CSI terminals	Non CSI terminals	Mann-Whitney *U*	Z	Asymptotic significance (2-tailed)
MPI	1.037	0.866	206	-1.95	0.560
PEC	1.013	0.957	155	-2.15	0.010**
SEC	0.982	0.854	125	-2.44	0.219**
TC	1.044	1.084	213.5	-1.626	0.016**

*: 5% significance level, **: 10% significance level

CHAPTER VII:
CONCLUSIONS AND RECOMMENDATIONS

The events and aftermaths of 11 September 2001 have not only prompted a new regulatory framework for port and maritime security but also triggered a fundamental shift in the way procedural security is being managed and operated at container ports and terminals. The port and maritime industry, in its wider definition, has come from a compliance culture where fragmented thinking has been the norm rather than the exception. For many years, the international port community has solely responded to the crude influence of internal commercial pressures whereby security was only considered during times of huge claims and insurance premiums, or because of wars and political conflicts. With the growing pressure from external regulatory sources, container ports and terminals in the world have had to integrate the security element into both their management and operational procedures. Nevertheless, while the new security provisions are becoming widely accepted and implemented, the efficiency costs and benefits of the new regulatory regime are yet to be examined in the context of container port and terminal operations. This research attempts to study and analyse the impact of security regulations on the operational efficiency of container ports and terminals. As far as we are aware, and at the time of submitting this thesis, this research is the first study that attempts to measure empirically the ex-post impact of procedural security on container port efficiency.

This concluding chapter brings together the various discussions and analytical results from previous chapters with a view to providing a comprehensive summary of findings and outlining the relationship between operational efficiency and procedural security. In particular, the chapter highlights the lessons learnt from implementing security so that terminal working and operating procedures can be redesigned towards improving efficiency and achieving best-class operational benchmarks. We also introduce a generic model for assessing the cost-benefit of security investment using the frameworks and methods applied in previous chapters. The model allows ports to measure the gap between security performance and the regulatory efficiency frontier and can help terminal operators select the appropriate regulatory bundle for secure and efficient operations.

VII.1 Research Summary

The approach and progression used in this thesis highlight a number of issues related to container-port efficiency and procedural security. Chapter I presented the general background and scope of the thesis and defined the research problem and objectives of the study.

In Chapter II, we first described the regulatory framework of port and maritime security with a particular focus on the programmes targeted at container-port security, namely the ISPS Code, the Container Security Initiative (CSI), and the 24-hour Advance Vessel Manifest Rule (the 24-hour rule). We then reviewed the literature on cost and operational impact of security. The review has shown that much of the literature on the subject has focused on the computation of the cost of compliance of the measures in place and on their *ex-ante* economic evaluation. Furthermore, published work on the subject mostly applies either economic impact analysis or simulation-based modelling. However, neither approach has been found appropriate for conducting an empirical assessment of the impacts of procedural security on container-port efficiency and benchmarking.

Chapter III provided a comprehensive review of the literature on port efficiency and performance benchmarking. The literature on the subject was grouped into four broad categories namely economic-impact studies, performance metrics and productivity index methods, the frontier analysis, and process approaches. For each category, we reviewed the main techniques being used and their applications in port operations and management. We noticed the increasing popularity of frontier applications in port benchmarking studies and highlighted the shortcomings of the two main frontier techniques used to assess port efficiency, namely the stochastic frontier analysis (SFA) and the data envelopment analysis (DEA). The Chapter concluded with a discussion on the core differences underlying the problematical issues relative to the subject of performance benchmarking and its applications in ports and terminals.

In attempting to design a viable research approach and methodology, Chapter IV set out a framework that links theory with port practice. We started by reviewing container-port configurations, handling systems and terminal procedures and exploring the factors that are within and beyond the control of terminal management. By describing the configuration typologies and technology variations in container-terminal handling systems and operating procedures, we demonstrated why such aspects must be taken into consideration in the context of the analysis of productive efficiency and procedural security. The design of the research methodology proceeded from this by defining the main research questions and selecting the appropriate analytical techniques for this study, namely the Integration Definition Model 0 (IDEF0) for prescriptive modelling and process mapping, the data envelopment analysis (DEA) for efficiency measurement and performance benchmarking, and the Malmquist productivity index (MPI) for productivity change analysis. A research framework was designed so that various research components are linked and integrated through a logical chain of influence and relationships.

Chapter V set out to formalise the analytical models and techniques selected for this research. We first built up the IDEF0 modelling structure for container terminal operations, and then specified three IDEF0 models for import, export, and transhipment flows, respectively. Based on the results of the IDEF0 modelling exercise, we then formalised several DEA models, in particular a DEA supply chain model, which is believed to capture the network structure of container terminal operations. In a similar vein, we specified the MPI and its sub-categories with a view to assessing productivity change analysis. Finally, we defined the sampling frame and variable selection for this study and described the sources and methods of data collection. Both the aggregate and specific datasets selected for this study were validated and tested in view of DEA.

In Chapter VI, we presented the findings and results of the research. The approach adopted in Chapter VI was to present and interpret the empirical results by type of analysis and research problem in order to emphasise the findings from both the benchmarking exercise and the productivity change analysis. First, we presented the results of the benchmarking analysis under constant technology using both contemporaneous and inter-temporal DEA models. Assuming a stationary frontier, both models provide a snapshot of productive efficiency under different dataset sizes and time observations. This proved useful for comparing the results of alternative DEA models (input orientation *versus* output orientation, constant returns to scale *versus* variable returns to scale) and testing a number of hypotheses that were implied from the operational assumptions discussed in previous chapters. In particular, four operational hypotheses have been tested: the relationship between scale efficiency and incremental port investment, the extent of the impact of exogenous factors on terminal's productive efficiency, the relationship between productive efficiency and terminal handling configuration, and the relationship between productive efficiency and terminal operating procedures. We also used both contemporaneous and inter-temporal DEA models to analyse site-specific and network efficiencies. The purpose of this analysis was to test whether disproportionate performance levels exists or not between terminal sites and sub-systems (mainly the quay and yard sites), and how these sub-systems influence the efficiency of both aggregate and network terminal operations.

In the second part of Chapter VI, we presented the results of the productivity change analysis for both the multi-year and regulatory-run models. For the former, the results of the year-by-year MPI analysis were tested and discussed with a view of tracking short-term changes in productive efficiency both for total factor productivity (TFP) change and for its three main components or sources of efficiency, namely the pure technical efficiency change (PEC), the scale efficiency change (SEC), and the technical change (TC). For the latter, the results of the regulatory period MPI analysis were tested and compared with a view of tracking changes in productive efficiency before and after the introduction of procedural security and between terminals that have implemented security measures and those that have not. The results of the productivity change impacts from both the combined and individual security regulations were presented and fully discussed, in particular those related to the productivity impacts of the ISPS Code, the 24-hour rule, and the CSI.

This final Chapter, Chapter VII, provides a summary of the research findings and revisits both the assumptions and perspectives of the research in order to highlight the value and achievements of this thesis as well as identify its gaps and limitations. The Chapter concludes with a series of recommendations on the way forward for future research. It also builds on the frameworks and methods applied in the thesis to introduce a generic model for assessing the cost-benefit of security investment.

VII.2 Research Findings, Achievements, and Limitations

VII.2.1 Research Objectives and Propositions Revisited

As pointed out in the first sections of this thesis, this research seeks to assess and analyse the *ex-post* impacts of procedural security, stemming from the requirements of the new port security regulations, on the productive efficiency and performance benchmarking of container terminal operations. The main research question for this study has been formulated as follows:

> *'What is the impact, in terms of productivity gains or losses, of procedural security on the efficiency of container terminal operations?'*

In trying to answer the above question, three issues were identified:

- What is the operational and procedural scope of port security programmes?

- How can container-port operational efficiency be measured and benchmarked?

- How can we measure and quantify the impact of procedural security?

To direct the problem more precisely, there was a methodological difficulty in linking procedural security with port efficiency and benchmarking. To resolve this, we adopted an integrative approach that incorporates within a logical framework of analysis measures and techniques for benchmarking container terminal efficiency with tools for assessing procedural port security. There were three ultimate research objectives:

1. Construct and apply an analytical model for measuring and benchmarking the operational efficiency of international container-terminal operations,

2. Assess and analyse the ex-post procedural impacts of port security measures on container terminal operational efficiency, and

3. Identify and incorporate the variations in container-port operating sites, production technologies and handling configurations in the benchmarking exercise as well as in the analytical process for the purpose of port's functional modelling and assessment of security scope and impacts.

VII.2.2 Research Findings and Achievements

Being the first empirical work that investigates the ex-post impact of procedural security on container terminal efficiency, this study achieves both originality and exclusivity. The study also incorporates the variations in equipment technology, handling configurations and operating procedures in an attempt to narrow the gap between port theory and practice. Furthermore, this research applies a rare combination of prescriptive modelling methods, analytical benchmarking models, and productivity change analysis techniques so as to link procedural security with container-port efficiency and benchmarking. Last, but not least, the research tests a number of operational hypotheses and applies alternative DEA models in order to investigate aggregate, site-specific, and network efficiency of container terminal operations. In this respect, this study can be quoted as being the first work that applies a supply chain DEA model to container port and terminal operations.

Following the analysis of the interplay between container-terminal efficiency and procedural port security, the main research findings for this study can be summarised as follows:

A. The number of container terminal DMUs identified as efficient in both the inter-temporal and contemporaneous models accounts for 10.5% and 15% of the total when the DEA-CCR model is applied against 22.1% and 38.3% of the total when the DEA-BCC model is applied, respectively. This suggests that the sample is dominated by inefficient terminal DMUs.

B. The analysis in terms of comparative efficiency scores of container terminals in the sample reveal that on average a considerable proportion of inputs were wasted in the global container terminal industry throughout the observation period from 2000 to 2006. The analysis also shows that the more efficient terminals tend to have less relative variability over time than the less efficient terminals. These findings are at variance with those of the mainstream port benchmarking literature. We believe that this is due to the sampling procedure used in most port benchmarking studies where DMUs are usually selected from top-ranked ports in terms of throughput or from ports located within the same country or region.

C. The analysis of the relationship between scale of production and operational efficiency reveals that a large proportion of terminals exhibit increasing returns to scale properties, which asserts that the container terminal industry clearly depicts a VRS production technology. The analysis also shows that the larger terminals and those investing in new facilities tend to depict decreasing returns to scale. Further analysis of two cases studies (LCB1 and LCIT terminals in Laem Chabang) and other terminals having started their operations in the year 2000 confirms the high correlation between incremental increases in port investment and the variations in productive efficiency, and concludes that a full utilisation of port capacity is detrimental to port efficiency in the medium and long runs.

D. The relationship between productive efficiency and the proportion of cargo mix shows that market differences have a direct effect on terminal efficiency. Terminals with high proportion of transhipment, FEU, and/or empty containers tend to yield higher efficiency scores than their other counterparts. This suggests that both exogenous factors and the nature of the market served can have a significant effect on terminal's efficiency ranking, even for terminals with similar levels of operational efficiency.

Operating configurations also have a direct impact on terminal efficiency. Terminals operating on automated systems tend to depict the highest efficiency ratings (71.8%), followed by terminals operating on yard gantry systems (69.3%), then those operating on hybrid (67.4%) and straddle carrier (67.3%) systems. Terminals operating on the wheeled or tractor-chassis system tend to achieve the lowest efficiency rating (0.50%). Further analysis using the paired-sample tests show that the RTG and the SCD systems yield higher efficiency levels than the SCR and the RMG systems, with the RTG system depicting the highest productive efficiency.

E. In a similar vein, operating policies and work procedures were also found to have an influence on productive efficiency. In particular, the yard storage policy and the gate operating procedure seem to have, each, a direct impact on terminal's efficiency. Further analysis has shown that a simple change in a terminal's working procedures, such as the implementation of a new appointment system in the case of YCT, can sometimes yield a significant improvement in its productive efficiency.

F. The analysis of site-specific efficiency shows that quay-site operations tend to exhibit higher performance levels than aggregate terminal operations. Conversely, yard operations tend to yield lower efficiency ratings (68.5%) than those yielded by aggregate terminal operations (91.6%) when DEA-BCC-I models are applied. Even though, there was a low correlation between berth efficiency and terminal efficiency. This is because STS-crane move per hour and other micro-performance indicators for the quay site tend to be independent from throughput figures and other macro performance indicators for terminal operations. The analysis also shows that cargo dwell time and yard operations are the most critical processes in container terminal efficiency.

G. The analysis of network efficiency confirms the above findings in that container terminals exhibit disproportionate performance levels between terminal sites and sub-systems. By applying a DEA supply chain model on terminal export processes, further insight was shed on the network structure of terminal operating systems and on how to manage them efficiently. For instance, in order to counterbalance disproportionate performance levels between terminal sites, appropriate adjustments can be taken by either accelerating or decelerating the rate of container handling at the relevant site.

H. For the productivity change analysis, the stepwise multi-year Malmquist DEA confirms the general trend of decreasing container-terminal efficiency (249 DMUs have experienced a productivity loss out of a total of 420) but there is a visible trend of average productivity gains after 2004, immediately followed by an equally noticeable decline in 2005. The year-by-year MPI has shown that on average container terminals in the sample have incurred productivity losses in the periods 2000-2001, 2001-2002, 2002-2003, and 2005-2006 against productivity gains experienced in the two successive periods of 2003-2004 and 2004-2005.

I. The analysis of the efficiency changes in MPI sub-categories has revealed an almost flat trend in average pure efficiency change (PEC) throughout the observation periods, against an increasing trend in average scale efficiency change (SEC). Further analysis of the relationship between MPI and its sub-categories shows a stronger impact of scale efficiency compared with the non-scale (pure) technical efficiency, which suggests that the focus from the part of terminal operators was on achieving operational efficiency through terminal expansion rather than through the rationalisation of input use. The analysis of the impact of technical change (TC) provided first insights on the shifts in the frontier technology and on the impact of the technological progress following the introduction of security regulations.

J. When analysing productivity change by regulatory runs, the results show regressing average total factor productivity change (TFPC) for all observation periods, but with varying degrees of productivity losses. In particular, container terminals in the sample have experienced a larger deterioration of their average total factor productivity in the period following the introduction of security measures (2004-2006, MPI=0.959) than in the period prior to the introduction of security measures (2000-2004, MPI=0.769).

K. The analysis of the correlation between the regulatory-run MPI and its sub-categories suggests that TFP change has been driven mainly by adjustments in port production scales. Further comparison of the correlation results from the periods before and after the introduction of procedural security shows that the impact of technical change (TC) has increased dramatically between the two periods at the expense of both pure technical efficiency (PEC) and scale efficiency changes (SEC). These results suggest that container terminals in the sample have benefited positively from technological investment in security following the introduction of the new measures.

L. The analysis of regulatory-specific MPI has shown that for the impact of the ISPS Code, no clear trend of productivity change can be traced among container terminals in the sample. This is largely due to the confusion in the ISPS Code interpretation and execution, including for investment requirements in security equipment and technology. For the impact of the 24-hour rule, the analysis has shown that container terminals complying with the 24-hour rule have experienced a loss in pure technical efficiency (PEC) due to the requirement of detailed reporting and the increased congestion and cargo dwell time brought about by the implementation of the Rule. On the other hand, the same terminals have experienced efficiency gains from technical change (TC) due the shift from paper-based to electronic submission of cargo manifests through AMS (Automated Manifest System). A particularly adverse impact of the 24-hour rule was the disturbance to ship schedules and stability with observed larger extension of ship's bunching and arrival headways. This is particular detrimental to ports located in a downstream position in the liner-shipping string as was demonstrated in the case of Kingston Container Terminal (KCT). Finally, the impact of the CSI shows contradictory results, both for the MPI and for its sub-categories, to those of the 24-hour rule impact. Further investigation has found that these contradictory results are consistent with the functioning of the US Customs screening process for inbound containers. This is because containers that have been pre-screened and approved through the 24-hour rule would normally enjoy a fast lane treatment from the US CBP customs. On the other hand, containers that have been identified as high risk would undergo rigorous inspection from the CSI agents.

VII.2.3 Gaps and Limitations

Although we endeavoured to provide a logical framework for analysing the ex-post impact of procedural security on container terminal efficiency, a number of gaps and limitations still exist. Perhaps, the major limitation of this thesis is the unavailability of detailed and reliable data, which prevented us from extending the sample size to more global ports and terminals as well as from undertaking further analysis on the network structure of container terminal operations. Another limitation lies in the theoretical gaps of the analytical techniques used in this study, particularly those related to DEA. Even though, we tried to minimise the drawback of DEA by using panel data and applying the MPI stepwise analysis. We also validated the definition and selection of the dataset and variables for carrying out performance benchmarking by means of DEA. Other gaps may be more inherent to the nature of the container-port production system or to the research problem for this study, for instance in terms of the complexity of the network structure of container terminal operations or because of the use of macro-performance indicators such as container throughput to derive efficiency scores.

VII.3 Directions for Future Research

This thesis aims at analysing the ex-post impact of security regulations on container terminal efficiency and performance benchmarking. It designs a research approach that incorporates technology and performance variations in container port handling systems, the network structure of container terminal operating processes, and the spatial and operational scope of security regulations. In so doing, we developed an integrative and logical framework that links procedural security with container-terminal efficiency and benchmarking.

Quite independently from security impacts, the results of this thesis can be used to understand further the network structure of container terminal operations and appreciate the impacts of handling configurations and operating procedures on terminal and site efficiency. In view of the current global financial crisis and economic downturn, and the derived slowdown of global maritime and trade flows, we believe that container terminal operators will aim to achieve operational efficiency by shifting their focus from investments in capacity expansion to further rationalisation of input use.

When security impacts are considered, the framework and methods developed in this thesis could serve as a roadmap for port operators, policy makers, academics, practitioners, and other transport and logistics stakeholders to assess and manage the efficiency impacts of procedural security and other similar regulatory and policy measures. The latter may range from further port, transport and logistics security regulations, e.g. bulk-port security, ship security, airport security, supply chain security; to wider regulatory and policy decisions such as changes in trade facilitation policy (trade liberalisation, simplification of customs procedures, etc.) and institutional structuring (corporatisation, privatisation, etc.). More precisely, the results and methods of this study can be used to investigate the mechanisms and implications of future security requirements such as the 100% container scanning provision required by the US Secure freight initiative (SFI), which is due to be implemented in 2012. Equally, the study can be used to select and assess the cost and benefit of future security investments, especially when overlapping security regulations and procedures are involved. As shown in Appendix 29, we build on the frameworks and methods applied in this thesis to introduce a generic model that translates various security regulations into a set of security components and assesses their costs and benefits with a view to reducing costs and risk exposure and/or optimising commercial rewards.

Finally, further research can build on this study to develop detailed models for mapping container-port operations and processes, including for the incorporation of the time and cargo dimension of terminal flows and processes. In addition, further analysis is needed to fully understand the nature and extent of the impacts of operating technologies, handling configurations, and exogenous factors on container-port efficiency and performance benchmarking. In particular, more sophisticated DEA models may be developed to analyse the network structure of container-port operations and, more widely, the supply chain configuration of global port and maritime systems.

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Appendix 1: ISPS Port Facility Security Equipment Checklist

ISPS Part/ Reference	Port Facility Security Plan Topic	ISPS category	Equipment category	Equipment required
A.16.3.2	The plan shall address measures designed to prevent unauthorised access to the port facility, ships at the facility & restricted areas	Access to port facility	Access control	Fencing / gates
B.16.17.1	At security level 1, the plan should establish control points for the following: restricted areas, which should be bounded by fencing or other barriers to a standard which should be approved by the Contracting Government	Access to port facility	Access control	Fencing / gates
B.16.19.2	At security level 2, the plan should establish the additional measures: limiting the number of access points to the port facility, and identifying those to be closed and the means of adequately securing them	Access to port facility	Access control	Fencing / gates
B.16.28.7	At security level 2, the plan should address: establishing and restricting access to areas adjacent to the restricted areas	Access to port facility	Access control	Fencing / gates
B.16.27.2	At security level 1, the plan should address the provision of access points controlled by security guards when not locked	Access to port facility	Access control	Gates
B16.25.4	Restricted areas may include the locations where security-sensitive information, including cargo documentation, is held.	Access to port facility	Access control	Locked premises
B.16.29.1	At security level 3, the plan should address: setting up additional restricted areas within the port facility in proximity to the security incident, to which access is denied;	Access to port facility	Access control	Mobile barriers
B.16.27.1	At security level 1, the plan should address: provision of permanent or temporary barriers to surround the restricted area of a Government approved standard	Access to port facility	Access control	Restricted area barriers: fencing / gates
B.16.28.1	At security level 2, the plan should address: enhancing the effectiveness of the barriers or fencing surrounding restricted areas, including the use of patrols or automatic intrusion-detection devices	Access to port facility	Access control	Restricted area barriers: fencing / gates
B.16.38.3	The security measures in the plan relating to the delivery of ships stores should prevent tampering	Access to port facility	Access control	Restricted area barriers: fencing / gates
B.16.19.3	At security level 2, the plan should establish the additional measures: providing for means of impeding movement through the remaining access points e.g. security barriers	Access to port facility	Access control	Security barriers

A.16.3.12	The plan shall address measures designed to ensure effective security of cargo and the cargo handling equipment at the port facility	Access to port facility	Access control	
B.16.20.1	At security level 3, the plan should detail the security measures which address the suspension of access to all or part of the port facility	Access to port facility	Access control / comms	Automatic alerts / alarm systems / PA / VHF / UHF
B.16.20.2	At security level 3, the plan should detail the security measures which address the granting of access only to those responding to security incident or threat thereof	Access to port facility	Access control / comms / biometrics	ID passes
B16.8.13	At all security levels, the procedures for assisting ship security officers in confirming the identity of those seeking to board the ship when requested	Access to port facility	Biometrics	ID passes
B.16.8.14	At all security levels, procedures for facilitating shore leave for ships' crews, or crew changes, or legitimate social & welfare visitors?	Access to port facility	Biometrics	ID passes
A.16.3.15	The plan shall address procedures for facilitating shore leave for ship's crews or crew changes, or legitimate welfare and social ship visitors	Access to port facility	Biometrics	ID passes
B.16.17.2	At security level 1, the plan should establish control points for the following: checking identity of all persons seeking entry to the port facility in connection with a ship including passengers, ship's personnel and visitors, and confirming their reasons for doing so by checking, for example, joining instructions, passenger tickets, boarding party, work orders etc.	Access to port facility	Biometrics	ID passes
A.16.3.5	The plan shall address procedures for evacuation in case of security threat or breaches	Access to port facility	Comms	Alarm systems
B.16.20.5	At security level 3, the plan should detail the security measures which address the suspension of port operation within all or part of the port facility	Access to port facility	Comms	Automatic alerts / alarm systems / gates / PA / VHF / UHF
B.16.20.7	At security level 3, the plan should detail the security measures which address evacuation of all or part of the port facility	Access to port facility	Comms	Automatic alerts / alarm systems / pa / vhf uhf
B.16.20.3	At security level 3, the plan should detail the security measures which address the suspension of pedestrian or vehicular movement within all or part of the facility;	Access to port facility	Comms / access control	Automatic alerts / alarm systems / gates / PA / VHF / UHF
B.16.17.4	At security level 1, the plan should identify control points for the verification of the identity of port facility personnel and those within the port facility and their vehicles	Access to port facility	Data recording / biometrics	ID passes / vehicle passes

B.16.27.6	At security level 1, the plan should address: providing automatic intrusion detection devices, surveillance equipment, or systems designed to prevent unauthorised access into or movement within restricted areas	Access to port facility	Intrusion detection device / CCTV / access control	
B.16.50	When used, automatic intrusion-detection devices should activate an audible and/or visual alarm at a location that is continuously attended or monitored	Access to port facility	Intrusion detection devices / audio & visual alarms	Intrusion detection devices / audio & visual alarms
B.16.28.8	At security level 2, the plan should address: enforcing restrictions on access by unauthorised craft to the waters adjacent to ships using the port facility	Access to port facility	Patrol vessels	Patrol vessels
B.16.17.3	At security level 1, the plan should identify control points for the following: checking vehicles used by those seeking entry to the port facility in connection with a ship	Access to port facility	Screening equipment	Mobile scanning equipment
B.16.17.6	At security level 1, the plan should identify control points for the undertaking of searches of persons, personal effects, vehicles & their contents	Access to port facility	Screening equipment	Mobile scanning equipment
B.16.19.4	At security level 2, the plan should establish the additional measures: increasing the frequency of searches of persons, personal effects, and vehicles;	Access to port facility	Screening equipment	Mobile scanning equipment
B.16.45	The plan should establish routines for screening unaccompanied baggage and personnel effects, whether of passengers or crew, before it enters the port facility, and if the storage arrangements dictate, before it is transferred between port facility and ship. At Security Level 1, the PFSP should allow for some X-ray screening: at Security level 2, 100% X-ray screening should be invoked	Access to port facility	Screening equipment	X-ray
A.16.3.1	The plan shall address measures designed to prevent weapons or any other dangerous substances & devices whose carriage is not authorised from entering the port facility or ship	Access to port facility	Screening equipment	X-ray scanners
B.16.44	The plan should detail the security measures which could be taken by the port facility, which may include preparation for restriction or suspension, of the delivery of ship's stores within all, or part, of the port facility	Delivery of ship's stores	Comms	VHF / UHF
B.16.8.10	At all security levels procedures covering the delivery of ships' stores	Delivery of ship's stores	Screening equipment	Hand held scanner
B.16.40.3	At security level 1, the security measures in the plan relating to the delivery of ships stores should ensure the searching the delivery vehicle	Delivery of ship's stores	Screening equipment	Mobile scanning equipment

B.16.41	At security level 1, the use of scanners/detection equipment, mechanical devices and dogs, may be used for checking of ship's stores?	Delivery of ship's stores	Screening equipment	Mobile scanning equipment
B.16.42.1	At security level 2, the plan should establish the additional security measures to be applied to enhance the control of the delivery of ship's stores, which may include detailed checking of ship's stores	Delivery of ship's stores	Screening equipment	Mobile scanning equipment
B.16.42.2	At security level 2, the plan should establish the additional security measures to be applied to enhance the control of the delivery of ship's stores, which may include detailed searches of the delivery vehicles	Delivery of ship's stores	Screening equipment	Mobile scanning equipment
B.16.37.1	At security level 3, the plan should detail the security measures which could be taken by the port facility in cooperation with those responding and the ships, which may include: restriction or suspension of cargo movements or operations within all or part of the facility or specific ships	Handling of cargo	Comms	Automatic alerts / alarms / VHF / UHF
B.16.35.4	At security level 2, the plan should establish the additional security measures to be applied during cargo handling to enhance control, which may include: increased frequency and detail in checking of seals and other methods used to prevent tampering	Handling of cargo	E-seal integrity checking equipment	E-seal integrity checking equipment
B.16.32.4	At security level 1, the plan should address security measures to be applied during cargo handling which may include: checking of seals and other methods used to prevent tampering upon entering the port facility and upon storage within the port facility	Handling of cargo	E-seal integrity checking equipment	
B.16.32.3	At security level 1, the plan should address security measures to be applied during cargo handling which may include: searches of vehicles	Handling of cargo	Screening equipment	Mobile scanning equipment
B.16.35.3	At security level 2, the plan should establish the additional security measures to be applied during cargo handling to enhance control, which may include: intensified searches of vehicles	Handling of cargo	Screening equipment	Mobile scanning equipment
B.16.32.1	At security level 1, the plan should address security measures to be applied during cargo handling which may include: routine checking of cargo, cargo transporters and cargo storage areas within the port facility prior to and during cargo handling	Handling of cargo	Screening equipment	Mobile scanning equipment / x-ray

B.16.35.1	At security level 2, the plan should establish additional security measures to be applied during cargo handling to enhance control, which may include: detailed checking of cargo, cargo transporters, and cargo storage areas within the port facility	Handling of cargo	Screening equipment	Mobile scanning equipment / x-ray
B.16.48.1	The plan should stipulate that at Security Level 3, unaccompanied baggage should be subject to more extensive screening, for example x-raying it from at least two different angles	Handling of unaccompanied baggage	Screening equipment	X-ray
B.16.8.7	At all security levels, procedures to assess the continuing effectiveness of security measures, procedures & equipment, including identification of & response to equipment failure or malfunction;	Monitoring security of port facility	Backup systems	
B.16.51	The plan should establish procedures and equipment needed at each Security Level and the means of ensuring that monitoring equipment will be able to perform continually, including consideration of the possible effects of weather conditions or of power disruptions?	Monitoring security of port facility	Backup systems	
B.16.28.5	At security level 2, the plan should address: use of continuously monitored & recording surveillance equipment	Monitoring security of port facility	CCTV	CCTV
B.16.54.2	For security level 3, the plan should detail the security measures which could be taken by the port facility which may include: switching on of all surveillance equipment capable of recording activities within, or adjacent to, the port facility	Monitoring security of port facility	CCTV	CCTV
B.16.54.3	For security level 3, the plan should detail the security measures which could be taken by the port facility which may include: maximising the length of time such surveillance equipment can continue to record	Monitoring security of port facility	CCTV / data recording	CCTV / data recording
A.16.3.14	The plan shall address procedures for responding in case the ship security alert system of a ship at the port facility has been activated	Monitoring security of port facility	Comms	Automatic alerts / alarm systems / VHF / UHF
A.16.3.3	The plan shall address procedures for responding to security threats or breaches of security, including provisions for maintaining critical operations of ship or ship/port interface	Monitoring security of port facility	Comms	Automatic alerts / alarm systems / VHF / UHF
A.16.3.4	The plan shall address procedures for responding to any security instructions the contracting government may give at Security Level 3	Monitoring security of port facility	Comms	Automatic alerts / alarm systems / VHF / UHF / PA

B.16.57	The plan should establish the procedures to be followed when, on the instructions of the Contracting Government, the PFSO requests a DoS or when a DoS is requested by a ship	Monitoring security of port facility	Comms	Email alert
B.16.3.2	Links and communications arrangements with ships in port and other relevant authorities	Monitoring security of port facility	Comms	VHF / UHF
B.16.8.4	At all security levels a communications system which allows effective & continuous communication between port facility security personnel & ships & national or local security authorities	Monitoring security of port facility	Comms	VHF / UHF
A.16.3.7	The plan shall address procedures for interfacing with ship security activities	Monitoring security of port facility	Comms	VHF / UHF
B.16.20.6	At security level 3, the plan should detail the security measures which address the direction of vessel movements relating to all or part of the port facility	Monitoring security of port facility	Comms	VHF / UHF
B.16.27.7	At security level 1, the plan should address the control of the movement of vessels in the vicinity of ships using the port facility.	Monitoring security of port facility	Comms	VHF / UHF
B.16.56.1	The plan should establish procedures and security measures the port facility should apply when it is interfacing with a ship which has been at a port of a State which is not a Contracting Government	Monitoring security of port facility	Comms	VHF / UHF
B.16.56.2	The plan should establish procedures and security measures the port facility should apply when it is interfacing with a ship to which the Code does not apply	Monitoring security of port facility	Comms	VHF / UHF
B.16.56.3	The plan should establish procedures and security measures the port facility should apply when it is interfacing with fixed or floating platforms or mobile offshore drilling unit on location.	Monitoring security of port facility	Comms	VHF / UHF
B16.8.12	At all security levels, the means of alerting & obtaining waterside patrols & specialist search teams including bomb & underwater;	Monitoring security of port facility	Comms / patrol vessels / IED detection equipment	Vhf uhf / patrol vessels / IED detection equipment
A.16.7	If the plan is kept in an electronic format, it shall be protected by procedures aimed at preventing its unauthorised deletion, destruction, or amendment	Monitoring security of port facility	Data recording	Data protection system
B.16.8.6	At all security levels protection of security information held in paper or electronic format	Monitoring security of port facility	Data security	Fire proof cabinet / encrypted software
A.16.8	The plan shall be protected from unauthorized access or disclosure	Monitoring security of port facility	Data security	Fire proof cabinet / encrypted software

A.16.3.11	The plan shall address measures to ensure the security of the information in the plan	Monitoring security of port facility	Data security	Fireproof safe / encryption software
B.16.7	Guidance on the bearing and use of firearms (if appropriate)	Monitoring security of port facility	Firearms cabinets	Firearms cabinets
B.16.49.3	The plan should include as means of monitoring the port facility day and night, and the ships and areas surrounding them, the following measures: automatic intrusion-detection devices and surveillance equipment	Monitoring security of port facility	Intrusion detection devices / CCTV	Intrusion detection devices / CCTV
B.16.49.1	The plan should include as means of monitoring the port facility day and night, and the ships and areas surrounding them, the following measures: lighting	Monitoring security of port facility	Lighting	Lighting
B.16.54.1	For security level 3, the plan should detail the security measures which could be taken by the port facility which may include: switching on of all lighting within, or illuminating the vicinity of, the port facility	Monitoring security of port facility	Lighting	Lighting
B.16.52.2	For Security Level 1, the plan should establish the security measures to be applied, which may be a combination of lighting, security guards or use of security and surveillance equipment to allow port facility security personnel to observe access points, barriers and restricted areas	Monitoring security of port facility	Lighting / CCTV	Lighting / CCTV
B.16.53.1	For security level 2, the plan should establish the security levels to be applied for increasing the coverage and intensity of lighting and surveillance equipment, including the provision of additional lighting and surveillance coverage	Monitoring security of port facility	Lighting / CCTV	Lighting / CCTV
B.16.52.1	For Security Level 1, the plan should establish the security measures to be applied, which may be a combination of lighting, security guards or use of security and surveillance equipment to allow port facility security personnel to observe the general port facility area, including shore and waterside accesses to it	Monitoring security of port facility	Lighting / CCTV / radar	Lighting / CCTV / radar
B.16.19.6	At security level 2, the plan should establish the additional measures: using patrol vessels to enhance water-side security	Monitoring security of port facility	Patrol vessels	Patrol vessels
B.16.28.6	At security level 2, the plan should address: enhancing the number and frequency of patrols, including water-side patrols, undertaken on the boundaries of the restricted areas & within the areas	Monitoring security of port facility	Patrol vessels	Patrol vessels
B.16.49.2	The plan should include as means of monitoring the port facility day and night, and the ships and areas surrounding them, the following measures: security guards including foot, vehicle and waterborne patrols	Monitoring security of port facility	Patrol vessels	Patrol vessels

B.16.53.2	For security level 2, the plan should establish the security levels to be applied for increasing the frequency of foot, vehicle and waterborne patrols	Monitoring security of port facility	Patrol vessels	Patrol vessels
B.16.52.3	For Security Level 1, the plan should establish the security measures to be applied, which may be a combination of lighting, security guards or use of security and surveillance equipment to allow port facility security personnel to monitor areas and movements adjacent to ships using the port facility, including augmentation of lighting provided by ships themselves	Monitoring security of port facility	Radar	Radar
B.16.27.3	At security level 1, the plan should address providing compulsorily displayed restricted area passes.	Restricted areas	Biometrics	Id passes
B.16.27.4	At security level 1, the plan should address clearly marking vehicles allowed access to restricted areas.	Restricted areas	Biometrics	Vehicle markings
B.16.25.7	Restricted areas may include areas where security & surveillance equipment are located.	Restricted areas	Signage	Locked premises
B.16.25.1	Restricted areas may include: shore and waterside areas immediately adjacent to the ship	Restricted areas	Signage	Signs
B.16.25.2	Restricted areas may include: embarkation and disembarkation areas, passenger and ship's personnel holding & processing areas, including search points.	Restricted areas	Signage	Signs
B.16.25.3	Restricted areas may include: areas where loading, unloading or storage of cargo and stores is undertaken.	Restricted areas	Signage	Signs
B.16.25.5	Restricted areas may include: areas where dangerous goods and hazardous substances are held.	Restricted areas	Signage	Signs
B.16.25.8	Restricted areas may include: essential electrical, radio & telecommunication, water & other utility installations.	Restricted areas	Signage	Signs
B.16.25.9	Restricted areas may include: other locations in the port facility where access by vessels, vehicles and individuals should be restricted.	Restricted areas	Signage	Signs
B16.25.6	Restricted areas may include: VTM system control rooms, aids to navigation & port control buildings, including security & surveillance control rooms.	Restricted areas	Signage / security control room	Control systems

Appendix 2: Minimum standards for CSI expansion (Source: CBP, 2004)

Minimum Standards for CSI Expansion

Standards must be present in every potential CSI port:

1) Seaport must have regular, direct, and substantial container traffic to ports in the United States.
2) Customs must be able to inspect cargo originating, transiting, exiting, or being transshipped through a country.
3) Non-intrusive inspection (NII) equipment (gamma or X-ray) and radiation detection equipment must be available for use at or near the potential CSI port.

Minimum Standards for CSI Expansion

Potential CSI ports must also commit to:

4) Establish an automated risk management system.
5) Share critical data, intelligence, and risk management information with U.S. Customs and Border Protection (CBP)
6) Conduct a thorough port assessment and commit to resolving port infrastructure vulnerabilities.
7) Maintain integrity programs, and identify and combat breaches in integrity.

Appendix 3: The 24-hour Advance Manifest Rule as Published in the US Federal Register (excluding comments and answers)

Administration amends part 39 of the Federal Aviation Regulations (14 CFR part 39) as follows:

PART 39—AIRWORTHINESS DIRECTIVES

1. The authority citation for part 39 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701.

§ 39.13 [Amended]

2. Section 39.13 is amended by adding the following new airworthiness directive:

2002–22–05 Boeing: Amendment 39–12929. Docket 2002–NM–214–AD.

Applicability: All Model 737–100, –200, –200C, –300, –400, and –500 series airplanes; certificated in any category.

Note 1: This AD applies to each airplane identified in the preceding applicability provision, regardless of whether it has been modified, altered, or repaired in the area subject to the requirements of this AD. For airplanes that have been modified, altered, or repaired so that the performance of the requirements of this AD is affected, the owner/operator must request approval for an alternative method of compliance in accordance with paragraph (d) of this AD. The request should include an assessment of the effect of the modification, alteration, or repair on the unsafe condition addressed by this AD; and, if the unsafe condition has not been eliminated, the request should include specific proposed actions to address it.

Compliance: Required as indicated, unless accomplished previously.

To prevent severe flap asymmetry due to fractures of the carriage spindles on an outboard mid-flap, which could result in reduced control or loss of controllability of the airplane, accomplish the following:

Repetitive Inspections

(a) Do general visual and nondestructive test (NDT) inspections of each carriage spindle (two on each flap) of the left and right outboard mid-flaps to find cracks, fractures, or corrosion at the later of the times specified in paragraphs (a)(1) and (a)(2) of this AD, as applicable, per the Work Instructions of Boeing Alert Service Bulletin 737–57A1277, dated July 25, 2002. Repeat the inspection at least every 180 days until paragraph (c) of this AD is done.

(1) Before the accumulation of 12,000 total flight cycles or 8 years in-service on new or overhauled carriage spindles, whichever is first.

(2) Within 90 days after the effective date of this AD.

Note 2: For the purposes of this AD, a general visual inspection is defined as: "A visual examination of an interior or exterior area, installation, or assembly to detect obvious damage, failure, or irregularity. This level of inspection is made from within touching distance unless otherwise specified. A mirror may be necessary to enhance visual access to all exposed surfaces in the inspection area. This level of inspection is made under normally available lighting conditions such as daylight, hangar lighting, flashlight, or droplight and may require removal or opening of access panels or doors. Stands, ladders, or platforms may be required to gain proximity to the area being checked."

Corrective Action

(b) If any crack, fracture, or corrosion is found during any inspection required by paragraph (a) of this AD: Before further flight, do the applicable actions for that spindle as specified in paragraph (b)(1) or (b)(2) of this AD, per the Work Instructions of Boeing Alert Service Bulletin 737–57A1277, dated July 25, 2002. Then repeat the inspections required by paragraph (a) of this AD every 12,000 flight cycles or 8 years, whichever is first; on the overhauled or replaced spindle only.

(1) If any corrosion is found in the carriage spindle, overhaul the spindle.

(2) If any crack or fracture is found in the carriage spindle, replace with a new or overhauled carriage spindle.

Note 3: Although the service bulletin recommends that operators report inspection findings of any crack or fracture in the carriage spindle to the manufacturer, this AD does not contain such a reporting requirement.

Optional Overhaul or Replacement

(c) Overhaul or replacement, as applicable, of all four carriage spindles, per the Work Instructions of Boeing Alert Service Bulletin 737–57A1277, dated July 25, 2002, extends the repetitive inspection interval specified in paragraph (a) of this AD to every 12,000 flight cycles or 8 years, whichever is first.

Alternative Methods of Compliance

(d) An alternative method of compliance or adjustment of the compliance time that provides an acceptable level of safety may be used if approved by the Manager, Seattle Aircraft Certification Office (ACO), FAA. Operators shall submit their requests through an appropriate FAA Principal Maintenance Inspector, who may add comments and then send it to the Manager, Seattle ACO.

Note 4: Information concerning the existence of approved alternative methods of compliance with this AD, if any, may be obtained from the Seattle ACO.

Special Flight Permits

(e) Special flight permits may be issued in accordance with sections 21.197 and 21.199 of the Federal Aviation Regulations (14 CFR 21.197 and 21.199) to operate the airplane to a location where the requirements of this AD can be accomplished.

Incorporation by Reference

(f) The actions shall be done in accordance with Boeing Alert Service Bulletin 737–57A1277, dated July 25, 2002. This incorporation by reference was approved by the Director of the Federal Register in accordance with 5 U.S.C. 552(a) and 1 CFR part 51. Copies may be obtained from Boeing Commercial Airplane Group, PO Box 3707, Seattle, Washington 98124–2207. Copies may be inspected at the FAA, Transport Airplane Directorate, 1601 Lind Avenue, SW., Renton, Washington; or at the Office of the Federal Register, 800 North Capitol Street, NW., suite 700, Washington, DC.

Effective Date

(g) This amendment becomes effective on November 15, 2002.

Issued in Renton, Washington, on October 22, 2002.

Vi L. Lipski,

Manager, Transport Airplane Directorate, Aircraft Certification Service.

[FR Doc. 02–27315 Filed 10–30–02; 8:45 am]

BILLING CODE 4910–13–P

DEPARTMENT OF THE TREASURY

Customs Service

19 CFR Parts 4, 113 and 178

[T.D. 02–62]

RIN 1515–AD11

Presentation of Vessel Cargo Declaration to Customs Before Cargo Is Laden Aboard Vessel at Foreign Port for Transport to the United States

AGENCY: Customs Service, Department of the Treasury.

ACTION: Final rule.

SUMMARY: This document amends the Customs Regulations to require the advance and accurate presentation of certain manifest information prior to lading at the foreign port and to encourage the presentation of this information electronically. The document also allows a non-vessel operating common carrier (NVOCC) having an International Carrier Bond to electronically present cargo manifest information to Customs. This information is required in advance and is urgently needed in order to enable Customs to evaluate the risk of smuggling weapons of mass destruction through the use of oceangoing cargo containers before goods are loaded on vessels for importation into the United States, while, at the same time, enabling Customs to facilitate the prompt release of legitimate cargo following its arrival in the United States. Failure to provide the required information in the time period prescribed may result in the delay of a permit to unlade and/or the assessment of civil monetary penalties or claims for liquidated damages.

EFFECTIVE DATE: December 2, 2002.

FOR FURTHER INFORMATION CONTACT:

For Legal matters: Larry L. Burton, Office of Regulations and Rulings, (202–572–8724).

For National Targeting Center issues: David Tipton, (202–927–0108).

For Container Security Initiatives: Adam Wysocki, (202–927–0724).

For Trade Compliance issues: Kimberly Nott, (202–927–0042).

SUPPLEMENTARY INFORMATION:

Background

The Customs laws impose certain requirements upon vessels that will arrive in the United States to discharge their cargo. In particular, vessels destined for the United States must comply with 19 U.S.C. 1431, which requires that every vessel bound for the United States and required to make entry under 19 U.S.C. 1434 have a manifest that meets the requirements that are prescribed by regulation. To this end, under 19 U.S.C. 1431(d), Customs may by regulation specify the form for, and the information and data that must be contained in, the vessel manifest, as well as the manner of production for, and the delivery or electronic transmittal of, the vessel manifest.

Currently, § 4.7, Customs Regulations (19 CFR 4.7), requires: That the master of every vessel arriving in the United States and required to make entry have on board the vessel a manifest in accordance with 19 U.S.C. 1431 and § 4.7; and that an original and one copy of the manifest must be ready for production upon demand and must be delivered to the first Customs officer who demands the manifest. Sections 4.7(a) and 4.7a, Customs Regulations (19 CFR 4.7(a) and 4.7a), set forth the documentary and informational requirements that constitute the vessel manifest.

Pursuant to § 4.7(a), the cargo declaration (Customs Form 1302 or its electronic equivalent) is one of the documents that comprises a vessel manifest. The cargo declaration must list all the inward foreign cargo on board the vessel regardless of the intended U.S. port of discharge of the cargo (§ 4.7a(c)(1)).

Furthermore, 19 U.S.C. 1448 provides, in pertinent part, that no merchandise may be unladen from a vessel which is required to make entry under section 1434 until Customs has issued a permit for its unlading. In addition, under section 1448, Customs possesses a reasonable measure of regulatory discretion as to whether, and under what circumstances and conditions, to issue a permit to unlade incoming cargo from a vessel arriving in the United States. Section 4.30, Customs Regulations (19 CFR 4.30), lists the requirements and conditions under which Customs may issue a permit to unlade foreign merchandise from a vessel arriving in the United States.

In addition, 19 U.S.C. 1436(a)(1) and (a)(4) provide that it is unlawful to fail to comply with sections 1431, 1433 or 1434 or any regulation prescribed under any of those statutory authorities. Moreover, 19 U.S.C. 1436(a)(2) states that it is unlawful to present or transmit, electronically or otherwise, any forged, altered or false document, paper, data or manifest to the Customs Service under 19 U.S.C. 1431, 1433(d) or 1434. Under section 1436(b), the master of a vessel who commits any such violation is liable for a civil penalty of $5,000 for the first violation and $10,000 for each subsequent violation and any conveyance used in connection with any such violation is subject to seizure and forfeiture.

Proposed Rulemaking; Advance Presentation of Vessel Cargo Manifest to Customs; Required Information

By a document published in the **Federal Register** (67 FR 51519) on August 8, 2002, Customs proposed to amend § 4.7 to provide that, pursuant to 19 U.S.C. 1431(d), for any vessel subject to entry under 19 U.S.C. 1434 upon its arrival in the United States, Customs must receive the vessel's cargo manifest (declaration) from the carrier 24 hours before the related cargo is laden aboard the vessel at the foreign port. The proposed rule also enumerated the specific informational elements that would need to be included in the submitted cargo manifest.

Necessity for Advance Presentation of Vessel Cargo Manifest to Customs

As explained in the preamble of the Notice of Proposed Rulemaking (67 FR at 51520), the United States Customs Service recently launched the Container Security Initiative (''CSI''). CSI will secure an indispensable, but vulnerable link in the chain of global trade: Containerized shipping. Approximately 90% of world cargo moves by container; 200 million cargo containers are transported between the world's seaports each year, constituting the most critical component of global trade. Nearly half of all incoming trade to the United States (by value) arrives by ship, and most of that is in sea containers. Annually, nearly 6 million cargo containers are offloaded at U.S. seaports.

There is, however, virtually no security for this critical global trading system. And the consequences of a terrorist incident using a container would be profound. As experts like Dr. Stephen E. Flynn, Senior Fellow, Council on Foreign Relations, have pointed out repeatedly, if terrorists used a sea container to conceal a weapon of mass destruction—a nuclear device, for example—and detonated it on arrival at a port, the impact on global trade and the global economy would be immediate and devastating. All nations would be affected because there would be no mechanism for identifying weapons of mass destruction before they reached our shores and before they posed a threat to the global economy.

Al Qaeda and other terrorist organizations pose an immediate and substantial threat. And the threat is not just to harm and kill American citizens, it is a threat to damage and destroy the U.S. and the world economy.

To address the threat terrorists pose to containerized shipping, Customs developed CSI. Under CSI, U.S. Customs is working with other governments to identify high-risk cargo containers and pre-screen those containers at the foreign ports *before* they are shipped to the U.S. CSI has four core elements:

(1) Identify ''high-risk'' containers. In connection with its domestic targeting efforts, Customs has already established criteria and automated targeting tools for identifying ''high risk'' shipments. Indeed, every one of the shipments that arrives in the United States by sea container is *currently* assessed for risk using these tools and advance manifest data. If this data were provided earlier, Customs could use these same tools to detect high risk shipments before they were carried to the United States. Accordingly, to enhance domestic targeting and to enable overseas targeting and screening of containers, Customs has proposed a rule requiring accurate and detailed information to be transmitted before shipments are laden on vessels destined for the United States.

(2) Pre-screen containers *before* they are shipped. As discussed above, to protect the United States and global trade from the risks posed by international terrorists, security screening should be done at the port of departure rather than the port of arrival.

(3) Use technology to screen high-risk containers. Technology enables screening to be done rapidly without slowing down the movement of trade. This technology includes large-scale x-ray and gamma machines and radiation detection devices.

(4) Use more secure containers to ensure the integrity of containers screened overseas.

CSI thus offers real protection, on a day-to-day basis, for the primary system of international trade—a system on which all economies depend. Given the security afforded by CSI, the investments made by ports and members of the trade to implement CSI represent relatively inexpensive forms of insurance against the terrorist threat. In the event of an attack using a cargo container, the CSI network of ports will be able to remain operational because those ports will already have an effective security system in place—one that will deter and prevent terrorists from using it. Without such a network, the damage to global trade caused by a terrorist attack involving international shipping would be staggering.

In addition to protecting global trade, CSI should *facilitate* the flow of that trade. When a container has been pre-screened and sealed under CSI, U.S. Customs will not, absent additional information affecting its risk analysis, need to inspect it for security purposes when it reaches the U.S. Moreover, this system could reduce the processing time for certain shipments because the screening at a CSI port will in most cases take place during "down time." Most containers sit on a terminal for an average of several days prior to lading. This window of "down time" will be used to screen containers for security purposes. On arrival at the U.S. seaport, the CSI-screened container should be released immediately by U.S. Customs, which could shave hours, if not days, off of the shipping cycle. In this manner, CSI should increase the speed and predictability for the movement of cargo containers shipped to the U.S.

For these reasons, CSI is a critical component of the President's Homeland Security Strategy. It has also been endorsed by the G–8 as well as the World Customs Organization.

As a result of this broad support, CSI has been expanding rapidly. When Customs launched CSI this past January, the first step was to implement CSI as quickly as possible in Canada and the top 20 ports (by volume) that ship to the United States. When fully implemented in these locations, CSI will substantially increase the security of the United States and the global trading system because the top 20 ports alone account for nearly 70% of all the containers shipped to U.S. seaports. To date, Canada, the Netherlands, Belgium, France, Germany, Singapore, Hong Kong, and Japan have agreed to implement CSI. These countries represent 11 of the top 20 ports. Customs anticipates that several other nations will agree to implement CSI in the near term, and that CSI will expand beyond the top 20 ports during the next year.

CSI is already operational in Canada and the Netherlands. It will be implemented at several additional ports within the next 90 days. Given this explosive growth, it is critical that the information necessary to implement CSI fully be provided to Customs in the near term. For this reason, Customs proposed this rulemaking on August 8, 2002 and, following the comment period, is issuing this final rule today.

Non-Vessel Operating Common Carriers (NVOCCs)

Under the proposed rule, the conditions of the International Carrier Bond (19 CFR 113.64) were proposed to be amended to recognize the status of a Non-Vessel Operating Common Carrier (NVOCC) as a manifesting party and to obligate any NVOCC having such a bond and electing to provide cargo manifest information to Customs electronically under § 4.7 and 4.7a to accurately transmit such information to Customs 24 or more hours before the related cargo is laden aboard the vessel at the foreign port. Breach of these obligations would result in liquidated damages against the NVOCC. For purposes of the proposed rule, a non-vessel operating common carrier (NVOCC) as a common carrier that does not operate the vessels by which the ocean transportation is provided, would be considered a shipper in its relationship with an ocean common carrier.

Penalties or Liquidated Damages for False or Untimely Filing of Manifest Data

If the master of a vessel failed to present or transmit accurate manifest data in the required time period or presented or transmitted any false, forged or altered document, paper, manifest or data to Customs, the proposed regulations specified that monetary penalties could be assessed under the provisions of 19 U.S.C. 1436(b). Likewise, if an NVOCC having an International Carrier Bond elected to transmit such data electronically to Customs and failed to do so in the required time period or transmitted any false, forged or altered document, paper, manifest or data to Customs, the NVOCC could be liable for the payment of liquidated damages for breach of the conditions of the International Carrier Bond, in addition to any other applicable penalties.

Issuance of Permit To Unlade Cargo

The proposed rule also provided that if the carrier did not present cargo declaration information to Customs prior to the lading of the cargo aboard the vessel at the foreign port, Customs could, in addition to assessment of civil monetary penalties, delay issuance of a permit to unlade the entire vessel or a portion thereof until all required information was received.

Preliminary Entry

Finally, it was proposed that § 4.8 be amended to make clear that the granting of preliminary entry by Customs would be conditioned upon the electronic submission of the Cargo Declaration (Customs Form (CF) 1302), as well as the provision to Customs either electronically or in paper form of all other forms required by § 4.7.

Discussion of Comments

A total of 78 commenters responded to the notice of proposed rulemaking. Nearly all of the commenters recognized the need to act immediately to protect the global trading systems, and in particular to protect the most important element in the movement of international trade—containerized cargo. They also recognized the urgency and seriousness of the threat posed by terrorist organizations and the smuggling of weapons of mass destruction, including radiological and nuclear materials. They complimented the Customs Service on newly created programs such as the Customs-Trade Partnership Against Terrorism (C–TPAT) and the Container Security Initiative (CSI), which are designed to address this threat.

Most commenters questioned how the regulation would be implemented. They raised operational issues regarding the movement of containers, the security of containers and the interfaces between the U.S. Customs Service and the trade. They also noted that the regulation would require changes to existing business practices that could take several months to fully implement.

While the aim of this regulation is to better secure containerized cargo from the threat of terrorism, it is important to note that carriers, shippers, importers and others should realize significant benefits from its implementation. Most notably, once a cargo container is pre-screened in a foreign port, in the absence of additional information affecting Customs risk analysis, Customs will rarely need to again screen the container or inspect its contents for security purposes upon arrival in the United States. This offers greater predictability for freight forwarders and importers to arrange for transportation upon discharge of the cargo. This and other benefits, however, will only be fully realized after the Customs Service is able to pre-screen containers overseas, using the accurate and complete information required by this regulation.

We have carefully considered all of the comments, and as a result, we have

Appendix 4: Conventional methodologies used to assess port impacts on the economy

A. Impacts on the economic wealth: value-added measurements

When statistical data is available, economic impacts are assessed using the input/output matrix:

Impact on employment	**Impact on the National wealth**
General impact on employment: $G_{iw} = \sum D_w + \sum I_w$ Overall impact on employment: $T_{iw} = \sum(G_{iw} + K_w)$ Where: G_{iw}: General impact on employment D_w: Direct employment I_w: Indirect employment T_{iw}: Overall impact on employment K_w: Ratio of induced employment (variable)	General impact on GDP: $G_{ip} = \sum D_p + \sum I_p$ Overall impact on GDP: $T_{ip} = \sum(G_{ip} + K_p)$ Where: G_{ip}: General impact on the GDP D_p: Aggregated direct added-value I_p: Aggregated indirect added-value T_{ip}: Overall impact on the GDP K_p : Ratio of induced added value (variable)

When detailed data is not available or not reliable, two techniques may be used:

Direct flows calculations	**Mass calculations**
Aggregated added value by port operator: $T_{ip} = \sum salaries + \sum profits + \sum taxes$ Overall aggregated added value: $Port\ contribution = Tip/(regional\ or\ national\ GDP)$ The overall contribution is estimated through the multiplier factor (K_{ip}). The more the distribution of output is diversified, the higher the multiplier factor.	When it is too expensive or too long to undertake a direct-flows survey, the mass calculation method is more convenient. The method consists in affecting the overall added value of the firms geographically located in the port area (not those located outside the port). Mass-calculations are not a very refined method, but can still inform about port contribution.

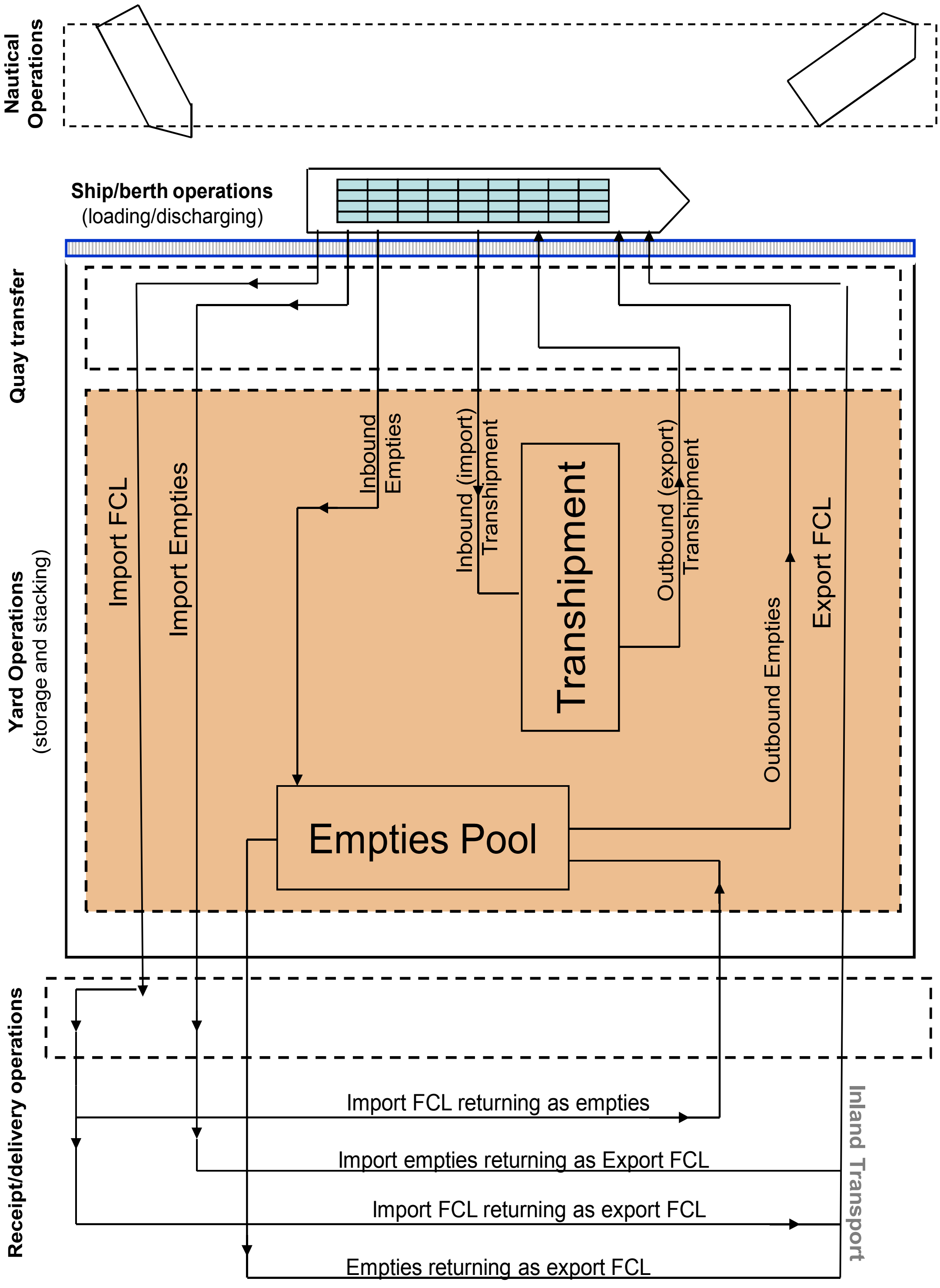
B. Impacts on the economic wealth: value-added measurements

Port efficiency can have a major impact on the efficiency of the national economy. This impact takes place on at least four major elements:

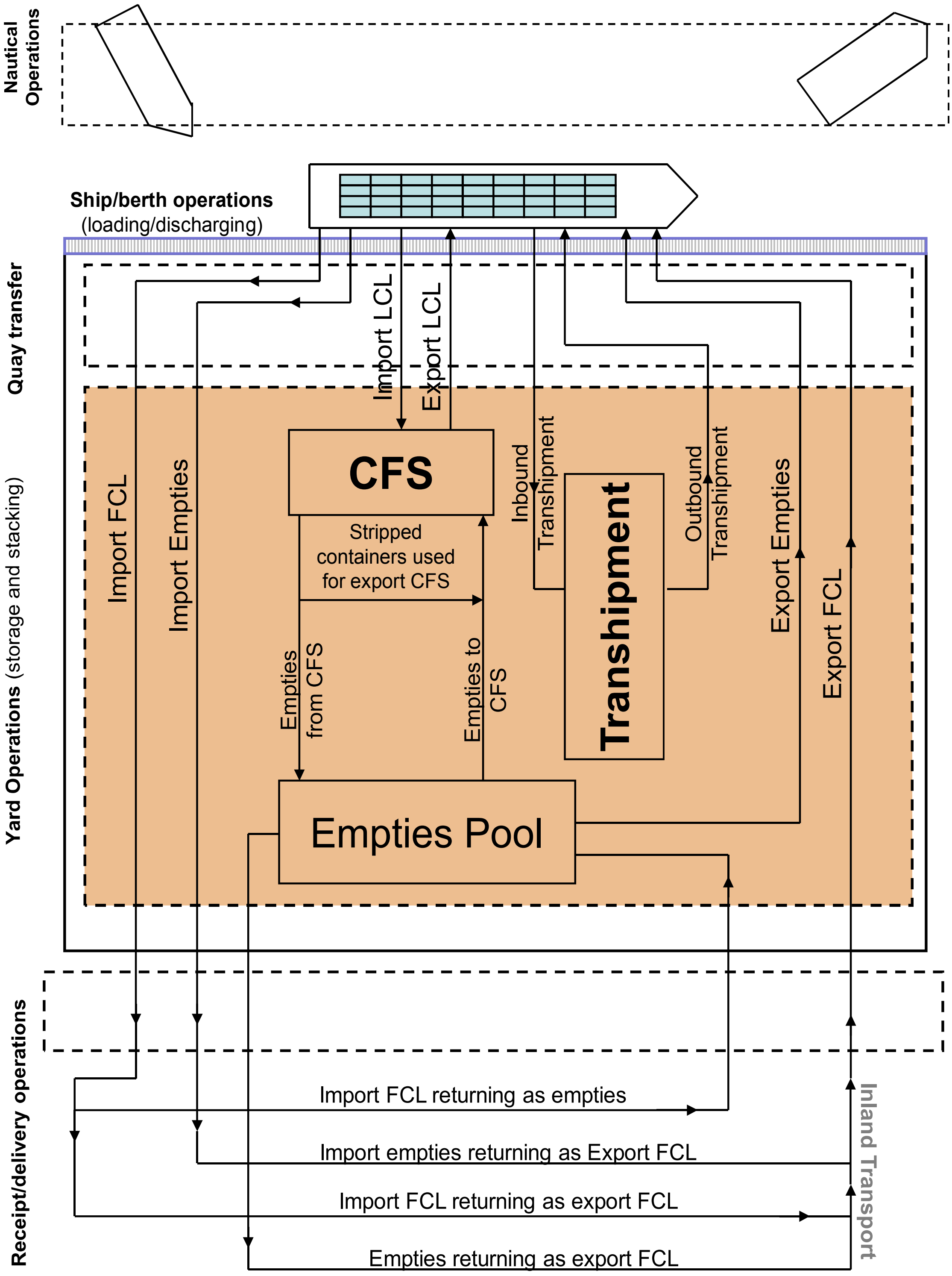
- Impact on the competition between ports: share of hinterland and market leadership,
- Impact on export/import trade competition: Role of ports in international trade,
- Impact on the price of imported/exported goods: port costs as proportion of total price of the goods,
- Impacts on the balance of payments: port as a source of foreign currencies and employment.

(Source: compiled and adapted from various sources including UNCTAD and World Bank sources

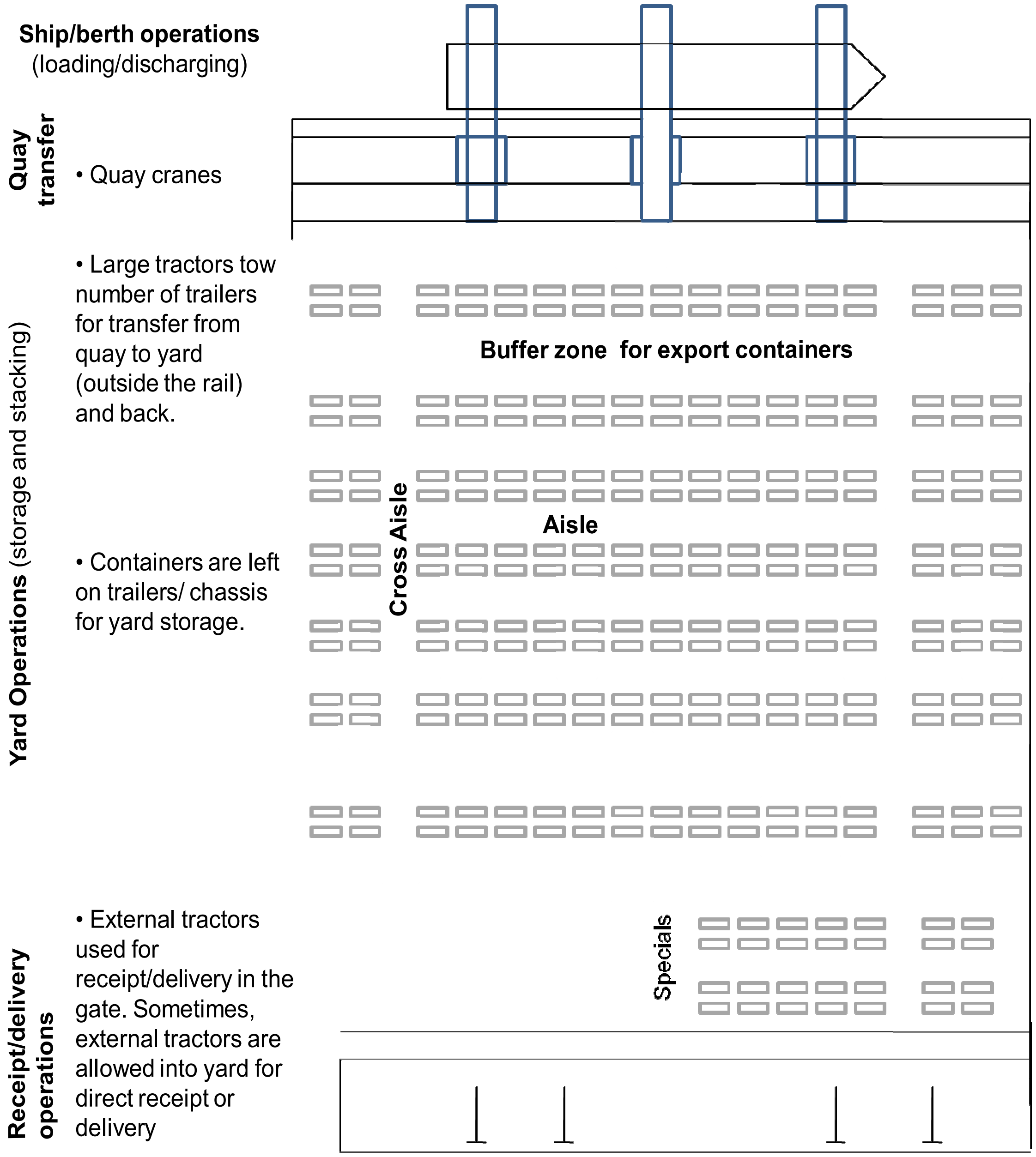
Appendix 5: Container Flow in a Terminal without CFS



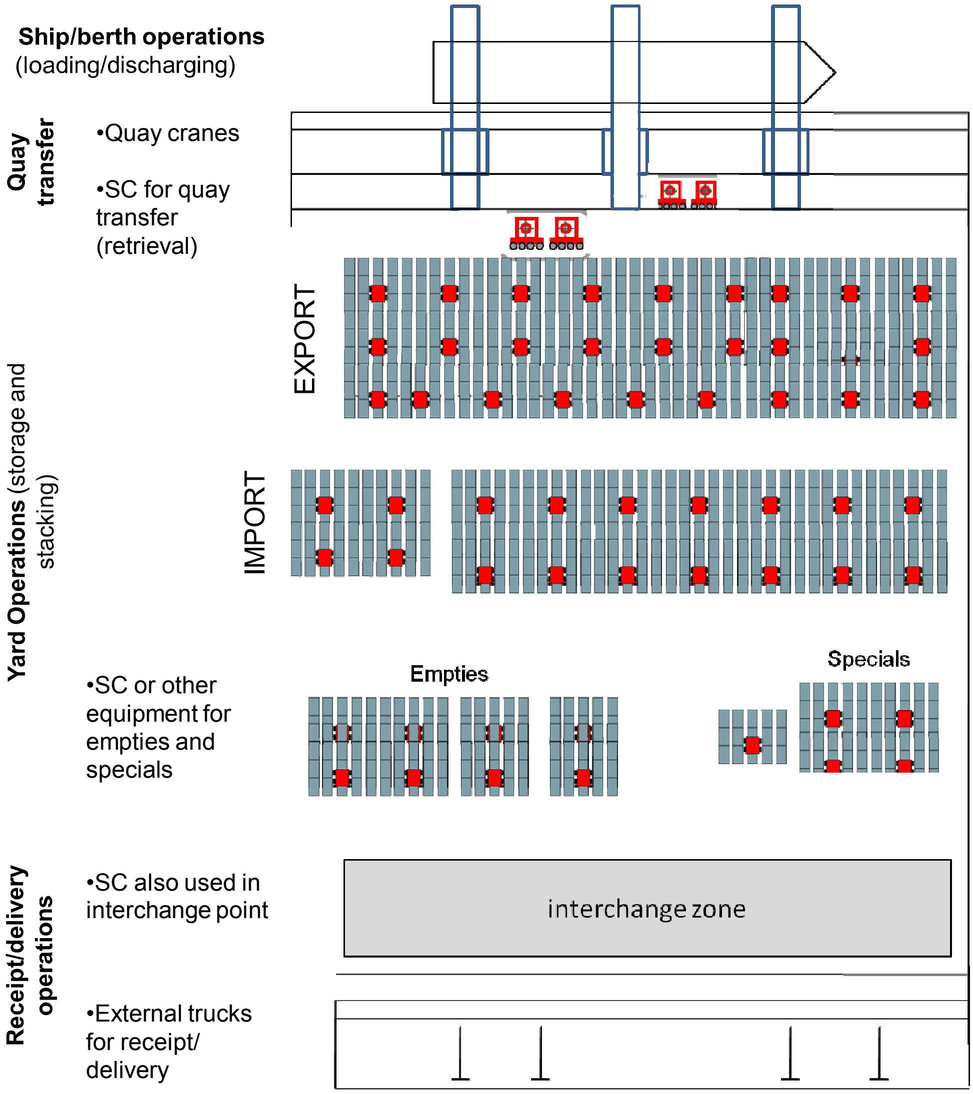
Appendix 6: Container Flow in a Terminal with CFS



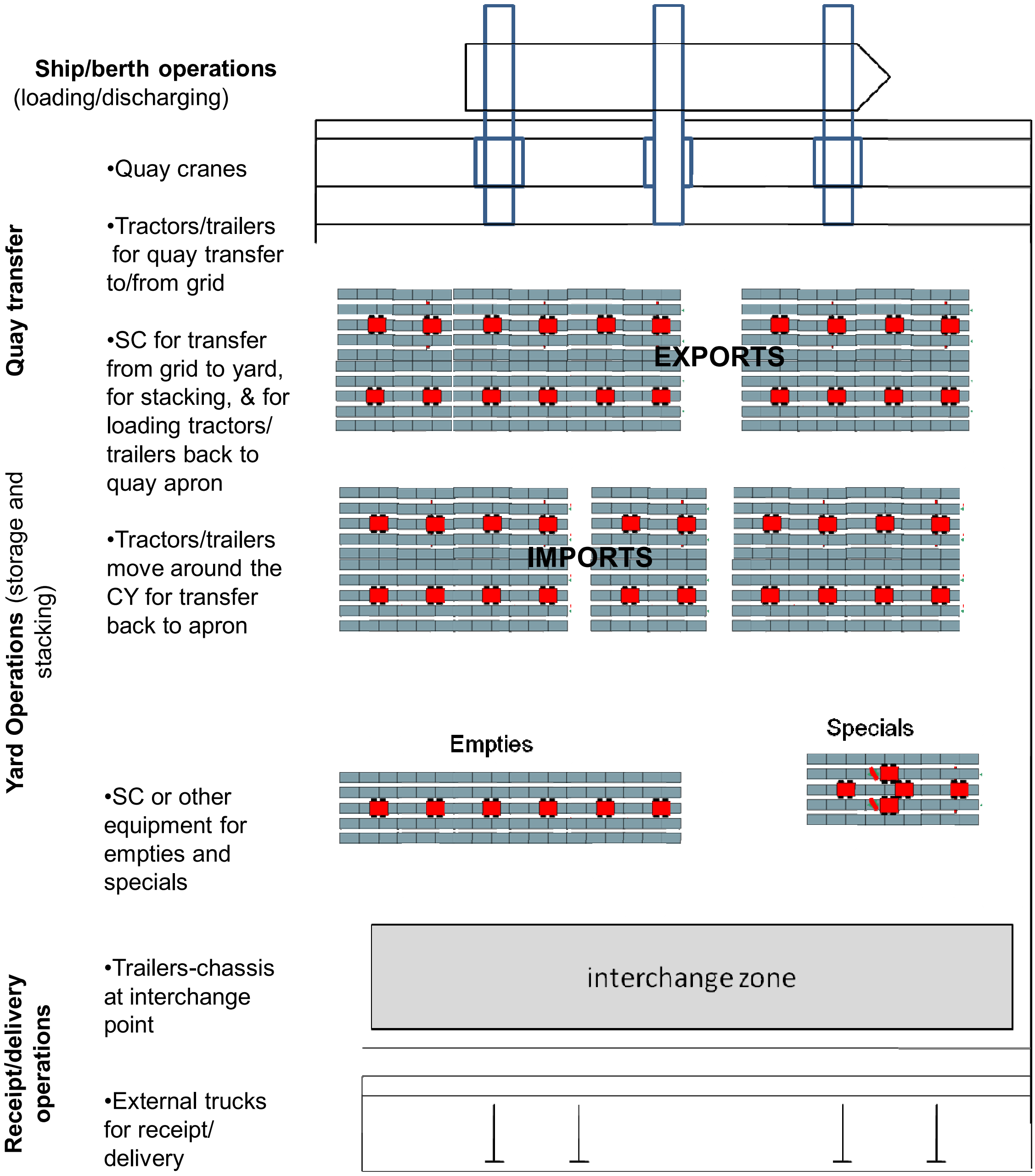
Appendix 7: Sample Layout of a Tractor / Chassis Wheeled System Supported with Terminal Handlers (e.g. Forklift Trucks)



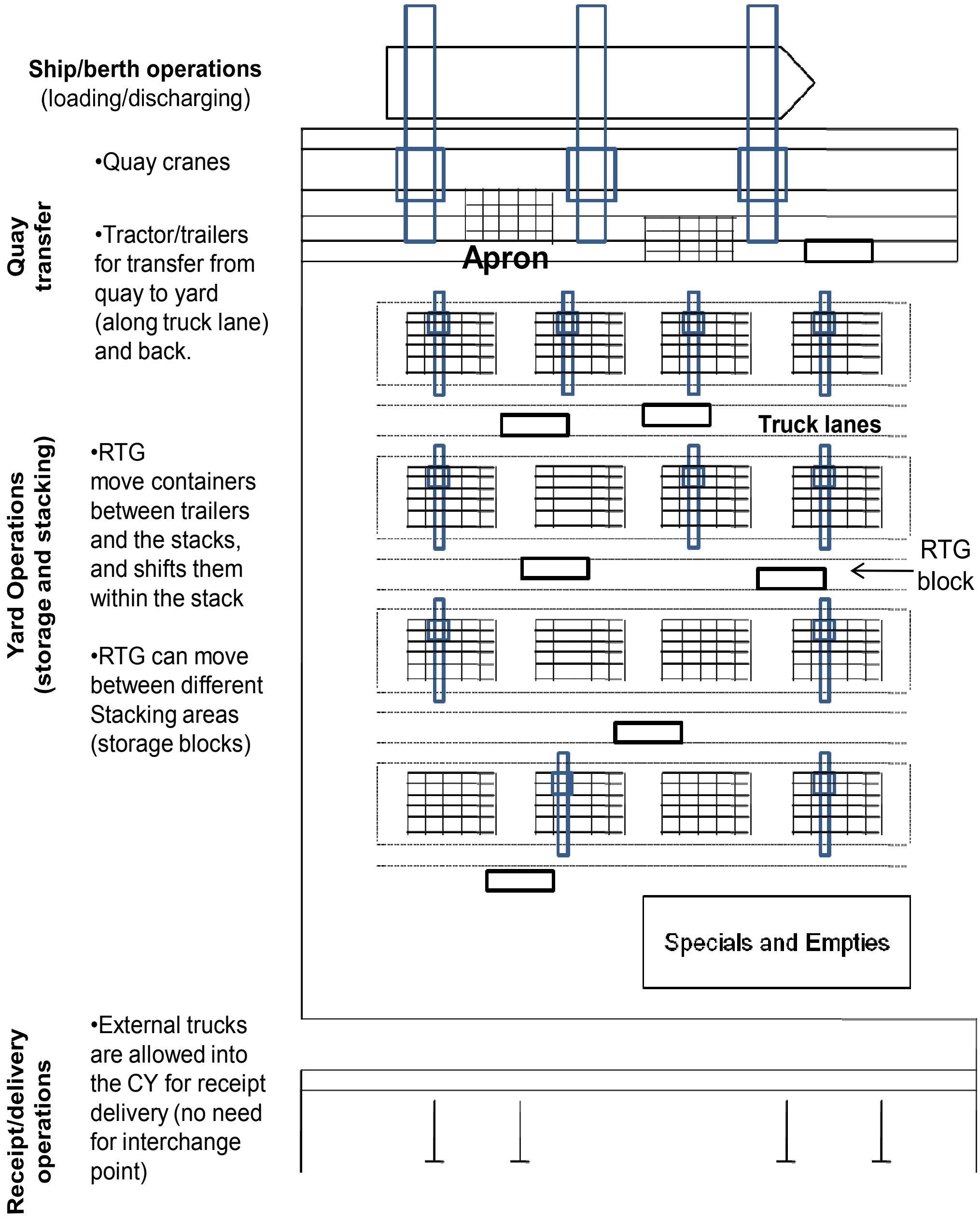
Appendix 8: Sample Layout of Straddle Carrier Direct System



Appendix 9: Sample Layout of Straddle Carrier Relay System



Appendix 10: Sample Layout of Rubber-Tired Yard Gantry System



Ship/berth operations
(loading/discharging)

Quay transfer

- Quay cranes
- Tractor/trailers for transfer from quay to yard (along truck lane) and back.

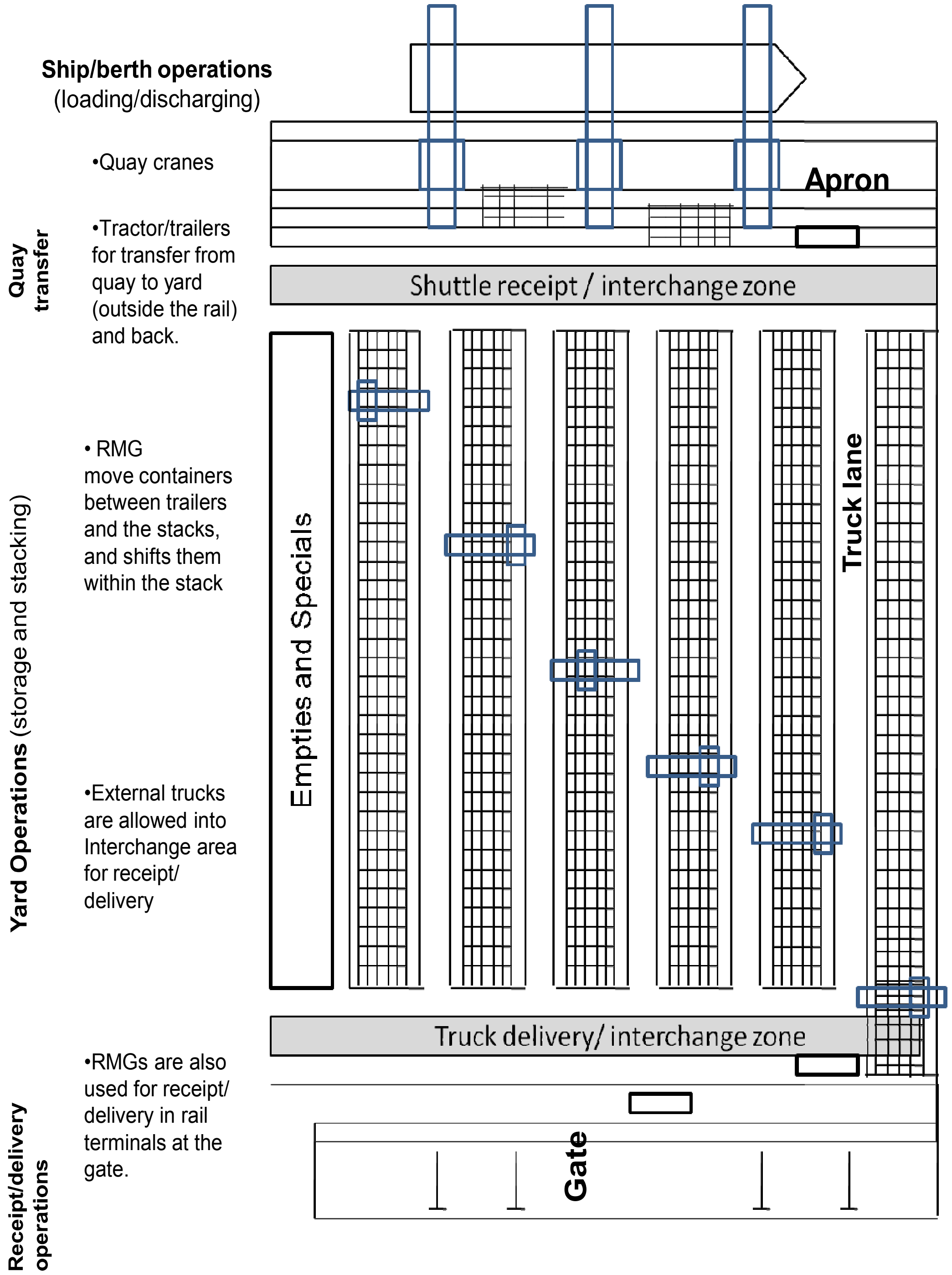
Yard Operations (storage and stacking)

- RTG move containers between trailers and the stacks, and shifts them within the stack
- RTG can move between different Stacking areas (storage blocks)

Receipt/delivery operations

- External trucks are allowed into the CY for receipt delivery (no need for interchange point)

Appendix 11: Sample Layout of Rail-Mounted Yard System



Appendix 12: Container Ports and Terminals in the Sample

Port	Country	Terminal	Abbreviation	Terminal Operator (as of 01/10/2008)
Hong Kong	Hong Kong (China)	Container Terminal 3	**CT3**	DP World
		Terminal 8 East	**T8E**	COSCO / HIT
		Modern Terminals (1,2,5,8W & 9S)	**MTL**	Modern Terminals
		Hong Kong International Terminals (4,6,7 & 9N)	**HIT**	HPH
Shanghai	China	Shanghai Container Terminal	**SCT**	Shanghai CT
Shenzhen	China	Shekou Container Terminal	**SKCT**	SK/HPH/ YPG
		Yantian International Container Terminal	**YICT**	HPH /YPG
Busan	South Korea	Gamman Container Terminal	**GCT**	Hanjing, HPH, Korea Express, Global Enterprise
		Jaseongdae Container Terminal	**HBCT**	HBCT (Hutchison Busan Container Terminal)
		Shinseondae/ Pusan East Container Terminal	**PECT**	PECT Co.
		Hanjing/ Gamcheon Container Terminal	**HGCT**	Hanjing
		Uam Container Terminal	**UCT**	Uam Terminal Co
Rotterdam	Holland	ECT Delta Container Terminals	**ECTD**	ECT (HPH)
		Maersk Delta Container Terminal	**MDCT**	APMT
Los Angeles	USA	Yusen Container Terminal	**YCT**	NYK
Hamburg	Germany	Burchardkai Container Terminal	**BCT**	HHLA
		Container Terminal Tollerort	**TTC**	HHLA
		Eurogate Container Terminal Hamburg	**CTH**	Eurogate
Dubai	UAE	Jebel Ali Container Terminal	**JACT**	DP World

		Port Rashid Container Terminal	**PRCT**	DP World
Long Beach	USA	Long Beach Pier F	**LBPF**	LBCTI (OOCL)
		Long Beach Pier T	**LBPT**	TTI (Hanjin)
Port Kelang	Malaysia	Northport Container Terminals (1 & 2)	**NPCT**	Northport (NCB)
		Westport Container Terminals (1,2,3 & 4)	**WPCT**	Kelang/HPH
Qingdao	China	Qingdao Qianwan Container Terminal	**QQCT**	DP World/ APM Terminals /COSCO
New York/ New Jersey	USA	Port Newark Container Terminal	**PNTC**	AIG
Tanjung Pelepas	Malaysia	Tanjung Pelepas Container Terminal	**PTP**	STSB/ APM Terminals
Tianjin	China	Tianjin Orient Container Terminal	**TOCT**	DP World/ NWS
Xiamen	China	Xiamen New World Xiangyu Terminal	**XNWT**	NWS
Nagoya	Japan	Nabeta Pier Container Terminal	**NP**	NUCT
		Tobishima Piers (North & South)	**TP**	NTPC
		Nagoya Container Berth	**NCB**	NTSC
Laem Chabang	Thailand	Laem Chabang International Terminal	**LCIT**	DP World
		Laem Chabang Container Berth 1	**LCB1**	LCB1/ APM Terminals
Bremen/ Bremerhaven	Germany	Container Terminal Bremerhaven	**CTB**	Bremen Ports / Eurogate
		North Sea Container Terminal	**NSCT**	NTB
Algeciras	Spain	Algeciras Maersk Container Terminal	**AMCT**	APM Terminals
Gioia Tauro	Italy	Med-Centre Container Terminal	**MCT**	APM Terminals/ Contship (Eurogate)
Manila	The Philippines	Manila International Container Terminal	**MICT**	ICTSI
Jeddah	Saudi Arabia	Jeddah Southern Container Terminal	**JSCT**	DP World/ Syanco
		Jeddah Northern Container Terminal	**JNCT**	GSCO
Jawaharlal	India	Nhava Sheva International Container Terminal	**NSICT**	DP World

Nehru				
Colombo	Sri Lanka	South Asia Gateway Terminal	**SAGT**	SAGT/ APM Terminals/ Evergreen/
Barcelona	Spain	Muelle Principe De Espana	**MPE**	TERCAT
Santos	Brazil	Terminal 37	**T37**	Libra Terminals
		Tecon Terminal	**TT**	Santos Brazil Ltd.
Durban	South Africa	Durban Container Terminal	**DCT**	SAPO
Liverpool	UK	Royal Sea-forth Container Terminal	**RSCT**	MDHC
Thames-port	UK	Thames-port Container Terminal	**TPCT**	HPH
Salalah	Oman	Salalah Port Container Terminal	**SPCT**	Salalah Co/ APM Terminals
Lisbon	Portugal	Alcantara-Sul Container Terminal	**ASCT**	LISCONT
		Santa Apolonia Container Terminal	**SACT**	SOTAGUS
Piraeus	Greece	Venizelos Container Terminal	**VCT**	Piraeus Port Authority
Genoa	Italy	Voltri Terminal	**VT**	VTE
La Spezia	Italy	La Spezia Container Terminal	**LSCT**	Contship (Eurogate)
Kingston	Jamaica	Kingston Container Terminal	**KCT**	APM Terminals
Colon	Panama	Colon Container Terminal	**CCT**	Evergreen
Manzanillo	Panama	Manzanillo International Terminal	**MIT**	SSA (Carrix)
Port Qasim	Pakistan	Port Qasim International Terminal	**PQIT**	DP World
Alexandria	Egypt	Alexandria Container Terminal	**ACT**	HCMLT

Appendix 13: On-line questionnaire sent to operations mangers of terminals in the sample

Dear xxx,

We are undertaking a global study on the impact of security on container-terminal efficiency. We’ve gathered data on different aspects of terminal operations from trade journals such as Containerisation International, but we still need detailed data on output physical measures such as average dwell time and quay crane mover per hour. We would be very grateful if you can complete the attached table **(for your terminal)** and return the same to me via e-mail at your earliest convenience. Obviously we will treat the information provided as strictly confidential, but we will be happy to share with you the result of our global study once completed. Your assistance is very much appreciated.

Thank you in advance

Best regards,
Khalid Bichou

Year	Terminal throughput in TEU	Total terminal area in m^2	Maximum draft in meter	Total quay length in meter	Number of sea-to-shore cranes (STS)	Lifting capacity in tons	Average STS crane move per hour	Number & type of yard stacking equipment	Average staking height of yard equipment	Number of internal trucks and vehicles	Average dwell time in the yard	Number of gates or gate lanes
2000												
2001												
2002												
2003												
2004												
2005												
2006												

Appendix 14: Terminal Efficiency Estimates in the Year 2000 under Cross-Sectional DEA

Terminal	Throughput (1000s TEU)	Input Orientation				Output Orientation			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
CT3	1,176	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
T8E	1,413	1.000	0.962	0.301	Increasing	1.000	1.040	0.313	Increasing
MTL	3,360	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
HIT	6,600	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
SCT	2,951	1.000	0.917	0.687	Increasing	1.000	1.091	0.749	Increasing
SKCT	720	0.892	0.472	0.343	Increasing	2.024	2.117	0.727	Increasing
YICT	2,147	0.922	0.825	0.496	Increasing	1.164	1.212	0.601	Increasing
GCT	1,769	0.977	0.888	0.639	Increasing	1.033	1.126	0.720	Increasing
HBCT	1,434	0.874	0.618	0.496	Increasing	1.528	1.618	0.802	Increasing
PECT	1,295	0.762	0.507	0.562	Increasing	1.894	1.974	1.110	Decreasing
HGCT	387	1.000	0.427	0.163	Increasing	1.000	2.344	0.383	Increasing
UCT	312	1.000	0.353	0.138	Increasing	1.000	2.832	0.391	Increasing
ECTD	1,500	0.691	0.439	0.432	Increasing	2.276	2.278	0.983	Increasing
MDCT	404	0.651	0.184	0.165	Increasing	5.211	5.422	0.896	Increasing
YCT	500	0.854	0.336	0.353	Increasing	2.907	2.977	1.052	Decreasing
BCT	2,200	0.904	0.852	0.852	Increasing	1.174	1.174	1.000	Increasing
TTC	500	0.748	0.344	0.238	Increasing	2.457	2.909	0.693	Increasing
CTH	1,340	0.764	0.685	0.839	Increasing	1.443	1.460	1.225	Decreasing
JACT	2,300	0.667	0.462	0.516	Increasing	2.118	2.166	1.119	Decreasing
PRCT	821	0.856	0.498	0.464	Increasing	1.969	2.010	0.932	Increasing
LBPF	290	0.717	0.186	0.231	Increasing	4.596	5.383	1.243	Decreasing
LBPT	900	0.689	0.594	0.822	Increasing	1.640	1.682	1.383	Decreasing
NPCT	2,120	0.858	0.640	0.651	Increasing	1.556	1.564	1.018	Decreasing
WPCT	1,027	0.698	0.240	0.274	Increasing	4.090	4.166	1.141	Decreasing
QQCT	1,600	0.893	0.345	0.284	Increasing	2.338	2.902	0.823	Increasing
PNTC	390	0.861	0.339	0.327	Increasing	2.928	2.946	0.965	Increasing
PTP	1,672	0.774	0.517	0.525	Increasing	1.932	1.934	1.016	Decreasing
TOCT	240	0.797	0.131	0.133	Increasing	7.627	7.631	1.017	Decreasing
XNWT	265	1.000	0.301	0.086	Increasing	1.000	3.319	0.284	Increasing
NP	180	0.886	0.169	0.105	Increasing	4.629	5.908	0.620	Increasing

Appendix 14 (2000 Cross-Sectional: Continued)

Terminal	**Throughput** (1000s TEU)	**Input Orientation**				**Output Orientation**			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
TP	662	0.733	0.298	0.211	Increasing	3.034	3.359	0.708	Increasing
NCB	401	1.000	0.577	0.188	Increasing	1.000	1.733	0.325	Increasing
LCIT	440	1.000	0.428	0.178	Increasing	1.000	2.336	0.416	Increasing
LCB1	750	1.000	0.588	0.173	Increasing	1.000	1.701	0.294	Increasing
CTB	1,077	0.794	0.445	0.177	Increasing	2.041	2.247	0.398	Increasing
NSCT	2,009	0.827	0.659	0.593	Increasing	1.495	1.518	0.900	Increasing
AMCT	2,653	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
MCT	958	1.000	0.984	0.787	Increasing	1.000	1.016	0.800	Increasing
MICT	889	0.757	0.518	0.424	Increasing	1.836	1.931	0.819	Increasing
JSCT	125	0.735	0.347	0.284	Increasing	2.709	2.878	0.816	Increasing
JNCT	619	0.724	0.068	0.051	Increasing	13.470	14.744	0.758	Increasing
NSICT	301	0.929	0.468	0.299	Increasing	1.628	2.136	0.639	Increasing
SAGT	250	1.000	0.356	0.177	Increasing	1.000	2.806	0.496	Increasing
MPE	399	0.878	0.144	0.066	Increasing	4.282	6.922	0.455	Increasing
T37	219	0.986	0.507	0.447	Increasing	1.357	1.973	0.882	Increasing
TT	1,291	0.849	0.204	0.202	Increasing	4.891	4.899	0.991	Increasing
DCT	475	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
RSCT	500	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
TPCT	1,000	0.933	0.590	0.373	Increasing	1.228	1.696	0.632	Increasing
SPCT	123	0.748	0.480	0.325	Increasing	1.868	2.081	0.677	Increasing
ASCT	123	1.000	0.211	0.064	Increasing	1.000	4.744	0.305	Increasing
SACT	1,148	1.000	0.201	0.089	Increasing	1.000	4.976	0.443	Increasing
VCT	744	0.841	0.732	0.589	Increasing	1.289	1.367	0.805	Increasing
VT	781	1.000	0.983	0.598	Increasing	1.000	1.017	0.608	Increasing
LSCT	410	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
KCT	177	1.000	0.597	0.248	Increasing	1.000	1.676	0.416	Increasing
CCT	1,016	1.000	0.213	0.127	Increasing	1.000	4.686	0.595	Increasing
MIT	160	0.803	0.587	0.613	Increasing	1.699	1.703	1.044	Decreasing
PQIT	540	1.000	0.478	0.195	Increasing	1.000	2.090	0.408	Increasing
ACT	662	1.000	0.691	0.285	Increasing	1.000	1.446	0.413	Increasing

Appendix 15: Terminal Efficiency Estimates in the Year 2001 under Cross-Sectional DEA

Terminal	Throughput (1000s TEU)	Input Orientation				Output Orientation			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
CT3	1,119	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
T8E	1,302	1.000	0.942	0.295	Increasing	1.000	1.061	0.313	Increasing
MTL	3,520	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
HIT	6,200	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
SCT	2,611	1.000	0.858	0.583	Increasing	1.000	1.165	0.680	Increasing
SKCT	751	0.899	0.521	0.378	Increasing	1.837	1.921	0.727	Increasing
YICT	2,700	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
GCT	1,923	1.000	0.975	0.657	Increasing	1.000	1.026	0.674	Increasing
HBCT	1,272	0.869	0.554	0.426	Increasing	1.617	1.806	0.768	Increasing
PECT	1,331	0.778	0.548	0.560	Increasing	1.810	1.823	1.021	Decreasing
HGCT	433	1.000	0.502	0.192	Increasing	1.000	1.992	0.383	Increasing
UCT	448	1.000	0.500	0.195	Increasing	1.000	2.002	0.391	Increasing
ECTD	3,300	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
MDCT	418	0.651	0.200	0.175	Increasing	4.841	5.005	0.877	Increasing
YCT	550	0.864	0.380	0.396	Increasing	2.580	2.633	1.042	Decreasing
BCT	2,300	0.923	0.908	0.940	Increasing	1.092	1.101	1.034	Decreasing
TTC	513	0.757	0.368	0.253	Increasing	2.332	2.718	0.688	Increasing
CTH	1,320	0.765	0.660	0.808	Increasing	1.493	1.516	1.225	Decreasing
JACT	2,600	0.667	0.553	0.565	Increasing	1.799	1.810	1.022	Decreasing
PRCT	900	0.874	0.556	0.505	Increasing	1.698	1.799	0.908	Increasing
LBPF	280	0.721	0.190	0.232	Increasing	4.565	5.277	1.226	Decreasing
LBPT	986	0.710	0.659	0.903	Increasing	1.480	1.516	1.369	Decreasing
NPCT	2,200	0.883	0.704	0.700	Increasing	1.419	1.420	0.994	Increasing
WPCT	1,457	0.703	0.362	0.411	Increasing	2.713	2.763	1.136	Decreasing
QQCT	2,040	0.920	0.465	0.382	Increasing	1.698	2.151	0.823	Increasing
PNTC	420	0.875	0.382	0.358	Increasing	2.609	2.618	0.938	Increasing
PTP	2,050	0.792	0.606	0.615	Increasing	1.648	1.649	1.014	Decreasing
TOCT	261	0.799	0.140	0.142	Increasing	7.124	7.128	1.012	Decreasing
XNWT	288	1.000	0.342	0.096	Increasing	1.000	2.921	0.282	Increasing
NP	336	0.890	0.309	0.152	Increasing	2.375	3.237	0.493	Increasing

Appendix 15 (2001 Cross-Sectional: Continued)

Terminal	Throughput (1000s TEU)	Input Orientation				Output Orientation			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
TP	738	0.747	0.370	0.260	Increasing	2.451	2.704	0.704	Increasing
NCB	662	1.000	0.597	0.191	Increasing	1.000	1.675	0.320	Increasing
LCIT	529	1.000	0.594	0.247	Increasing	1.000	1.683	0.416	Increasing
LCB1	479	1.000	0.679	0.200	Increasing	1.000	1.474	0.294	Increasing
CTB	1,002	0.820	0.609	0.289	Increasing	1.505	1.643	0.474	Increasing
NSCT	1,236	0.869	0.730	0.657	Increasing	1.286	1.369	0.900	Increasing
AMCT	2,152	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
MCT	2,488	1.000	0.948	0.768	Increasing	1.000	1.055	0.810	Increasing
MICT	928	0.763	0.505	0.427	Increasing	1.936	1.979	0.845	Increasing
JSCT	878	0.740	0.360	0.283	Increasing	2.633	2.775	0.785	Increasing
JNCT	148	0.724	0.081	0.061	Increasing	11.356	12.297	0.747	Increasing
NSICT	888	0.970	0.686	0.424	Increasing	1.111	1.458	0.619	Increasing
SAGT	330	1.000	0.412	0.205	Increasing	1.000	2.424	0.496	Increasing
MPE	299	0.896	0.183	0.083	Increasing	3.310	5.473	0.456	Increasing
T37	478	0.997	0.618	0.485	Increasing	1.063	1.619	0.785	Increasing
TT	250	0.849	0.237	0.235	Increasing	4.193	4.214	0.991	Increasing
DCT	1,228	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
RSCT	500	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
TPCT	504	0.940	0.591	0.339	Increasing	1.158	1.693	0.573	Increasing
SPCT	1,187	0.777	0.577	0.363	Increasing	1.569	1.734	0.629	Increasing
ASCT	128	1.000	0.221	0.067	Increasing	1.000	4.529	0.305	Increasing
SACT	140	1.000	0.228	0.099	Increasing	1.000	4.387	0.434	Increasing
VCT	1,162	0.874	0.743	0.576	Increasing	1.252	1.346	0.775	Increasing
VT	818	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
LSCT	841	1.000	0.916	0.516	Increasing	1.000	1.092	0.563	Increasing
KCT	579	1.000	0.736	0.432	Increasing	1.000	1.358	0.587	Increasing
CCT	206	1.000	0.258	0.153	Increasing	1.000	3.882	0.593	Increasing
MIT	960	0.807	0.571	0.587	Increasing	1.745	1.751	1.029	Decreasing
PQIT	163	1.000	0.341	0.165	Increasing	1.000	2.934	0.485	Increasing
ACT	500	1.000	0.677	0.279	Increasing	1.000	1.478	0.413	Increasing

Appendix 16: Terminal Efficiency Estimates in the Year 2002 under Cross-Sectional DEA

Terminal	**Throughput** (1000s TEU)	**Input Orientation**				**Output Orientation**			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
CT3	1,105	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
T8E	1,526	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
MTL	3,610	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
HIT	6,600	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
SCT	3,049	1.000	0.808	0.614	Increasing	1.000	1.238	0.759	Increasing
SKCT	884	0.928	0.581	0.229	Increasing	1.425	1.721	0.393	Increasing
YICT	4,182	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
GCT	2,261	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
HBCT	1,535	0.896	0.633	0.530	Increasing	1.446	1.581	0.838	Increasing
PECT	1,548	0.788	0.615	0.640	Increasing	1.608	1.626	1.040	Decreasing
HGCT	506	1.000	0.568	0.217	Increasing	1.000	1.761	0.383	Increasing
UCT	502	1.000	0.551	0.215	Increasing	1.000	1.814	0.390	Increasing
ECTD	3,300	0.966	0.960	0.946	Increasing	1.040	1.041	0.985	Increasing
MDCT	1,306	0.757	0.598	0.537	Increasing	1.636	1.671	0.898	Increasing
YCT	607	0.878	0.426	0.433	Increasing	2.336	2.346	1.016	Decreasing
BCT	2,461	0.967	0.948	0.898	Increasing	1.042	1.055	0.947	Increasing
TTC	537	0.776	0.374	0.257	Increasing	2.323	2.675	0.688	Increasing
CTH	1,333	0.763	0.475	0.597	Increasing	2.102	2.105	1.257	Decreasing
JACT	3,200	0.759	0.636	0.660	Increasing	1.563	1.573	1.037	Decreasing
PRCT	1,000	0.912	0.602	0.522	Increasing	1.503	1.660	0.866	Increasing
LBPF	291	0.739	0.213	0.232	Increasing	4.445	4.689	1.086	Decreasing
LBPT	1,000	0.734	0.651	0.823	Increasing	1.519	1.536	1.264	Decreasing
NPCT	2,483	0.910	0.761	0.751	Increasing	1.296	1.314	0.987	Increasing
WPCT	2,050	0.771	0.488	0.519	Increasing	2.033	2.048	1.064	Decreasing
QQCT	2,950	0.979	0.633	0.521	Increasing	1.161	1.580	0.823	Increasing
PNTC	450	0.879	0.393	0.357	Increasing	2.442	2.546	0.908	Increasing
PTP	2,660	0.835	0.749	0.780	Increasing	1.331	1.335	1.041	Decreasing
TOCT	375	0.815	0.179	0.165	Increasing	5.397	5.601	0.923	Increasing
XNWT	381	1.000	0.427	0.120	Increasing	1.000	2.341	0.282	Increasing
NP	471	0.898	0.392	0.136	Increasing	1.823	2.553	0.347	Increasing

Appendix 16 (2002 Cross-Sectional: Continued)

Terminal	**Throughput** (1000s TEU)	**Input Orientation**				**Output Orientation**			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
TP	694	0.746	0.333	0.234	Increasing	2.756	3.005	0.704	Increasing
NCB	625	1.000	0.535	0.171	Increasing	1.000	1.869	0.320	Increasing
LCIT	724	1.000	0.788	0.328	Increasing	1.000	1.270	0.416	Increasing
LCB1	509	1.000	0.694	0.204	Increasing	1.000	1.440	0.294	Increasing
CTB	900	0.824	0.484	0.238	Increasing	1.740	2.066	0.493	Increasing
NSCT	1,487	0.930	0.842	0.390	Increasing	1.120	1.187	0.463	Increasing
AMCT	2,234	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
MCT	2,897	1.000	0.913	0.718	Increasing	1.000	1.095	0.786	Increasing
MICT	1,040	0.782	0.515	0.507	Increasing	1.942	1.943	0.985	Increasing
JSCT	822	0.736	0.320	0.262	Increasing	3.025	3.123	0.819	Increasing
JNCT	437	0.733	0.224	0.200	Increasing	4.341	4.469	0.894	Increasing
NSICT	1,140	1.000	0.837	0.587	Increasing	1.000	1.195	0.701	Increasing
SAGT	558	0.847	0.544	0.389	Increasing	1.598	1.837	0.715	Increasing
MPE	347	0.890	0.200	0.091	Increasing	3.288	4.991	0.456	Increasing
T37	505	1.000	0.637	0.406	Increasing	1.000	1.569	0.637	Increasing
TT	313	0.897	0.293	0.255	Increasing	3.110	3.409	0.870	Increasing
DCT	1,305	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
RSCT	523	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
TPCT	505	0.881	0.577	0.267	Increasing	1.335	1.733	0.462	Increasing
SPCT	1,211	0.761	0.544	0.451	Increasing	1.757	1.838	0.829	Increasing
ASCT	240	1.000	0.413	0.123	Increasing	1.000	2.420	0.299	Increasing
SACT	167	1.000	0.259	0.093	Increasing	1.000	3.861	0.361	Increasing
VCT	1,395	0.930	0.857	0.681	Increasing	1.115	1.167	0.794	Increasing
VT	876	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
LSCT	840	1.000	0.880	0.488	Increasing	1.000	1.136	0.554	Increasing
KCT	616	0.978	0.640	0.384	Increasing	1.102	1.564	0.600	Increasing
CCT	294	1.000	0.360	0.213	Increasing	1.000	2.780	0.593	Increasing
MIT	955	0.847	0.570	0.561	Increasing	1.747	1.754	0.984	Increasing
PQIT	226	1.000	0.373	0.133	Increasing	1.000	2.684	0.358	Increasing
ACT	510	1.000	0.667	0.221	Increasing	1.000	1.500	0.332	Increasing

Appendix 17: Terminal Efficiency Estimates in the Year 2003 under Cross-Sectional DEA

Terminal	**Throughput** (1000s TEU)	**Input Orientation**				**Output Orientation**			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
CT3	1,010	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
T8E	1,514	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
MTL	3,990	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
HIT	6,400	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
SCT	3,401	1.000	0.869	0.658	Increasing	1.000	1.151	0.758	Increasing
SKCT	1,323	0.974	0.953	0.861	Increasing	1.041	1.049	0.903	Increasing
YICT	5,258	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
GCT	2,546	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
HBCT	1,584	0.909	0.600	0.507	Increasing	1.398	1.666	0.845	Increasing
PECT	1,790	0.782	0.597	0.616	Increasing	1.672	1.675	1.032	Decreasing
HGCT	512	1.000	0.626	0.263	Increasing	1.000	1.597	0.419	Increasing
UCT	533	1.000	0.585	0.239	Increasing	1.000	1.710	0.410	Increasing
ECTD	3,300	0.876	0.858	0.875	Increasing	1.161	1.165	1.019	Decreasing
MDCT	1,514	0.793	0.674	0.764	Increasing	1.481	1.485	1.135	Decreasing
YCT	760	0.887	0.500	0.504	Increasing	1.996	1.999	1.007	Decreasing
BCT	2,374	0.903	0.840	0.824	Increasing	1.187	1.191	0.982	Increasing
TTC	638	0.782	0.387	0.303	Increasing	2.550	2.587	0.784	Increasing
CTH	2,050	0.834	0.672	0.370	Increasing	1.458	1.489	0.551	Increasing
JACT	4,100	0.827	0.768	0.796	Increasing	1.290	1.302	1.037	Decreasing
PRCT	1,156	0.922	0.678	0.605	Increasing	1.325	1.475	0.893	Increasing
LBPF	303	0.792	0.325	0.241	Increasing	2.673	3.078	0.743	Increasing
LBPT	1,170	0.718	0.580	0.636	Increasing	1.705	1.725	1.097	Decreasing
NPCT	2,540	0.908	0.755	0.660	Increasing	1.255	1.324	0.874	Increasing
WPCT	2,301	0.798	0.643	0.674	Increasing	1.548	1.554	1.047	Decreasing
QQCT	4,000	1.000	0.887	0.728	Increasing	1.000	1.128	0.821	Increasing
PNTC	505	0.880	0.344	0.306	Increasing	2.835	2.907	0.889	Increasing
PTP	3,490	0.910	0.860	0.851	Increasing	1.162	1.163	0.989	Increasing
TOCT	1,035	0.815	0.498	0.445	Increasing	1.891	2.007	0.894	Increasing
XNWT	561	1.000	0.653	0.208	Increasing	1.000	1.531	0.319	Increasing
NP	591	0.910	0.456	0.150	Increasing	1.497	2.195	0.330	Increasing

Appendix 17 (2003 Cross-Sectional: Continued)

Terminal	Throughput (1000s TEU)	Input Orientation				Output Orientation			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
TP	722	0.768	0.366	0.255	Increasing	2.654	2.730	0.695	Increasing
NCB	617	1.000	0.531	0.165	Increasing	1.000	1.884	0.311	Increasing
LCIT	876	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
LCB1	576	1.000	0.919	0.436	Increasing	1.000	1.088	0.475	Increasing
CTB	1,200	0.880	0.618	0.338	Increasing	1.424	1.619	0.548	Increasing
NSCT	1,602	0.897	0.713	0.321	Increasing	1.255	1.403	0.450	Increasing
AMCT	2,516	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
MCT	3,081	1.000	0.972	0.785	Increasing	1.000	1.029	0.807	Increasing
MICT	1,140	0.810	0.548	0.507	Increasing	1.806	1.825	0.926	Increasing
JSCT	885	0.712	0.303	0.212	Increasing	3.163	3.303	0.701	Increasing
JNCT	730	0.733	0.365	0.337	Increasing	2.711	2.740	0.923	Increasing
NSICT	1,231	1.000	0.941	0.651	Increasing	1.000	1.063	0.692	Increasing
SAGT	624	0.839	0.526	0.421	Increasing	1.822	1.902	0.800	Increasing
MPE	463	0.922	0.270	0.122	Increasing	2.481	3.703	0.451	Increasing
T37	569	1.000	0.592	0.296	Increasing	1.000	1.690	0.500	Increasing
TT	443	0.915	0.399	0.288	Increasing	1.959	2.509	0.723	Increasing
DCT	1,566	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
RSCT	578	1.000	0.989	0.110	Increasing	1.000	1.011	0.111	Increasing
TPCT	500	0.852	0.523	0.323	Increasing	1.452	1.910	0.616	Increasing
SPCT	2,000	0.907	0.841	0.616	Increasing	1.129	1.190	0.733	Increasing
ASCT	279	1.000	0.504	0.152	Increasing	1.000	1.986	0.303	Increasing
SACT	180	1.000	0.296	0.092	Increasing	1.000	3.381	0.312	Increasing
VCT	1,590	0.939	0.863	0.686	Increasing	1.097	1.159	0.795	Increasing
VT	868	0.902	0.670	0.477	Increasing	1.240	1.492	0.711	Increasing
LSCT	868	0.951	0.783	0.429	Increasing	1.088	1.278	0.548	Increasing
KCT	1,081	1.000	0.989	0.588	Increasing	1.000	1.011	0.595	Increasing
CCT	336	1.000	0.413	0.245	Increasing	1.000	2.422	0.593	Increasing
MIT	1,126	0.858	0.662	0.650	Increasing	1.493	1.511	0.983	Increasing
PQIT	334	1.000	0.537	0.182	Increasing	1.000	1.861	0.339	Increasing
ACT	541	1.000	0.813	0.533	Increasing	1.000	1.231	0.656	Increasing

Appendix 18: Terminal Efficiency Estimates in the Year 2004 under Cross-Sectional DEA

Terminal	Throughput (1000s TEU)	Input Orientation				Output Orientation			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
CT3	695	1.000	0.944	0.569	Increasing	1.000	1.059	0.603	Increasing
T8E	1,697	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
MTL	4,360	0.931	0.895	0.895	Increasing	1.118	1.118	1.000	Constant
HIT	7,452	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
SCT	3,650	1.000	0.813	0.698	Increasing	1.000	1.230	0.859	Increasing
SKCT	2,241	0.862	0.743	0.719	Increasing	1.325	1.346	0.967	Increasing
YICT	6,260	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
GCT	2,724	0.974	0.956	0.609	Increasing	1.028	1.046	0.637	Increasing
HBCT	1,826	0.962	0.637	0.327	Increasing	1.273	1.569	0.514	Increasing
PECT	1,963	0.809	0.646	0.651	Increasing	1.547	1.548	1.008	Decreasing
HGCT	548	1.000	0.629	0.271	Increasing	1.000	1.590	0.431	Increasing
UCT	550	1.000	0.630	0.368	Increasing	1.000	1.588	0.584	Increasing
ECTD	3,350	0.869	0.753	0.757	Increasing	1.325	1.328	1.006	Decreasing
MDCT	1,550	0.778	0.579	0.542	Increasing	1.719	1.728	0.937	Increasing
YCT	800	0.939	0.516	0.518	Increasing	1.936	1.936	1.004	Decreasing
BCT	2,560	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
TTC	850	0.825	0.522	0.257	Increasing	1.786	1.917	0.493	Increasing
CTH	2,270	0.854	0.715	0.816	Increasing	1.396	1.398	1.140	Decreasing
JACT	5,000	0.846	0.824	0.953	Increasing	1.204	1.213	1.156	Decreasing
PRCT	1,215	0.934	0.625	0.332	Increasing	1.412	1.600	0.531	Increasing
LBPF	330	0.794	0.346	0.112	Increasing	2.407	2.888	0.324	Increasing
LBPT	1,600	0.755	0.641	0.336	Increasing	1.474	1.560	0.524	Increasing
NPCT	2,688	0.971	0.747	0.629	Increasing	1.137	1.339	0.842	Increasing
WPCT	2,556	0.845	0.671	0.676	Increasing	1.489	1.490	1.007	Decreasing
QQCT	4,533	0.776	0.659	0.741	Increasing	1.508	1.517	1.124	Decreasing
PNTC	711	0.872	0.420	0.423	Increasing	2.382	2.384	1.007	Decreasing
PTP	4,020	0.939	0.900	0.848	Increasing	1.095	1.111	0.942	Increasing
TOCT	933	0.833	0.433	0.406	Increasing	2.275	2.312	0.939	Increasing
XNWT	603	1.000	0.494	0.142	Increasing	1.000	2.025	0.288	Increasing
NP	692	0.933	0.497	0.126	Increasing	1.540	2.014	0.254	Increasing

Appendix 18 (2004 Cross-Sectional: Continued)

Terminal	**Throughput** (1000s TEU)	**Input Orientation**				**Output Orientation**			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
TP	778	0.791	0.385	0.304	Increasing	2.525	2.598	0.791	Increasing
NCB	667	1.000	0.658	0.150	Increasing	1.000	1.520	0.228	Increasing
LCIT	1,037	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
LCB1	600	0.841	0.414	0.337	Increasing	2.309	2.418	0.816	Increasing
CTB	1,535	0.806	0.526	0.255	Increasing	1.726	1.899	0.484	Increasing
NSCT	1,858	0.994	0.869	0.368	Increasing	1.008	1.151	0.424	Increasing
AMCT	2,937	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
MCT	3,261	1.000	0.948	0.652	Increasing	1.000	1.055	0.688	Increasing
MICT	1,204	0.822	0.568	0.259	Increasing	1.700	1.762	0.457	Increasing
JSCT	1,028	0.724	0.345	0.154	Increasing	2.824	2.897	0.446	Increasing
JNCT	1,051	0.757	0.524	0.328	Increasing	1.860	1.909	0.626	Increasing
NSICT	1,214	0.997	0.933	0.736	Increasing	1.006	1.072	0.789	Increasing
SAGT	898	0.830	0.535	0.566	Increasing	1.855	1.869	1.058	Decreasing
MPE	631	0.934	0.348	0.246	Increasing	1.879	2.872	0.706	Increasing
T37	699	0.917	0.624	0.142	Increasing	1.312	1.602	0.228	Increasing
TT	567	0.901	0.373	0.218	Increasing	2.377	2.683	0.585	Increasing
DCT	1,687	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
RSCT	600	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
TPCT	600	0.838	0.561	0.127	Increasing	1.359	1.783	0.226	Increasing
SPCT	2,200	0.982	0.944	0.344	Increasing	1.020	1.059	0.365	Increasing
ASCT	245	1.000	0.460	0.157	Increasing	1.000	2.176	0.342	Increasing
SACT	193	1.000	0.314	0.070	Increasing	1.000	3.189	0.225	Increasing
VCT	1,533	0.912	0.800	0.622	Increasing	1.150	1.250	0.778	Increasing
VT	892	0.888	0.652	0.457	Increasing	1.285	1.534	0.700	Increasing
LSCT	889	0.886	0.640	0.362	Increasing	1.434	1.563	0.566	Increasing
KCT	1,243	1.000	0.939	0.570	Increasing	1.000	1.064	0.607	Increasing
CCT	422	0.821	0.313	0.260	Increasing	3.070	3.194	0.832	Increasing
MIT	1,460	0.888	0.770	0.466	Increasing	1.238	1.298	0.605	Increasing
PQIT	496	1.000	0.733	0.116	Increasing	1.000	1.365	0.159	Increasing
ACT	600	1.000	0.909	0.414	Increasing	1.000	1.100	0.455	Increasing

Appendix 19: Terminal Efficiency Estimates in the Year 2005 under Cross-Sectional DEA

Terminal	**Throughput** (1000s TEU)	**Input Orientation**				**Output Orientation**			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
CT3	211	1.000	0.328	0.110	Increasing	1.000	3.052	0.336	Increasing
T8E	1,841	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
MTL	5,040	0.974	0.962	0.962	Increasing	1.040	1.040	1.000	Constant
HIT	8,000	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
SCT	3,647	1.000	0.832	0.725	Increasing	1.000	1.202	0.871	Increasing
SKCT	2,664	0.768	0.549	0.563	Increasing	1.820	1.822	1.026	Decreasing
YICT	7,660	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
GCT	2,822	1.000	0.971	0.693	Increasing	1.000	1.029	0.713	Increasing
HBCT	2,127	0.854	0.737	0.711	Increasing	1.343	1.357	0.965	Increasing
PECT	2,009	0.816	0.717	0.636	Increasing	1.389	1.396	0.887	Increasing
HGCT	498	1.000	0.528	0.227	Increasing	1.000	1.896	0.431	Increasing
UCT	577	1.000	0.681	0.180	Increasing	1.000	1.468	0.264	Increasing
ECTD	3,350	0.843	0.656	0.663	Increasing	1.517	1.524	1.011	Decreasing
MDCT	1,570	0.784	0.565	0.587	Increasing	1.770	1.770	1.038	Decreasing
YCT	820	0.972	0.530	0.374	Increasing	1.249	1.888	0.706	Increasing
BCT	2,600	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
TTC	900	0.845	0.529	0.333	Increasing	1.570	1.890	0.630	Increasing
CTH	2,700	0.866	0.829	0.949	Increasing	1.200	1.206	1.145	Decreasing
JACT	6,390	0.854	0.728	0.799	Increasing	1.252	1.373	1.097	Decreasing
PRCT	1,300	0.938	0.696	0.611	Increasing	1.313	1.436	0.878	Increasing
LBPF	350	0.759	0.302	0.235	Increasing	3.156	3.316	0.778	Increasing
LBPT	1,850	0.869	0.860	0.751	Increasing	1.163	1.163	0.874	Increasing
NPCT	2,632	0.966	0.745	0.640	Increasing	1.205	1.343	0.859	Increasing
WPCT	2,992	0.840	0.718	0.695	Increasing	1.368	1.393	0.968	Increasing
QQCT	5,443	0.797	0.727	0.820	Increasing	1.363	1.376	1.129	Decreasing
PNTC	850	0.844	0.482	0.377	Increasing	2.039	2.075	0.783	Increasing
PTP	4,177	0.952	0.940	0.653	Increasing	1.063	1.064	0.695	Increasing
TOCT	1,095	0.838	0.504	0.399	Increasing	1.938	1.983	0.791	Increasing
XNWT	635	1.000	0.495	0.142	Increasing	1.000	2.020	0.288	Increasing
NP	769	0.937	0.533	0.133	Increasing	1.521	1.875	0.250	Increasing

Appendix 19 (2005 Cross-Sectional: Continued)

Terminal	Throughput (1000s TEU)	Input Orientation				Output Orientation			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
TP	816	0.792	0.405	0.151	Increasing	2.288	2.471	0.374	Increasing
NCB	715	1.000	0.666	0.152	Increasing	1.000	1.502	0.228	Increasing
LCIT	1,273	0.882	0.759	0.232	Increasing	1.189	1.317	0.305	Increasing
LCB1	591	0.839	0.429	0.176	Increasing	2.202	2.331	0.410	Increasing
CTB	1,820	0.816	0.585	0.284	Increasing	1.548	1.708	0.484	Increasing
NSCT	2,090	0.964	0.956	0.952	Increasing	1.045	1.046	0.996	Increasing
AMCT	3,180	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
MCT	3,118	0.777	0.713	0.688	Increasing	1.397	1.402	0.964	Increasing
MICT	1,213	0.820	0.560	0.519	Increasing	1.762	1.787	0.927	Increasing
JSCT	1,099	0.701	0.353	0.367	Increasing	2.814	2.836	1.042	Decreasing
JNCT	1,250	0.768	0.565	0.530	Increasing	1.713	1.769	0.937	Increasing
NSICT	1,311	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
SAGT	931	0.838	0.606	0.181	Increasing	1.552	1.649	0.299	Increasing
MPE	714	0.947	0.393	0.143	Increasing	1.708	2.543	0.364	Increasing
T37	720	0.922	0.708	0.316	Increasing	1.219	1.413	0.446	Increasing
TT	689	0.909	0.500	0.369	Increasing	1.921	2.000	0.739	Increasing
DCT	1,899	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
RSCT	616	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
TPCT	660	0.959	0.685	0.440	Increasing	1.094	1.460	0.642	Increasing
SPCT	2,500	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
ASCT	265	1.000	0.530	0.115	Increasing	1.000	1.885	0.217	Increasing
SACT	205	1.000	0.362	0.082	Increasing	1.000	2.759	0.225	Increasing
VCT	1,380	0.835	0.670	0.553	Increasing	1.364	1.492	0.824	Increasing
VT	859	0.883	0.568	0.398	Increasing	1.418	1.761	0.702	Increasing
LSCT	874	0.906	0.655	0.205	Increasing	1.318	1.527	0.314	Increasing
KCT	1,643	0.916	0.798	0.638	Increasing	1.167	1.254	0.800	Increasing
CCT	806	0.894	0.637	0.331	Increasing	1.390	1.569	0.519	Increasing
MIT	1,581	0.927	0.893	0.885	Increasing	1.118	1.120	0.992	Increasing
PQIT	544	1.000	0.683	0.386	Increasing	1.000	1.465	0.566	Increasing
ACT	616	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant

Appendix 20: Terminal Efficiency Estimates in the Year 2006 under Cross-Sectional DEA

Terminal	**Throughput** (1000s TEU)	**Input Orientation**				**Output Orientation**			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
CT3	418	1.000	0.627	0.159	Increasing	1.000	1.596	0.254	Increasing
T8E	1,689	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
MTL	5,430	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
HIT	8,235	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
SCT	3,703	0.998	0.820	0.747	Increasing	1.011	1.219	0.911	Increasing
SKCT	2,583	0.762	0.437	0.452	Increasing	2.287	2.289	1.034	Decreasing
YICT	8,865	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
GCT	2,559	0.945	0.813	0.577	Increasing	1.088	1.231	0.710	Increasing
HBCT	2,212	0.839	0.709	0.672	Increasing	1.394	1.410	0.947	Increasing
PECT	2,076	0.751	0.603	0.498	Increasing	1.659	1.660	0.826	Increasing
HGCT	504	1.000	0.568	0.245	Increasing	1.000	1.760	0.431	Increasing
UCT	548	1.000	0.637	0.205	Increasing	1.000	1.570	0.322	Increasing
ECTD	4,300	0.904	0.820	0.829	Increasing	1.214	1.219	1.011	Decreasing
MDCT	1,800	0.794	0.610	0.388	Increasing	1.555	1.640	0.636	Increasing
YCT	850	0.969	0.506	0.356	Increasing	1.340	1.974	0.702	Increasing
BCT	2,900	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
TTC	1,000	0.863	0.546	0.219	Increasing	1.419	1.832	0.402	Increasing
CTH	2,500	0.855	0.718	0.304	Increasing	1.389	1.394	0.423	Increasing
JACT	7,400	0.883	0.814	0.888	Increasing	1.131	1.229	1.091	Decreasing
PRCT	1,500	0.951	0.780	0.739	Increasing	1.213	1.282	0.947	Increasing
LBPF	400	0.754	0.331	0.244	Increasing	2.831	3.021	0.736	Increasing
LBPT	2,100	0.945	0.939	0.909	Increasing	1.065	1.065	0.968	Increasing
NPCT	2,680	0.953	0.720	0.618	Increasing	1.296	1.388	0.857	Increasing
WPCT	3,664	0.914	0.872	0.844	Increasing	1.134	1.147	0.968	Increasing
QQCT	6,770	0.874	0.872	0.983	Increasing	1.142	1.146	1.127	Decreasing
PNTC	900	0.852	0.471	0.309	Increasing	2.047	2.122	0.657	Increasing
PTP	4,770	0.974	0.939	0.907	Increasing	1.045	1.064	0.966	Increasing
TOCT	1,125	0.840	0.513	0.474	Increasing	1.941	1.948	0.923	Increasing
XNWT	736	1.000	0.512	0.084	Increasing	1.000	1.954	0.164	Increasing
NP	833	0.948	0.560	0.144	Increasing	1.284	1.787	0.257	Increasing

Appendix 20 (2006 Cross-Sectional: Continued)

Terminal	**Throughput** (1000s TEU)	**Input Orientation**				**Output Orientation**			
		BCC-I	CCR-I	SE	RTS	BCC-O	CCR-O	SE	RTS
TP	702	0.776	0.338	0.126	Increasing	2.690	2.959	0.374	Increasing
NCB	555	1.000	0.452	0.063	Increasing	1.000	2.211	0.139	Increasing
LCIT	1,281	0.876	0.745	0.228	Increasing	1.200	1.343	0.306	Increasing
LCB1	765	0.838	0.536	0.227	Increasing	1.754	1.867	0.424	Increasing
CTB	1,900	0.815	0.578	0.226	Increasing	1.520	1.731	0.392	Increasing
NSCT	2,216	0.947	0.918	0.811	Increasing	1.073	1.090	0.883	Increasing
AMCT	3,245	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
MCT	2,900	0.734	0.636	0.617	Increasing	1.562	1.573	0.970	Increasing
MICT	1,199	0.813	0.553	0.593	Increasing	1.794	1.807	1.071	Decreasing
JSCT	1,043	0.696	0.344	0.340	Increasing	2.900	2.909	0.988	Increasing
JNCT	1,500	0.820	0.689	0.614	Increasing	1.443	1.452	0.892	Increasing
NSICT	1,345	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
SAGT	1,335	0.921	0.836	0.250	Increasing	1.108	1.196	0.299	Increasing
MPE	800	0.951	0.425	0.155	Increasing	1.601	2.350	0.364	Increasing
T37	736	0.906	0.696	0.350	Increasing	1.270	1.436	0.502	Increasing
TT	737	0.899	0.505	0.299	Increasing	1.884	1.980	0.592	Increasing
DCT	2,199	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
RSCT	613	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant
TPCT	743	0.961	0.739	0.465	Increasing	1.074	1.353	0.630	Increasing
SPCT	2,400	0.987	0.849	0.590	Increasing	1.020	1.178	0.696	Increasing
ASCT	290	1.000	0.559	0.125	Increasing	1.000	1.789	0.223	Increasing
SACT	368	1.000	0.636	0.170	Increasing	1.000	1.574	0.267	Increasing
VCT	1,400	0.806	0.606	0.499	Increasing	1.512	1.649	0.823	Increasing
VT	925	0.878	0.566	0.402	Increasing	1.407	1.765	0.709	Increasing
LSCT	997	0.927	0.693	0.219	Increasing	1.235	1.443	0.315	Increasing
KCT	1,983	0.949	0.858	0.700	Increasing	1.085	1.165	0.815	Increasing
CCT	1,050	0.819	0.585	0.541	Increasing	1.665	1.710	0.924	Increasing
MIT	1,331	0.839	0.620	0.641	Increasing	1.609	1.613	1.034	Decreasing
PQIT	634	1.000	0.768	0.422	Increasing	1.000	1.301	0.549	Increasing
ACT	675	1.000	1.000	1.000	Constant	1.000	1.000	1.000	Constant

Appendix 21: Terminal Efficiency under Inter-Temporal DEA

Terminal-*year*	BCC-I	CCR-I	BCC-O	CCR-O
CT3-*2000*	1.000	1.000	1.000	1.000
CT3-*2001*	0.952	0.952	1.050	1.050
CT3-*2002*	0.940	0.940	1.063	1.063
CT3-*2003*	0.860	0.860	1.163	1.163
CT3-*2004*	0.591	0.591	1.691	1.691
CT3-*2005*	0.179	0.179	5.574	5.574
CT3-*2006*	0.355	0.355	2.814	2.814
T8E-*2000*	0.767	0.767	1.303	1.303
T8E-*2001*	0.707	0.707	1.414	1.414
T8E-*2002*	0.829	0.829	1.206	1.206
T8E-*2003*	0.822	0.822	1.216	1.216
T8E-*2004*	0.922	0.922	1.085	1.085
T8E-*2005*	1.000	1.000	1.000	1.000
T8E-*2006*	0.917	0.917	1.090	1.090
MTL-*2000*	0.869	0.851	1.150	1.175
MTL-*2001*	0.884	0.883	1.131	1.132
MTL-*2002*	0.905	0.905	1.105	1.105
MTL-*2003*	1.000	1.000	1.000	1.000
MTL-*2004*	0.814	0.814	1.228	1.228
MTL-*2005*	0.930	0.930	1.075	1.075
MTL-*2006*	1.000	1.000	1.000	1.000
HIT-*2000*	1.000	1.000	1.000	1.000
HIT-*2001*	0.939	0.939	1.065	1.065
HIT-*2002*	1.000	1.000	1.000	1.000
HIT-*2003*	0.970	0.959	1.031	1.043
HIT-*2004*	0.969	0.968	1.032	1.033
HIT-*2005*	0.971	0.971	1.029	1.029
HIT-*2006*	1.000	1.000	1.000	1.000
SCT-*2000*	1.000	0.744	1.000	1.345
SCT-*2001*	0.885	0.658	1.130	1.520
SCT-*2002*	0.871	0.680	1.148	1.471
SCT-*2003*	0.972	0.758	1.029	1.319
SCT-*2004*	0.836	0.784	1.196	1.276
SCT-*2005*	0.835	0.783	1.197	1.277
SCT-*2006*	0.848	0.795	1.179	1.257
SKCT-*2000*	0.523	0.465	1.913	2.148
SKCT-*2001*	0.545	0.485	1.836	2.061
SKCT-*2002*	0.612	0.561	1.634	1.783
SKCT-*2003*	0.813	0.777	1.230	1.287
SKCT-*2004*	0.647	0.642	1.546	1.557
SKCT-*2005*	0.516	0.510	1.940	1.959
SKCT-*2006*	0.432	0.429	2.313	2.330

Appendix 21 (Continued)

Terminal-*year*	BCC-I	CCR-I	BCC-O	CCR-O
YICT-*2000*	0.795	0.795	1.258	1.258
YICT-*2001*	1.000	1.000	1.000	1.000
YICT-*2002*	0.998	0.945	1.003	1.059
YICT-*2003*	1.000	1.000	1.000	1.000
YICT-*2004*	1.000	1.000	1.000	1.000
YICT-*2005*	0.926	0.926	1.080	1.080
YICT-*2006*	1.000	1.000	1.000	1.000
GCT-*2000*	0.992	0.763	1.008	1.311
GCT-*2001*	0.850	0.822	1.176	1.217
GCT-*2002*	1.000	0.966	1.000	1.035
GCT-*2003*	1.000	1.000	1.000	1.000
GCT-*2004*	0.965	0.908	1.036	1.102
GCT-*2005*	1.000	0.941	1.000	1.063
GCT-*2006*	0.907	0.787	1.103	1.270
HBCT-*2000*	0.636	0.532	1.573	1.879
HBCT-*2001*	0.564	0.472	1.772	2.118
HBCT-*2002*	0.681	0.569	1.469	1.756
HBCT-*2003*	0.703	0.588	1.423	1.701
HBCT-*2004*	0.793	0.613	1.261	1.631
HBCT-*2005*	0.817	0.714	1.224	1.400
HBCT-*2006*	0.850	0.683	1.176	1.465
PECT-*2000*	0.432	0.429	2.312	2.332
PECT-*2001*	0.445	0.441	2.250	2.269
PECT-*2002*	0.512	0.512	1.953	1.954
PECT-*2003*	0.546	0.545	1.831	1.834
PECT-*2004*	0.599	0.598	1.669	1.672
PECT-*2005*	0.613	0.612	1.632	1.635
PECT-*2006*	0.556	0.548	1.797	1.825
HGCT-*2000*	0.755	0.403	1.324	2.483
HGCT-*2001*	0.845	0.451	1.183	2.219
HGCT-*2002*	0.988	0.527	1.012	1.898
HGCT-*2003*	1.000	0.533	1.000	1.875
HGCT-*2004*	1.000	0.545	1.000	1.833
HGCT-*2005*	0.908	0.490	1.101	2.042
HGCT-*2006*	0.920	0.496	1.087	2.016
UCT-*2000*	0.622	0.313	1.609	3.196
UCT-*2001*	0.891	0.448	1.122	2.230
UCT-*2002*	1.000	0.503	1.000	1.987
UCT-*2003*	0.924	0.523	1.083	1.914
UCT-*2004*	0.952	0.539	1.050	1.856
UCT-*2005*	1.000	0.566	1.000	1.768
UCT-*2006*	0.949	0.537	1.054	1.862

Appendix 21 (Continued)

Terminal-*year*	BCC-I	CCR-I	BCC-O	CCR-O
ECTD-*2000*	0.455	0.435	2.200	2.301
ECTD-*2001*	1.000	0.956	1.000	1.046
ECTD-*2002*	1.000	0.956	1.000	1.046
ECTD-*2003*	1.000	0.910	1.000	1.099
ECTD-*2004*	0.882	0.824	1.134	1.214
ECTD-*2005*	0.801	0.759	1.248	1.318
ECTD-*2006*	1.000	0.974	1.000	1.027
MDCT-*2000*	0.265	0.184	3.774	5.426
MDCT-*2001*	0.274	0.191	3.649	5.246
MDCT-*2002*	0.856	0.596	1.168	1.679
MDCT-*2003*	0.954	0.629	1.048	1.590
MDCT-*2004*	0.861	0.629	1.161	1.589
MDCT-*2005*	0.872	0.638	1.146	1.568
MDCT-*2006*	1.000	0.731	1.000	1.368
YCT-*2000*	0.351	0.350	2.849	2.857
YCT-*2001*	0.386	0.385	2.590	2.597
YCT -*2002*	0.426	0.425	2.347	2.353
YCT -*2003*	0.534	0.532	1.874	1.880
YCT -*2004*	0.562	0.560	1.780	1.786
YCT -*2005*	0.576	0.574	1.737	1.742
YCT -*2006*	0.597	0.595	1.676	1.681
BCT-*2000*	0.894	0.894	1.119	1.119
BCT-*2001*	0.934	0.934	1.070	1.070
BCT-*2002*	1.000	1.000	1.000	1.000
BCT-*2003*	0.965	0.965	1.037	1.037
BCT-*2004*	0.883	0.883	1.133	1.133
BCT-*2005*	0.897	0.897	1.115	1.115
BCT-*2006*	1.000	1.000	1.000	1.000
TTC-*2000*	0.930	0.328	1.075	3.051
TTC-200*1*	0.955	0.336	1.048	2.974
TTC-*2002*	1.000	0.352	1.000	2.839
TTC-2003	0.638	0.379	1.569	2.641
TTC-*2004*	0.850	0.505	1.176	1.981
TTC-2005	0.900	0.535	1.111	1.871
TTC-*2006*	1.000	0.594	1.000	1.684
CTH-*2000*	1.000	0.530	1.000	1.888
CTH-*2001*	0.985	0.522	1.015	1.916
CTH-*2002*	0.494	0.389	2.026	2.573
CTH-*2003*	0.759	0.598	1.317	1.673
CTH-*2004*	0.841	0.662	1.189	1.511
CTH-*2005*	1.000	0.787	1.000	1.271
CTH-*2006*	0.926	0.718	1.080	1.394

Appendix 21 (Continued)

Terminal-*year*	BCC-I	CCR-I	BCC-O	CCR-O
JACT-*2000*	0.379	0.375	2.640	2.664
JACT-*2001*	0.428	0.424	2.335	2.357
JACT-*2002*	0.527	0.522	1.897	1.915
JACT-*2003*	0.675	0.669	1.481	1.495
JACT-*2004*	0.815	0.812	1.227	1.232
JACT-*2005*	0.764	0.707	1.309	1.413
JACT-*2006*	0.885	0.814	1.131	1.229
PRCT-*2000*	0.489	0.435	2.043	2.299
PRCT-*2001*	0.537	0.477	1.864	2.097
PRCT-*2002*	0.596	0.530	1.678	1.887
PRCT-*2003*	0.689	0.613	1.451	1.632
PRCT-*2004*	0.724	0.644	1.381	1.553
PRCT-*2005*	0.775	0.689	1.290	1.452
PRCT-*2006*	0.894	0.795	1.118	1.258
LBPF-*2000*	0.879	0.396	1.138	2.525
LBPF-*2001*	0.848	0.382	1.179	2.615
LBPF-*2002*	0.881	0.397	1.135	2.519
LBPF-*2003*	0.918	0.414	1.089	2.416
LBPF-*2004*	1.000	0.451	1.000	2.219
LBPF-*2005*	0.443	0.353	2.256	2.836
LBPF-*2006*	0.507	0.403	1.974	2.481
LBPT-*2000*	0.900	0.750	1.111	1.333
LBPT-*2001*	0.986	0.822	1.014	1.217
LBPT-*2002*	1.000	0.833	1.000	1.200
LBPT-*2003*	0.685	0.684	1.460	1.463
LBPT-*2004*	0.859	0.853	1.164	1.173
LBPT-*2005*	0.881	0.881	1.135	1.135
LBPT-*2006*	1.000	1.000	1.000	1.000
NPCT-*2000*	0.789	0.747	1.268	1.339
NPCT-*2001*	0.819	0.775	1.222	1.291
NPCT-*2002*	0.924	0.875	1.082	1.143
NPCT-*2003*	0.945	0.895	1.058	1.118
NPCT-*2004*	1.000	0.947	1.000	1.056
NPCT-*2005*	0.979	0.927	1.021	1.079
NPCT-*2006*	0.997	0.944	1.003	1.059
WPCT-*2000*	0.328	0.325	3.048	3.080
WPCT-*2001*	0.465	0.461	2.149	2.171
WPCT-*2002*	0.655	0.648	1.527	1.543
WPCT-*2003*	0.735	0.727	1.360	1.375
WPCT-*2004*	0.817	0.808	1.225	1.237
WPCT-*2005*	0.817	0.817	1.225	1.225
WPCT-*2006*	1.000	1.000	1.000	1.000

Appendix 21 (Continued)

Terminal-*year*	BCC-I	CCR-I	BCC-O	CCR-O
QQCT-*2000*	0.542	0.475	1.844	2.107
QQCT-*2001*	0.692	0.605	1.446	1.653
QQCT-*2002*	1.000	0.875	1.000	1.143
QQCT-*2003*	1.000	1.000	1.000	1.000
QQCT-*2004*	0.821	0.785	1.219	1.274
QQCT-*2005*	0.862	0.839	1.161	1.192
QQCT-*2006*	1.000	1.000	1.000	1.000
PNTC-*2000*	0.867	0.518	1.154	1.930
PNTC-*2001*	0.933	0.558	1.071	1.793
PNTC-*2002*	1.000	0.598	1.000	1.673
PNTC-*2003*	0.488	0.436	2.050	2.296
PNTC-*2004*	0.597	0.578	1.675	1.729
PNTC-*2005*	0.579	0.578	1.727	1.729
PNTC-*2006*	0.613	0.612	1.631	1.633
PTP-*2000*	0.479	0.479	2.087	2.087
PTP-*2001*	0.587	0.587	1.702	1.702
PTP-*2002*	0.762	0.762	1.312	1.312
PTP-*2003*	1.000	1.000	1.000	1.000
PTP-*2004*	0.962	0.962	1.039	1.039
PTP-*2005*	1.000	1.000	1.000	1.000
PTP-*2006*	1.000	1.000	1.000	1.000
TOCT-*2000*	0.162	0.151	6.167	6.629
TOCT-*2001*	0.176	0.164	5.675	6.099
TOCT-*2002*	0.230	0.216	4.355	4.632
TOCT-*2003*	0.634	0.596	1.578	1.678
TOCT-*2004*	0.513	0.499	1.950	2.005
TOCT-*2005*	0.602	0.585	1.662	1.709
TOCT-*2006*	0.618	0.601	1.617	1.663
XNWT-*2000*	0.921	0.348	1.086	2.877
XNWT-*2001*	1.000	0.378	1.000	2.649
XNWT-*2002*	0.679	0.499	1.473	2.005
XNWT-*2003*	1.000	0.735	1.000	1.361
XNWT-*2004*	0.819	0.479	1.221	2.088
XNWT-*2005*	0.863	0.504	1.159	1.983
XNWT-*2006*	1.000	0.585	1.000	1.711
NP-*2000*	0.305	0.179	3.279	5.580
NP -*2001*	0.569	0.334	1.757	2.991
NP-*2002*	0.796	0.468	1.256	2.137
NP-*2003*	1.000	0.588	1.000	1.702
NP-*2004*	0.948	0.639	1.054	1.564
NP-*2005*	0.923	0.711	1.084	1.407
NP-*2006*	1.000	0.770	1.000	1.298

Appendix 21 (Continued)

Terminal-*year*	BCC-I	CCR-I	BCC-O	CCR-O
TP-*2000*	0.394	0.393	2.535	2.546
TP-*2001*	0.467	0.465	2.142	2.151
TP-*2002*	0.439	0.437	2.277	2.286
TP-*2003*	0.457	0.455	2.189	2.199
TP-*2004*	0.492	0.490	2.031	2.040
TP-*2005*	0.516	0.514	1.937	1.946
TP-*2006*	0.444	0.442	2.251	2.261
NCB-*2000*	0.926	0.754	1.080	1.326
NCB-*2001*	0.926	0.754	1.080	1.326
NCB-*2002*	0.874	0.712	1.144	1.405
NCB-*2003*	0.863	0.703	1.159	1.423
NCB-*2004*	0.932	0.759	1.072	1.317
NCB-*2005*	1.000	0.814	1.000	1.228
NCB-*2006*	0.777	0.633	1.287	1.581
LCIT-*2000*	0.386	0.386	2.588	2.588
LCIT-*2001*	0.510	0.510	1.959	1.959
LCIT-*2002*	0.699	0.699	1.431	1.431
LCIT-*2003*	0.845	0.845	1.184	1.184
LCIT-*2004*	1.000	1.000	1.000	1.000
LCIT-*2005*	0.828	0.805	1.207	1.243
LCIT-*2006*	0.833	0.809	1.200	1.235
LCB1-*2000*	0.764	0.735	1.310	1.360
LCB1-*2001*	0.832	0.801	1.202	1.248
LCB1-*2002*	0.883	0.851	1.132	1.176
LCB1-*2003*	1.000	0.963	1.000	1.038
LCB1-*2004*	0.474	0.468	2.109	2.135
LCB1-*2005*	0.455	0.451	2.198	2.217
LCB1-*2006*	0.589	0.584	1.697	1.712
CTB-*2000*	0.632	0.525	1.582	1.905
CTB-*2001*	0.845	0.702	1.184	1.425
CTB-*2002*	0.607	0.542	1.648	1.844
CTB-*2003*	0.809	0.723	1.236	1.383
CTB-*2004*	0.661	0.647	1.513	1.545
CTB-*2005*	0.784	0.767	1.276	1.304
CTB-*2006*	0.818	0.801	1.222	1.249
NSCT-*2000*	0.724	0.663	1.381	1.508
NSCT-*2001*	0.832	0.762	1.203	1.313
NSCT-*2002*	1.000	0.916	1.000	1.092
NSCT-*2003*	0.862	0.862	1.160	1.160
NSCT-*2004*	1.000	1.000	1.000	1.000
NSCT-*2005*	1.000	1.000	1.000	1.000
NSCT-*2006*	1.000	1.000	1.000	1.000

Appendix 21 (Continued)

Terminal-*year*	BCC-I	CCR-I	BCC-O	CCR-O
AMCT-*2000*	1.000	0.974	1.000	1.027
AMCT-*2001*	0.855	0.855	1.169	1.169
AMCT-*2002*	0.888	0.888	1.126	1.126
AMCT-*2003*	1.000	1.000	1.000	1.000
AMCT-*2004*	0.917	0.917	1.091	1.091
AMCT-*2005*	0.992	0.992	1.008	1.008
AMCT-*2006*	1.000	1.000	1.000	1.000
MCT-*2000*	1.000	1.000	1.000	1.000
MCT-*2001*	0.938	0.938	1.066	1.066
MCT-*2002*	0.940	0.940	1.063	1.063
MCT-*2003*	1.000	1.000	1.000	1.000
MCT-*2004*	1.000	1.000	1.000	1.000
MCT-*2005*	0.864	0.831	1.157	1.204
MCT-*2006*	0.804	0.773	1.244	1.294
MICT-*2000*	0.523	0.521	1.912	1.918
MICT-*2001*	0.507	0.505	1.973	1.980
MICT-*2002*	0.568	0.566	1.761	1.767
MICT-*2003*	0.623	0.620	1.606	1.612
MICT-*2004*	0.657	0.655	1.521	1.526
MICT-*2005*	0.662	0.660	1.510	1.515
MICT-*2006*	0.655	0.652	1.527	1.533
JSCT-*2000*	0.359	0.352	2.786	2.838
JSCT-*2001*	0.355	0.348	2.819	2.872
JSCT-*2002*	0.332	0.326	3.012	3.068
JSCT-*2003*	0.345	0.343	2.898	2.920
JSCT-*2004*	0.401	0.398	2.494	2.512
JSCT-*2005*	0.429	0.426	2.333	2.350
JSCT-*2006*	0.407	0.404	2.458	2.477
JNCT-*2000*	0.069	0.068	14.470	14.609
JNCT-*2001*	0.082	0.081	12.245	12.363
JNCT-*2002*	0.241	0.239	4.144	4.184
JNCT-*2003*	0.404	0.400	2.478	2.501
JNCT-*2004*	0.581	0.575	1.722	1.738
JNCT-*2005*	0.620	0.618	1.614	1.619
JNCT-*2006*	0.743	0.741	1.345	1.349
NSICT-*2000*	0.543	0.483	1.841	2.071
NSICT-*2001*	0.779	0.692	1.284	1.444
NSICT-*2002*	1.000	0.889	1.000	1.125
NSICT-*2003*	0.916	0.916	1.092	1.092
NSICT-*2004*	0.903	0.903	1.107	1.107
NSICT-*2005*	0.975	0.975	1.025	1.025
NSICT-*2006*	1.000	1.000	1.000	1.000

Appendix 21 (Continued)

Terminal-*year*	BCC-I	CCR-I	BCC-O	CCR-O
SAGT-*2000*	0.912	0.507	1.097	1.973
SAGT-*2001*	1.000	0.556	1.000	1.799
SAGT-*2002*	0.887	0.791	1.128	1.264
SAGT-*2003*	0.728	0.687	1.374	1.456
SAGT-*2004*	0.673	0.673	1.487	1.487
SAGT-*2005*	0.698	0.698	1.434	1.434
SAGT-*2006*	1.000	1.000	1.000	1.000
MPE-*2000*	0.276	0.213	3.628	4.701
MPE-*2001*	0.330	0.254	3.033	3.930
MPE-*2002*	0.383	0.296	2.611	3.383
MPE-*2003*	0.511	0.394	1.958	2.537
MPE-*2004*	0.696	0.537	1.438	1.863
MPE-*2005*	0.787	0.607	1.271	1.646
MPE-*2006*	0.882	0.681	1.134	1.469
T37-*2000*	0.789	0.446	1.267	2.240
T37-*2001*	0.947	0.536	1.056	1.866
T37-*2002*	1.000	0.566	1.000	1.768
T37-*2003*	1.000	0.598	1.000	1.673
T37-*2004*	0.760	0.671	1.315	1.490
T37-*2005*	0.783	0.691	1.277	1.446
T37-*2006*	0.801	0.707	1.249	1.414
TT-*2000*	0.348	0.275	2.871	3.637
TT-*2001*	0.398	0.314	2.511	3.181
TT-*2002*	0.498	0.393	2.007	2.542
TT-*2003*	0.564	0.524	1.774	1.909
TT-*2004*	0.469	0.457	2.131	2.190
TT-*2005*	0.570	0.555	1.755	1.803
TT-*2006*	0.609	0.593	1.642	1.687
DCT-*2000*	0.977	0.774	1.024	1.292
DCT-*2001*	0.930	0.736	1.076	1.358
DCT-*2002*	0.987	0.782	1.013	1.278
DCT-*2003*	0.928	0.928	1.077	1.077
DCT-*2004*	1.000	1.000	1.000	1.000
DCT-*2005*	1.000	1.000	1.000	1.000
DCT-*2006*	1.000	1.000	1.000	1.000
RSCT-*2000*	0.950	0.950	1.053	1.053
RSCT-*2001*	1.000	1.000	1.000	1.000
RSCT-*2002*	1.000	0.955	1.000	1.048
RSCT-*2003*	1.000	1.000	1.000	1.000
RSCT-*2004*	0.974	0.974	1.027	1.027
RSCT-*2005*	1.000	1.000	1.000	1.000
RSCT-*2006*	0.995	0.995	1.005	1.005

Appendix 21 (Continued)

Terminal-*year*	BCC-I	CCR-I	BCC-O	CCR-O
TPCT-*2000*	0.725	0.585	1.379	1.709
TPCT-*2001*	0.731	0.590	1.368	1.696
TPCT-*2002*	0.733	0.591	1.365	1.692
TPCT-*2003*	0.645	0.508	1.550	1.969
TPCT-*2004*	0.774	0.610	1.292	1.641
TPCT-*2005*	0.851	0.670	1.175	1.491
TPCT-*2006*	0.958	0.755	1.044	1.325
SPCT-*2000*	0.400	0.400	2.500	2.500
SPCT-*2001*	0.475	0.475	2.106	2.106
SPCT-*2002*	0.484	0.484	2.064	2.064
SPCT-*2003*	0.800	0.800	1.250	1.250
SPCT-*2004*	0.880	0.880	1.136	1.136
SPCT-*2005*	1.000	1.000	1.000	1.000
SPCT-*2006*	0.960	0.960	1.042	1.042
ASCT-*2000*	0.423	0.269	2.363	3.716
ASCT-*2001*	0.440	0.280	2.275	3.578
ASCT-*2002*	0.827	0.526	1.210	1.903
ASCT-*2003*	0.962	0.611	1.040	1.635
ASCT-*2004*	0.845	0.537	1.184	1.862
ASCT-*2005*	0.914	0.581	1.094	1.721
ASCT-*2006*	1.000	0.636	1.000	1.573
SACT-*2000*	0.683	0.224	1.463	4.471
SACT-*2001*	0.778	0.255	1.286	3.928
SACT-*2002*	0.928	0.304	1.078	3.293
SACT-*2003*	1.000	0.327	1.000	3.055
SACT-*2004*	0.525	0.349	1.906	2.867
SACT-*2005*	0.557	0.371	1.794	2.699
SACT-*2006*	1.000	0.665	1.000	1.504
VCT-*2000*	0.684	0.648	1.462	1.543
VCT-*2001*	0.692	0.656	1.445	1.524
VCT-*2002*	0.831	0.788	1.204	1.269
VCT-*2003*	0.947	0.898	1.056	1.114
VCT-*2004*	0.913	0.866	1.095	1.155
VCT-*2005*	0.822	0.779	1.217	1.283
VCT-*2006*	0.834	0.791	1.199	1.265
VT-*2000*	0.850	0.850	1.177	1.177
VT-*2001*	0.935	0.935	1.070	1.070
VT-*2002*	1.000	1.000	1.000	1.000
VT-*2003*	0.666	0.537	1.502	1.861
VT-*2004*	0.684	0.552	1.463	1.812
VT-*2005*	0.652	0.532	1.534	1.881
VT-*2006*	0.702	0.573	1.424	1.746

Appendix 21 (Continued)

Terminal-*year*	BCC-I	CCR-I	BCC-O	CCR-O
LSCT-*2000*	1.000	1.000	1.000	1.000
LSCT-*2001*	1.000	0.901	1.000	1.110
LSCT-*2002*	0.999	0.900	1.001	1.111
LSCT-*2003*	1.000	0.915	1.000	1.093
LSCT-*2004*	0.912	0.896	1.096	1.117
LSCT-*2005*	0.896	0.880	1.116	1.137
LSCT-*2006*	1.000	1.000	1.000	1.000
KCT-*2000*	1.000	0.411	1.000	2.431
KCT-*2001*	0.748	0.500	1.337	1.999
KCT-*2002*	0.680	0.483	1.470	2.072
KCT-*2003*	1.000	0.827	1.000	1.210
KCT-*2004*	0.877	0.819	1.140	1.221
KCT-*2005*	0.859	0.853	1.164	1.172
KCT-*2006*	1.000	1.000	1.000	1.000
CCT-*2000*	1.000	0.233	1.000	4.292
CCT-*2001*	0.611	0.271	1.637	3.696
CCT-*2002*	0.873	0.387	1.145	2.587
CCT-*2003*	1.000	0.443	1.000	2.258
CCT-*2004*	0.477	0.341	2.096	2.932
CCT-*2005*	0.911	0.651	1.098	1.535
CCT-*2006*	0.663	0.619	1.507	1.616
MIT-*2000*	0.727	0.724	1.375	1.382
MIT-*2001*	0.687	0.684	1.456	1.463
MIT-*2002*	0.683	0.680	1.463	1.471
MIT-*2003*	0.711	0.705	1.407	1.418
MIT-*2004*	0.822	0.817	1.217	1.224
MIT-*2005*	0.890	0.885	1.124	1.130
MIT-*2006*	0.720	0.616	1.389	1.623
PQIT-*2000*	1.000	0.429	1.000	2.331
PQIT-*2001*	0.859	0.302	1.164	3.313
PQIT-*2002*	1.000	0.350	1.000	2.861
PQIT-*2003*	0.672	0.515	1.487	1.941
PQIT-*2004*	1.000	0.766	1.000	1.305
PQIT-*2005*	0.859	0.682	1.164	1.466
PQIT-*2006*	1.000	0.794	1.000	1.259
ACT-*2000*	1.000	0.909	1.000	1.100
ACT-*2001*	0.926	0.842	1.080	1.187
ACT-*2002*	0.756	0.756	1.324	1.324
ACT-*2003*	0.801	0.801	1.248	1.248
ACT-*2004*	0.889	0.889	1.125	1.125
ACT-*2005*	0.913	0.913	1.096	1.096
ACT-*2006*	1.000	1.000	1.000	1.000

Appendix 22: DEA-CCR-I Panel Data Estimates including Yard Storage Policy

Terminal-*year*	BCC-I	CCR-I	SE	RTS
CT3-*2000*	1.000	1.000	1.000	Constant
CT3-*2001*	1.000	0.952	0.952	Increasing
CT3-*2002*	1.000	0.940	0.940	Increasing
CT3-*2003*	1.000	0.860	0.860	Increasing
CT3-*2004*	1.000	0.591	0.591	Increasing
CT3-*2005*	1.000	0.179	0.179	Increasing
CT3-*2006*	1.000	0.355	0.355	Increasing
T8E-*2000*	1.000	0.767	0.767	Increasing
T8E-*2001*	1.000	0.707	0.707	Increasing
T8E-*2002*	1.000	0.829	0.829	Increasing
T8E-*2003*	1.000	0.822	0.822	Increasing
T8E-*2004*	1.000	0.922	0.922	Increasing
T8E-*2005*	1.000	1.000	1.000	Constant
T8E-*2006*	1.000	0.917	0.917	Increasing
MTL-*2000*	0.983	0.851	0.727	Increasing
MTL-*2001*	0.986	0.883	0.865	Increasing
MTL-*2002*	0.988	0.905	0.905	Increasing
MTL-*2003*	1.000	1.000	1.000	Constant
MTL-*2004*	0.970	0.814	0.814	Increasing
MTL-*2005*	0.985	0.930	0.930	Increasing
MTL-*2006*	1.000	1.000	1.000	Constant
HIT-*2000*	1.000	1.000	1.000	Constant
HIT-*2001*	0.997	0.939	0.939	Increasing
HIT-*2002*	1.000	1.000	1.000	Constant
HIT-*2003*	0.998	0.959	0.783	Increasing
HIT-*2004*	0.990	0.968	0.938	Increasing
HIT-*2005*	0.997	0.971	0.971	Increasing
HIT-*2006*	1.000	1.000	1.000	Constant
SCT-*2000*	1.000	0.744	0.478	Increasing
SCT-*2001*	1.000	0.658	0.423	Increasing
SCT-*2002*	0.972	0.680	0.491	Increasing
SCT-*2003*	0.992	0.758	0.548	Increasing
SCT-*2004*	0.938	0.784	0.554	Increasing
SCT-*2005*	0.938	0.783	0.553	Increasing
SCT-*2006*	0.941	0.795	0.562	Increasing
SKCT-*2000*	1.000	0.604	0.123	Increasing
SKCT-*2001*	1.000	0.630	0.128	Increasing
SKCT-*2002*	1.000	0.736	0.236	Increasing
SKCT-*2003*	1.000	1.000	1.000	Constant
SKCT-*2004*	1.000	0.716	0.258	Increasing
SKCT-*2005*	1.000	0.692	0.552	Increasing
SKCT-*2006*	1.000	0.579	0.434	Increasing

Appendix 22 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
YICT-*2000*	1.000	0.795	0.795	Increasing
YICT-*2001*	1.000	1.000	1.000	Constant
YICT-*2002*	1.000	1.000	1.000	Constant
YICT-*2003*	1.000	1.000	1.000	Constant
YICT-*2004*	1.000	1.000	1.000	Constant
YICT-*2005*	1.000	1.000	1.000	Constant
YICT-*2006*	1.000	1.000	1.000	Constant
GCT-*2000*	0.997	0.763	0.438	Increasing
GCT-*2001*	0.964	0.822	0.546	Increasing
GCT-*2002*	1.000	0.966	0.642	Increasing
GCT-*2003*	1.000	1.000	1.000	Constant
GCT-*2004*	0.983	0.908	0.672	Increasing
GCT-*2005*	1.000	0.941	0.696	Increasing
GCT-*2006*	0.954	0.787	0.472	Increasing
HBCT-*2000*	0.917	0.532	0.330	Increasing
HBCT-*2001*	0.903	0.472	0.292	Increasing
HBCT-*2002*	0.926	0.569	0.353	Increasing
HBCT-*2003*	0.930	0.588	0.364	Increasing
HBCT-*2004*	0.950	0.613	0.379	Increasing
HBCT-*2005*	0.933	0.714	0.442	Increasing
HBCT-*2006*	0.942	0.683	0.498	Increasing
PECT-*2000*	0.782	0.429	0.422	Increasing
PECT-*2001*	0.782	0.441	0.433	Increasing
PECT-*2002*	0.750	0.512	0.540	Increasing
PECT-*2003*	0.754	0.545	0.593	Increasing
PECT-*2004*	0.768	0.598	0.650	Increasing
PECT-*2005*	0.772	0.612	0.665	Increasing
PECT-*2006*	0.734	0.548	0.636	Increasing
HGCT-*2000*	1.000	0.403	0.186	Increasing
HGCT-*2001*	1.000	0.451	0.208	Increasing
HGCT-*2002*	1.000	0.527	0.243	Increasing
HGCT-*2003*	1.000	0.533	0.246	Increasing
HGCT-*2004*	1.000	0.545	0.285	Increasing
HGCT-*2005*	1.000	0.490	0.265	Increasing
HGCT-*2006*	1.000	0.496	0.268	Increasing
UCT-*2000*	1.000	0.313	0.093	Increasing
UCT-*2001*	1.000	0.448	0.134	Increasing
UCT-*2002*	1.000	0.503	0.150	Increasing
UCT-*2003*	1.000	0.523	0.186	Increasing
UCT-*2004*	1.000	0.539	0.191	Increasing
UCT-*2005*	1.000	0.566	0.201	Increasing
UCT-*2006*	1.000	0.537	0.191	Increasing

Appendix 22 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
ECTD-*2000*	0.958	0.435	0.178	Increasing
ECTD-*2001*	1.000	0.956	0.392	Increasing
ECTD-*2002*	1.000	0.956	0.392	Increasing
ECTD-*2003*	1.000	0.910	0.574	Increasing
ECTD-*2004*	0.990	0.824	0.625	Increasing
ECTD-*2005*	0.980	0.759	0.580	Increasing
ECTD-*2006*	1.000	0.974	0.745	Increasing
MDCT-*2000*	1.000	0.184	0.095	Increasing
MDCT-*2001*	1.000	0.191	0.098	Increasing
MDCT-*2002*	1.000	0.596	0.306	Increasing
MDCT-*2003*	1.000	0.629	0.231	Increasing
MDCT-*2004*	1.000	0.629	0.276	Increasing
MDCT-*2005*	1.000	0.638	0.280	Increasing
MDCT-*2006*	1.000	0.731	0.321	Increasing
YCT-*2000*	0.890	0.350	0.348	Increasing
YCT-*2001*	0.890	0.385	0.383	Increasing
YCT -*2002*	0.890	0.425	0.422	Increasing
YCT -*2003*	0.890	0.532	0.529	Increasing
YCT -*2004*	0.890	0.560	0.557	Increasing
YCT -*2005*	0.890	0.574	0.570	Increasing
YCT -*2006*	0.890	0.595	0.591	Increasing
BCT-*2000*	0.990	0.894	0.894	Increasing
BCT-*2001*	0.994	0.934	0.934	Increasing
BCT-*2002*	1.000	1.000	1.000	Constant
BCT-*2003*	0.997	0.965	0.965	Increasing
BCT-*2004*	0.984	0.883	0.883	Increasing
BCT-*2005*	0.986	0.897	0.897	Increasing
BCT-*2006*	1.000	1.000	1.000	Constant
TTC-*2000*	1.000	0.328	0.176	Increasing
TTC-200*1*	1.000	0.336	0.181	Increasing
TTC-*2002*	1.000	0.352	0.189	Increasing
TTC-2003	1.000	0.379	0.228	Increasing
TTC-*2004*	1.000	0.505	0.304	Increasing
TTC-2005	1.000	0.535	0.322	Increasing
TTC-*2006*	1.000	0.594	0.357	Increasing
CTH-*2000*	1.000	0.530	0.282	Increasing
CTH-*2001*	1.000	0.522	0.278	Increasing
CTH-*2002*	1.000	0.389	0.179	Increasing
CTH-*2003*	1.000	0.598	0.275	Increasing
CTH-*2004*	1.000	0.662	0.305	Increasing
CTH-*2005*	1.000	0.787	0.362	Increasing
CTH-*2006*	1.000	0.718	0.304	Increasing

Appendix 22 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
JACT-*2000*	0.837	0.375	0.361	Increasing
JACT-*2001*	0.843	0.424	0.409	Increasing
JACT-*2002*	0.860	0.522	0.503	Increasing
JACT-*2003*	0.884	0.669	0.644	Increasing
JACT-*2004*	0.873	0.815	0.804	Increasing
JACT-*2005*	0.902	0.745	0.789	Increasing
JACT-*2006*	0.927	0.863	0.913	Increasing
PRCT-*2000*	1.000	0.435	0.152	Increasing
PRCT-*2001*	1.000	0.477	0.167	Increasing
PRCT-*2002*	1.000	0.530	0.185	Increasing
PRCT-*2003*	1.000	0.613	0.214	Increasing
PRCT-*2004*	1.000	0.644	0.225	Increasing
PRCT-*2005*	1.000	0.689	0.241	Increasing
PRCT-*2006*	1.000	0.795	0.278	Increasing
LBPF-*2000*	1.000	0.400	0.159	Increasing
LBPF-*2001*	1.000	0.387	0.154	Increasing
LBPF-*2002*	1.000	0.401	0.160	Increasing
LBPF-*2003*	1.000	0.418	0.166	Increasing
LBPF-*2004*	1.000	0.456	0.181	Increasing
LBPF-*2005*	1.000	0.388	0.232	Increasing
LBPF-*2006*	1.000	0.443	0.265	Increasing
LBPT-*2000*	0.971	0.750	0.429	Increasing
LBPT-*2001*	0.996	0.822	0.470	Increasing
LBPT-*2002*	1.000	0.833	0.476	Increasing
LBPT-*2003*	0.881	0.694	0.658	Increasing
LBPT-*2004*	0.931	0.868	0.812	Increasing
LBPT-*2005*	0.958	0.881	0.881	Increasing
LBPT-*2006*	1.000	1.000	1.000	Constant
NPCT-*2000*	0.953	0.747	0.607	Increasing
NPCT-*2001*	0.959	0.775	0.630	Increasing
NPCT-*2002*	0.983	0.875	0.711	Increasing
NPCT-*2003*	0.988	0.895	0.728	Increasing
NPCT-*2004*	1.000	0.947	0.770	Increasing
NPCT-*2005*	0.995	0.927	0.754	Increasing
NPCT-*2006*	0.999	0.944	0.767	Increasing
WPCT-*2000*	0.803	0.325	0.301	Increasing
WPCT-*2001*	0.827	0.461	0.427	Increasing
WPCT-*2002*	0.875	0.649	0.601	Increasing
WPCT-*2003*	0.899	0.729	0.674	Increasing
WPCT-*2004*	0.922	0.810	0.749	Increasing
WPCT-*2005*	0.946	0.817	0.817	Increasing
WPCT-*2006*	1.000	1.000	1.000	Constant

Appendix 22 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
QQCT-*2000*	1.000	0.475	0.444	Increasing
QQCT-*2001*	1.000	0.605	0.566	Increasing
QQCT-*2002*	1.000	0.875	0.819	Increasing
QQCT-*2003*	1.000	1.000	1.000	Constant
QQCT-*2004*	0.890	0.799	0.848	Increasing
QQCT-*2005*	0.933	0.848	0.868	Increasing
QQCT-*2006*	1.000	1.000	1.000	Constant
PNTC-*2000*	1.000	0.525	0.337	Increasing
PNTC-*2001*	1.000	0.565	0.363	Increasing
PNTC-*2002*	1.000	0.606	0.389	Increasing
PNTC-*2003*	0.924	0.447	0.378	Increasing
PNTC-*2004*	0.954	0.616	0.465	Increasing
PNTC-*2005*	0.929	0.612	0.451	Increasing
PNTC-*2006*	0.948	0.648	0.478	Increasing
PTP-*2000*	0.856	0.479	0.479	Increasing
PTP-*2001*	0.881	0.587	0.587	Increasing
PTP-*2002*	0.929	0.762	0.762	Increasing
PTP-*2003*	1.000	1.000	1.000	Constant
PTP-*2004*	0.990	0.962	0.962	Increasing
PTP-*2005*	1.000	1.000	1.000	Constant
PTP-*2006*	1.000	1.000	1.000	Constant
TOCT-*2000*	1.000	0.163	0.107	Increasing
TOCT-*2001*	1.000	0.177	0.117	Increasing
TOCT-*2002*	1.000	0.233	0.153	Increasing
TOCT-*2003*	1.000	0.642	0.423	Increasing
TOCT-*2004*	1.000	0.540	0.340	Increasing
TOCT-*2005*	1.000	0.633	0.399	Increasing
TOCT-*2006*	1.000	0.651	0.410	Increasing
XNWT-*2000*	1.000	0.348	0.172	Increasing
XNWT-*2001*	1.000	0.378	0.186	Increasing
XNWT-*2002*	1.000	0.499	0.246	Increasing
XNWT-*2003*	1.000	0.735	0.363	Increasing
XNWT-*2004*	1.000	0.479	0.280	Increasing
XNWT-*2005*	1.000	0.504	0.295	Increasing
XNWT-*2006*	1.000	0.585	0.342	Increasing
NP-*2000*	1.000	0.179	0.093	Increasing
NP -*2001*	1.000	0.334	0.173	Increasing
NP-*2002*	1.000	0.468	0.242	Increasing
NP-*2003*	1.000	0.588	0.304	Increasing
NP-*2004*	1.000	0.639	0.376	Increasing
NP-*2005*	1.000	0.711	0.418	Increasing
NP-*2006*	1.000	0.770	0.453	Increasing

Appendix 22 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
TP-*2000*	0.813	0.410	0.291	Increasing
TP-*2001*	0.814	0.485	0.344	Increasing
TP-*2002*	0.813	0.456	0.324	Increasing
TP-*2003*	0.813	0.475	0.337	Increasing
TP-*2004*	0.816	0.511	0.363	Increasing
TP-*2005*	0.819	0.536	0.380	Increasing
TP-*2006*	0.813	0.462	0.327	Increasing
NCB-*2000*	1.000	0.754	0.409	Increasing
NCB-*2001*	1.000	0.754	0.409	Increasing
NCB-*2002*	1.000	0.712	0.386	Increasing
NCB-*2003*	1.000	0.703	0.381	Increasing
NCB-*2004*	1.000	0.759	0.411	Increasing
NCB-*2005*	1.000	0.814	0.441	Increasing
NCB-*2006*	1.000	0.633	0.343	Increasing
LCIT-*2000*	1.000	0.386	0.386	Increasing
LCIT-*2001*	1.000	0.510	0.510	Increasing
LCIT-*2002*	1.000	0.699	0.699	Increasing
LCIT-*2003*	1.000	0.845	0.845	Increasing
LCIT-*2004*	1.000	1.000	1.000	Constant
LCIT-*2005*	0.884	0.828	0.829	Increasing
LCIT-*2006*	0.887	0.833	0.834	Increasing
LCB1-*2000*	1.000	0.735	0.424	Increasing
LCB1-*2001*	1.000	0.801	0.462	Increasing
LCB1-*2002*	1.000	0.851	0.491	Increasing
LCB1-*2003*	1.000	0.963	0.556	Increasing
LCB1-*2004*	0.878	0.468	0.463	Increasing
LCB1-*2005*	0.876	0.451	0.445	Increasing
LCB1-*2006*	0.904	0.584	0.577	Increasing
CTB-*2000*	1.000	0.541	0.340	Increasing
CTB-*2001*	1.000	0.722	0.454	Increasing
CTB-*2002*	1.000	0.592	0.366	Increasing
CTB-*2003*	1.000	0.789	0.488	Increasing
CTB-*2004*	1.000	0.766	0.597	Increasing
CTB-*2005*	1.000	0.908	0.708	Increasing
CTB-*2006*	1.000	0.948	0.739	Increasing
NSCT-*2000*	1.000	0.663	0.510	Increasing
NSCT-*2001*	1.000	0.762	0.586	Increasing
NSCT-*2002*	1.000	0.916	0.704	Increasing
NSCT-*2003*	1.000	0.862	0.862	Increasing
NSCT-*2004*	1.000	1.000	1.000	Constant
NSCT-*2005*	1.000	1.000	1.000	Constant
NSCT-*2006*	1.000	1.000	1.000	Constant

Appendix 22 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
AMCT-*2000*	1.000	0.974	0.799	Increasing
AMCT-*2001*	0.966	0.855	0.855	Increasing
AMCT-*2002*	0.974	0.888	0.888	Increasing
AMCT-*2003*	1.000	1.000	1.000	Constant
AMCT-*2004*	0.972	0.917	0.917	Increasing
AMCT-*2005*	0.997	0.992	0.992	Increasing
AMCT-*2006*	1.000	1.000	1.000	Constant
MCT-*2000*	1.000	1.000	1.000	Constant
MCT-*2001*	0.994	0.938	0.938	Increasing
MCT-*2002*	0.985	0.940	0.940	Increasing
MCT-*2003*	1.000	1.000	1.000	Constant
MCT-*2004*	1.000	1.000	1.000	Constant
MCT-*2005*	0.889	0.842	0.892	Increasing
MCT-*2006*	0.861	0.783	0.829	Increasing
MICT-*2000*	0.886	0.570	0.409	Increasing
MICT-*2001*	0.882	0.552	0.396	Increasing
MICT-*2002*	0.897	0.619	0.444	Increasing
MICT-*2003*	0.911	0.678	0.487	Increasing
MICT-*2004*	0.921	0.716	0.514	Increasing
MICT-*2005*	0.922	0.722	0.518	Increasing
MICT-*2006*	0.920	0.713	0.512	Increasing
JSCT-*2000*	0.820	0.352	0.338	Increasing
JSCT-*2001*	0.820	0.348	0.334	Increasing
JSCT-*2002*	0.820	0.326	0.312	Increasing
JSCT-*2003*	0.767	0.343	0.373	Increasing
JSCT-*2004*	0.767	0.398	0.434	Increasing
JSCT-*2005*	0.769	0.426	0.464	Increasing
JSCT-*2006*	0.767	0.404	0.440	Increasing
JNCT-*2000*	0.820	0.069	0.074	Increasing
JNCT-*2001*	0.820	0.081	0.088	Increasing
JNCT-*2002*	0.820	0.240	0.260	Increasing
JNCT-*2003*	0.820	0.401	0.435	Increasing
JNCT-*2004*	0.820	0.577	0.626	Increasing
JNCT-*2005*	0.833	0.618	0.646	Increasing
JNCT-*2006*	0.861	0.741	0.775	Increasing
NSICT-*2000*	1.000	0.483	0.427	Increasing
NSICT-*2001*	1.000	0.692	0.612	Increasing
NSICT-*2002*	1.000	0.889	0.786	Increasing
NSICT-*2003*	0.976	0.916	0.916	Increasing
NSICT-*2004*	0.973	0.903	0.903	Increasing
NSICT-*2005*	0.993	0.975	0.975	Increasing
NSICT-*2006*	1.000	1.000	1.000	Constant

Appendix 22 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
SAGT-*2000*	1.000	0.507	0.231	Increasing
SAGT-*2001*	1.000	0.556	0.253	Increasing
SAGT-*2002*	0.984	0.791	0.334	Increasing
SAGT-*2003*	0.951	0.687	0.585	Increasing
SAGT-*2004*	0.882	0.673	0.673	Increasing
SAGT-*2005*	0.891	0.698	0.698	Increasing
SAGT-*2006*	1.000	1.000	1.000	Constant
MPE-*2000*	0.878	0.213	0.137	Increasing
MPE-*2001*	0.878	0.254	0.164	Increasing
MPE-*2002*	0.887	0.296	0.190	Increasing
MPE-*2003*	0.910	0.394	0.254	Increasing
MPE-*2004*	0.944	0.537	0.346	Increasing
MPE-*2005*	0.961	0.607	0.391	Increasing
MPE-*2006*	0.978	0.681	0.439	Increasing
T37-*2000*	0.988	0.446	0.260	Increasing
T37-*2001*	0.997	0.536	0.312	Increasing
T37-*2002*	1.000	0.566	0.329	Increasing
T37-*2003*	1.000	0.598	0.313	Increasing
T37-*2004*	0.919	0.671	0.309	Increasing
T37-*2005*	0.927	0.691	0.318	Increasing
T37-*2006*	0.933	0.707	0.325	Increasing
TT-*2000*	0.967	0.275	0.092	Increasing
TT-*2001*	0.967	0.314	0.106	Increasing
TT-*2002*	0.967	0.393	0.132	Increasing
TT-*2003*	0.972	0.524	0.185	Increasing
TT-*2004*	0.880	0.457	0.237	Increasing
TT-*2005*	0.912	0.555	0.288	Increasing
TT-*2006*	0.926	0.593	0.307	Increasing
DCT-*2000*	0.997	0.774	0.744	Increasing
DCT-*2001*	0.991	0.736	0.708	Increasing
DCT-*2002*	0.998	0.782	0.752	Increasing
DCT-*2003*	0.989	0.928	0.928	Increasing
DCT-*2004*	1.000	1.000	1.000	Constant
DCT-*2005*	1.000	1.000	1.000	Constant
DCT-*2006*	1.000	1.000	1.000	Constant
RSCT-*2000*	1.000	0.950	0.950	Increasing
RSCT-*2001*	1.000	1.000	1.000	Constant
RSCT-*2002*	1.000	0.955	0.872	Increasing
RSCT-*2003*	1.000	1.000	1.000	Constant
RSCT-*2004*	1.000	0.974	0.974	Increasing
RSCT-*2005*	1.000	1.000	1.000	Constant
RSCT-*2006*	1.000	0.995	0.995	Increasing

Appendix 22 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
TPCT-*2000*	0.968	0.585	0.220	Increasing
TPCT-*2001*	0.968	0.590	0.222	Increasing
TPCT-*2002*	0.968	0.591	0.222	Increasing
TPCT-*2003*	0.968	0.508	0.213	Increasing
TPCT-*2004*	0.968	0.610	0.255	Increasing
TPCT-*2005*	0.977	0.670	0.281	Increasing
TPCT-*2006*	1.000	0.755	0.316	Increasing
SPCT-*2000*	0.785	0.400	0.400	Increasing
SPCT-*2001*	0.812	0.475	0.475	Increasing
SPCT-*2002*	0.815	0.484	0.484	Increasing
SPCT-*2003*	0.928	0.800	0.800	Increasing
SPCT-*2004*	0.957	0.880	0.880	Increasing
SPCT-*2005*	1.000	1.000	1.000	Constant
SPCT-*2006*	0.986	0.960	0.960	Increasing
ASCT-*2000*	1.000	0.269	0.068	Increasing
ASCT-*2001*	1.000	0.280	0.071	Increasing
ASCT-*2002*	1.000	0.526	0.133	Increasing
ASCT-*2003*	1.000	0.611	0.155	Increasing
ASCT-*2004*	1.000	0.537	0.136	Increasing
ASCT-*2005*	1.000	0.581	0.147	Increasing
ASCT-*2006*	1.000	0.636	0.161	Increasing
SACT-*2000*	1.000	0.224	0.055	Increasing
SACT-*2001*	1.000	0.255	0.063	Increasing
SACT-*2002*	1.000	0.304	0.075	Increasing
SACT-*2003*	1.000	0.327	0.081	Increasing
SACT-*2004*	1.000	0.349	0.084	Increasing
SACT-*2005*	1.000	0.371	0.090	Increasing
SACT-*2006*	1.000	0.665	0.161	Increasing
VCT-*2000*	0.832	0.648	0.592	Increasing
VCT-*2001*	0.836	0.656	0.599	Increasing
VCT-*2002*	0.907	0.788	0.720	Increasing
VCT-*2003*	0.968	0.898	0.820	Increasing
VCT-*2004*	0.949	0.866	0.791	Increasing
VCT-*2005*	0.902	0.779	0.712	Increasing
VCT-*2006*	0.909	0.791	0.722	Increasing
VT-*2000*	0.948	0.850	0.850	Increasing
VT-*2001*	0.977	0.935	0.935	Increasing
VT-*2002*	1.000	1.000	1.000	Constant
VT-*2003*	0.875	0.537	0.390	Increasing
VT-*2004*	0.879	0.552	0.400	Increasing
VT-*2005*	0.871	0.532	0.385	Increasing
VT-*2006*	0.882	0.573	0.415	Increasing

Appendix 22 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
LSCT-*2000*	1.000	1.000	1.000	Constant
LSCT-*2001*	1.000	0.901	0.468	Increasing
LSCT-*2002*	1.000	0.900	0.468	Increasing
LSCT-*2003*	1.000	0.915	0.596	Increasing
LSCT-*2004*	0.966	0.896	0.821	Increasing
LSCT-*2005*	0.961	0.880	0.806	Increasing
LSCT-*2006*	1.000	1.000	1.000	Constant
KCT-*2000*	1.000	0.411	0.181	Increasing
KCT-*2001*	0.935	0.500	0.293	Increasing
KCT-*2002*	0.940	0.483	0.277	Increasing
KCT-*2003*	1.000	0.827	0.487	Increasing
KCT-*2004*	0.927	0.819	0.583	Increasing
KCT-*2005*	0.936	0.853	0.822	Increasing
KCT-*2006*	1.000	1.000	1.000	Constant
CCT-*2000*	1.000	0.233	0.079	Increasing
CCT-*2001*	1.000	0.271	0.092	Increasing
CCT-*2002*	1.000	0.387	0.131	Increasing
CCT-*2003*	1.000	0.443	0.150	Increasing
CCT-*2004*	0.831	0.341	0.169	Increasing
CCT-*2005*	0.965	0.651	0.322	Increasing
CCT-*2006*	0.853	0.619	0.427	Increasing
MIT-*2000*	0.877	0.724	0.469	Increasing
MIT-*2001*	0.865	0.684	0.443	Increasing
MIT-*2002*	0.864	0.680	0.440	Increasing
MIT-*2003*	0.900	0.705	0.507	Increasing
MIT-*2004*	0.922	0.817	0.760	Increasing
MIT-*2005*	0.946	0.885	0.823	Increasing
MIT-*2006*	0.896	0.616	0.549	Increasing
PQIT-*2000*	1.000	0.429	0.096	Increasing
PQIT-*2001*	1.000	0.302	0.113	Increasing
PQIT-*2002*	1.000	0.350	0.099	Increasing
PQIT-*2003*	1.000	0.515	0.145	Increasing
PQIT-*2004*	1.000	0.766	0.216	Increasing
PQIT-*2005*	1.000	0.682	0.291	Increasing
PQIT-*2006*	1.000	0.794	0.339	Increasing
ACT-*2000*	1.000	0.909	0.572	Increasing
ACT-*2001*	1.000	0.842	0.530	Increasing
ACT-*2002*	1.000	0.756	0.756	Increasing
ACT-*2003*	1.000	0.801	0.801	Increasing
ACT-*2004*	1.000	0.889	0.889	Increasing
ACT-*2005*	1.000	0.913	0.913	Increasing
ACT-*2006*	1.000	1.000	1.000	Constant

Appendix 23: DEA-CCR-I Panel Data Estimates including Gate Closing Policy

Terminal-*year*	BCC-I	CCR-I	SE	RTS
CT3-*2000*	1.000	1.000	1.000	Constant
CT3-*2001*	1.000	0.952	0.952	Increasing
CT3-*2002*	1.000	0.940	0.940	Increasing
CT3-*2003*	1.000	0.860	0.860	Increasing
CT3-*2004*	1.000	0.692	0.463	Increasing
CT3-*2005*	1.000	0.210	0.140	Increasing
CT3-*2006*	1.000	0.416	0.278	Increasing
T8E-*2000*	1.000	0.767	0.767	Increasing
T8E-*2001*	1.000	0.707	0.707	Increasing
T8E-*2002*	1.000	0.829	0.829	Increasing
T8E-*2003*	1.000	0.822	0.822	Increasing
T8E-*2004*	1.000	0.922	0.922	Increasing
T8E-*2005*	1.000	1.000	1.000	Constant
T8E-*2006*	1.000	0.917	0.917	Increasing
MTL-*2000*	0.949	0.851	0.727	Increasing
MTL-*2001*	0.952	0.883	0.865	Increasing
MTL-*2002*	0.949	0.905	0.905	Increasing
MTL-*2003*	1.000	1.000	1.000	Constant
MTL-*2004*	0.888	0.814	0.814	Increasing
MTL-*2005*	0.963	0.931	0.924	Increasing
MTL-*2006*	1.000	1.000	1.000	Constant
HIT-*2000*	1.000	1.000	1.000	Constant
HIT-*2001*	0.985	0.939	0.939	Increasing
HIT-*2002*	1.000	1.000	1.000	Constant
HIT-*2003*	0.992	0.959	0.783	Increasing
HIT-*2004*	0.975	0.968	0.938	Increasing
HIT-*2005*	0.991	0.971	0.971	Increasing
HIT-*2006*	1.000	1.000	1.000	Constant
SCT-*2000*	1.000	0.744	0.478	Increasing
SCT-*2001*	1.000	0.658	0.423	Increasing
SCT-*2002*	0.965	0.680	0.491	Increasing
SCT-*2003*	0.992	0.758	0.548	Increasing
SCT-*2004*	0.933	0.784	0.554	Increasing
SCT-*2005*	0.933	0.783	0.553	Increasing
SCT-*2006*	0.938	0.795	0.562	Increasing
SKCT-*2000*	0.982	0.465	0.364	Increasing
SKCT-*2001*	0.982	0.485	0.379	Increasing
SKCT-*2002*	0.911	0.561	0.228	Increasing
SKCT-*2003*	0.893	0.777	0.500	Increasing
SKCT-*2004*	0.803	0.642	0.681	Increasing
SKCT-*2005*	0.726	0.510	0.575	Increasing
SKCT-*2006*	0.720	0.429	0.473	Increasing

Appendix 23 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
YICT-*2000*	1.000	0.795	0.795	Increasing
YICT-*2001*	1.000	1.000	1.000	Constant
YICT-*2002*	0.999	0.945	0.790	Increasing
YICT-*2003*	1.000	1.000	1.000	Constant
YICT-*2004*	1.000	1.000	1.000	Constant
YICT-*2005*	0.945	0.926	0.888	Increasing
YICT-*2006*	1.000	1.000	1.000	Constant
GCT-*2000*	0.997	0.763	0.438	Increasing
GCT-*2001*	0.964	0.822	0.546	Increasing
GCT-*2002*	1.000	0.966	0.642	Increasing
GCT-*2003*	1.000	1.000	1.000	Constant
GCT-*2004*	0.983	0.908	0.672	Increasing
GCT-*2005*	1.000	0.941	0.696	Increasing
GCT-*2006*	0.954	0.787	0.472	Increasing
HBCT-*2000*	0.917	0.532	0.330	Increasing
HBCT-*2001*	0.903	0.472	0.292	Increasing
HBCT-*2002*	0.926	0.569	0.353	Increasing
HBCT-*2003*	0.930	0.588	0.364	Increasing
HBCT-*2004*	0.950	0.613	0.379	Increasing
HBCT-*2005*	0.933	0.714	0.442	Increasing
HBCT-*2006*	0.942	0.683	0.498	Increasing
PECT-*2000*	0.792	0.431	0.313	Increasing
PECT-*2001*	0.794	0.444	0.322	Increasing
PECT-*2002*	0.766	0.516	0.374	Increasing
PECT-*2003*	0.774	0.548	0.482	Increasing
PECT-*2004*	0.787	0.601	0.529	Increasing
PECT-*2005*	0.791	0.615	0.541	Increasing
PECT-*2006*	0.743	0.548	0.636	Increasing
HGCT-*2000*	1.000	0.403	0.186	Increasing
HGCT-*2001*	1.000	0.451	0.208	Increasing
HGCT-*2002*	1.000	0.527	0.243	Increasing
HGCT-*2003*	1.000	0.533	0.246	Increasing
HGCT-*2004*	1.000	0.545	0.285	Increasing
HGCT-*2005*	1.000	0.490	0.265	Increasing
HGCT-*2006*	1.000	0.496	0.268	Increasing
UCT-*2000*	1.000	0.313	0.093	Increasing
UCT-*2001*	1.000	0.448	0.134	Increasing
UCT-*2002*	1.000	0.503	0.150	Increasing
UCT-*2003*	1.000	0.523	0.186	Increasing
UCT-*2004*	1.000	0.539	0.191	Increasing
UCT-*2005*	1.000	0.566	0.201	Increasing
UCT-*2006*	1.000	0.537	0.191	Increasing

Appendix 23 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
ECTD-*2000*	0.833	0.435	0.178	Increasing
ECTD-*2001*	1.000	0.956	0.392	Increasing
ECTD-*2002*	1.000	0.956	0.392	Increasing
ECTD-*2003*	1.000	0.910	0.574	Increasing
ECTD-*2004*	0.960	0.824	0.625	Increasing
ECTD-*2005*	0.919	0.759	0.580	Increasing
ECTD-*2006*	1.000	0.974	0.745	Increasing
MDCT-*2000*	0.979	0.184	0.095	Increasing
MDCT-*2001*	0.979	0.191	0.098	Increasing
MDCT-*2002*	0.988	0.596	0.306	Increasing
MDCT-*2003*	0.993	0.629	0.231	Increasing
MDCT-*2004*	0.994	0.629	0.276	Increasing
MDCT-*2005*	0.994	0.638	0.280	Increasing
MDCT-*2006*	1.000	0.731	0.321	Increasing
YCT-*2000*	0.773	0.400	0.348	Increasing
YCT-*2001*	0.795	0.400	0.383	Increasing
YCT -*2002*	0.833	0.500	0.422	Increasing
YCT -*2003*	0.855	0.532	0.529	Increasing
YCT -*2004*	0.919	0.655	0.557	Increasing
YCT -*2005*	0.971	0.878	0.570	Increasing
YCT -*2006*	1.000	1.000	0.591	Increasing
BCT-*2000*	0.996	0.894	0.894	Increasing
BCT-*2001*	0.997	0.934	0.934	Increasing
BCT-*2002*	1.000	1.000	1.000	Constant
BCT-*2003*	0.999	0.965	0.965	Increasing
BCT-*2004*	0.992	0.883	0.883	Increasing
BCT-*2005*	0.993	0.897	0.897	Increasing
BCT-*2006*	1.000	1.000	1.000	Constant
TTC-*2000*	1.000	0.328	0.176	Increasing
TTC-200*1*	1.000	0.336	0.181	Increasing
TTC-*2002*	1.000	0.352	0.189	Increasing
TTC-2003	1.000	0.379	0.228	Increasing
TTC-*2004*	1.000	0.505	0.304	Increasing
TTC-2005	1.000	0.535	0.322	Increasing
TTC-*2006*	1.000	0.594	0.357	Increasing
CTH-*2000*	1.000	0.530	0.282	Increasing
CTH-*2001*	1.000	0.522	0.278	Increasing
CTH-*2002*	1.000	0.389	0.179	Increasing
CTH-*2003*	1.000	0.598	0.275	Increasing
CTH-*2004*	1.000	0.662	0.305	Increasing
CTH-*2005*	1.000	0.787	0.362	Increasing
CTH-*2006*	1.000	0.718	0.304	Increasing

Appendix 23 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
JACT-*2000*	0.788	0.385	0.309	Increasing
JACT-*2001*	0.799	0.435	0.350	Increasing
JACT-*2002*	0.821	0.536	0.430	Increasing
JACT-*2003*	0.855	0.686	0.551	Increasing
JACT-*2004*	0.868	0.837	0.672	Increasing
JACT-*2005*	0.833	0.707	0.776	Increasing
JACT-*2006*	0.867	0.814	0.888	Increasing
PRCT-*2000*	0.887	0.435	0.152	Increasing
PRCT-*2001*	0.887	0.477	0.167	Increasing
PRCT-*2002*	0.887	0.530	0.185	Increasing
PRCT-*2003*	0.895	0.613	0.214	Increasing
PRCT-*2004*	0.899	0.644	0.225	Increasing
PRCT-*2005*	0.916	0.689	0.241	Increasing
PRCT-*2006*	0.957	0.795	0.278	Increasing
LBPF-*2000*	0.821	0.355	0.165	Increasing
LBPF-*2001*	0.843	0.365	0.159	Increasing
LBPF-*2002*	0.846	0.322	0.165	Decreasing
LBPF-*2003*	0.843	0.414	0.172	Increasing
LBPF-*2004*	0.882	0.521	0.187	Increasing
LBPF-*2005*	0.900	0.663	0.243	Increasing
LBPF-*2006*	1.000	0.690	0.278	Increasing
LBPT-*2000*	0.983	0.750	0.429	Increasing
LBPT-*2001*	0.893	0.710	0.470	Decreasing
LBPT-*2002*	0.813	0.639	0.476	Decreasing
LBPT-*2003*	0.942	0.864	0.637	Increasing
LBPT-*2004*	0.956	0.881	0.811	Increasing
LBPT-*2005*	0.998	0.922	0.881	Increasing
LBPT-*2006*	1.000	1.000	1.000	Constant
NPCT-*2000*	0.949	0.747	0.609	Increasing
NPCT-*2001*	0.957	0.775	0.632	Increasing
NPCT-*2002*	0.982	0.875	0.713	Increasing
NPCT-*2003*	0.987	0.895	0.729	Increasing
NPCT-*2004*	1.000	0.947	0.772	Increasing
NPCT-*2005*	0.995	0.927	0.756	Increasing
NPCT-*2006*	0.999	0.944	0.769	Increasing
WPCT-*2000*	0.800	0.325	0.319	Increasing
WPCT-*2001*	0.800	0.461	0.453	Increasing
WPCT-*2002*	0.847	0.648	0.638	Increasing
WPCT-*2003*	0.875	0.727	0.716	Increasing
WPCT-*2004*	0.904	0.808	0.795	Increasing
WPCT-*2005*	0.936	0.817	0.817	Increasing
WPCT-*2006*	1.000	1.000	1.000	Constant

Appendix 23 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
QQCT-*2000*	1.000	0.475	0.444	Increasing
QQCT-*2001*	1.000	0.605	0.566	Increasing
QQCT-*2002*	1.000	0.875	0.819	Increasing
QQCT-*2003*	1.000	1.000	1.000	Constant
QQCT-*2004*	0.832	0.785	0.865	Increasing
QQCT-*2005*	0.883	0.839	0.872	Increasing
QQCT-*2006*	1.000	1.000	1.000	Constant
PNTC-*2000*	1.000	0.518	0.336	Increasing
PNTC-*2001*	1.000	0.558	0.362	Increasing
PNTC-*2002*	1.000	0.598	0.388	Increasing
PNTC-*2003*	0.924	0.436	0.421	Increasing
PNTC-*2004*	0.919	0.578	0.565	Increasing
PNTC-*2005*	0.869	0.578	0.584	Increasing
PNTC-*2006*	0.878	0.612	0.619	Increasing
PTP-*2000*	0.855	0.479	0.479	Increasing
PTP-*2001*	0.880	0.587	0.587	Increasing
PTP-*2002*	0.925	0.762	0.762	Increasing
PTP-*2003*	1.000	1.000	1.000	Constant
PTP-*2004*	0.990	0.962	0.962	Increasing
PTP-*2005*	1.000	1.000	1.000	Constant
PTP-*2006*	1.000	1.000	1.000	Constant
TOCT-*2000*	0.928	0.155	0.107	Increasing
TOCT-*2001*	0.928	0.169	0.117	Increasing
TOCT-*2002*	0.928	0.226	0.156	Increasing
TOCT-*2003*	0.962	0.623	0.431	Increasing
TOCT-*2004*	0.943	0.538	0.373	Increasing
TOCT-*2005*	0.960	0.631	0.438	Increasing
TOCT-*2006*	0.967	0.648	0.450	Increasing
XNWT-*2000*	1.000	0.348	0.172	Increasing
XNWT-*2001*	1.000	0.378	0.186	Increasing
XNWT-*2002*	1.000	0.499	0.246	Increasing
XNWT-*2003*	1.000	0.735	0.363	Increasing
XNWT-*2004*	1.000	0.479	0.280	Increasing
XNWT-*2005*	1.000	0.504	0.295	Increasing
XNWT-*2006*	1.000	0.585	0.342	Increasing
NP-*2000*	1.000	0.179	0.093	Increasing
NP -*2001*	1.000	0.334	0.173	Increasing
NP-*2002*	1.000	0.468	0.242	Increasing
NP-*2003*	1.000	0.588	0.304	Increasing
NP-*2004*	1.000	0.639	0.376	Increasing
NP-*2005*	1.000	0.711	0.418	Increasing
NP-*2006*	1.000	0.770	0.453	Increasing

Appendix 23 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
TP-*2000*	0.805	0.393	0.410	Increasing
TP-*2001*	0.805	0.465	0.486	Increasing
TP-*2002*	0.805	0.437	0.457	Increasing
TP-*2003*	0.805	0.455	0.475	Increasing
TP-*2004*	0.805	0.490	0.512	Increasing
TP-*2005*	0.806	0.514	0.537	Increasing
TP-*2006*	0.805	0.442	0.462	Increasing
NCB-*2000*	1.000	0.754	0.409	Increasing
NCB-*2001*	1.000	0.754	0.409	Increasing
NCB-*2002*	1.000	0.712	0.386	Increasing
NCB-*2003*	1.000	0.703	0.381	Increasing
NCB-*2004*	1.000	0.759	0.411	Increasing
NCB-*2005*	1.000	0.814	0.441	Increasing
NCB-*2006*	1.000	0.633	0.343	Increasing
LCIT-*2000*	1.000	0.386	0.386	Increasing
LCIT-*2001*	1.000	0.510	0.510	Increasing
LCIT-*2002*	1.000	0.699	0.699	Increasing
LCIT-*2003*	1.000	0.845	0.845	Increasing
LCIT-*2004*	1.000	1.000	1.000	Constant
LCIT-*2005*	0.871	0.821	0.851	Increasing
LCIT-*2006*	0.874	0.826	0.856	Increasing
LCB1-*2000*	1.000	0.735	0.424	Increasing
LCB1-*2001*	1.000	0.801	0.462	Increasing
LCB1-*2002*	1.000	0.851	0.491	Increasing
LCB1-*2003*	1.000	0.963	0.556	Increasing
LCB1-*2004*	0.880	0.493	0.365	Increasing
LCB1-*2005*	0.871	0.480	0.362	Increasing
LCB1-*2006*	0.915	0.622	0.469	Increasing
CTB-*2000*	0.912	0.525	0.368	Increasing
CTB-*2001*	0.922	0.702	0.492	Increasing
CTB-*2002*	0.847	0.542	0.424	Increasing
CTB-*2003*	0.902	0.723	0.565	Increasing
CTB-*2004*	0.849	0.647	0.677	Increasing
CTB-*2005*	0.954	0.823	0.745	Increasing
CTB-*2006*	0.973	0.859	0.778	Increasing
NSCT-*2000*	1.000	0.663	0.510	Increasing
NSCT-*2001*	1.000	0.762	0.586	Increasing
NSCT-*2002*	1.000	0.916	0.704	Increasing
NSCT-*2003*	1.000	0.862	0.862	Increasing
NSCT-*2004*	1.000	1.000	1.000	Constant
NSCT-*2005*	1.000	1.000	1.000	Constant
NSCT-*2006*	1.000	1.000	1.000	Constant

Appendix 23 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
AMCT-*2000*	1.000	0.974	0.799	Increasing
AMCT-*2001*	1.000	0.855	0.855	Increasing
AMCT-*2002*	1.000	0.888	0.888	Increasing
AMCT-*2003*	1.000	1.000	1.000	Constant
AMCT-*2004*	1.000	0.917	0.917	Increasing
AMCT-*2005*	1.000	0.992	0.992	Increasing
AMCT-*2006*	1.000	1.000	1.000	Constant
MCT-*2000*	1.000	1.000	1.000	Constant
MCT-*2001*	0.993	0.938	0.938	Increasing
MCT-*2002*	0.984	0.940	0.940	Increasing
MCT-*2003*	1.000	1.000	1.000	Constant
MCT-*2004*	1.000	1.000	1.000	Constant
MCT-*2005*	0.912	0.904	0.863	Increasing
MCT-*2006*	0.875	0.841	0.803	Increasing
MICT-*2000*	1.000	0.647	0.272	Increasing
MICT-*2001*	1.000	0.627	0.264	Increasing
MICT-*2002*	1.000	0.703	0.295	Increasing
MICT-*2003*	1.000	0.770	0.324	Increasing
MICT-*2004*	1.000	0.813	0.342	Increasing
MICT-*2005*	1.000	0.820	0.345	Increasing
MICT-*2006*	1.000	0.810	0.340	Increasing
JSCT-*2000*	0.834	0.352	0.338	Increasing
JSCT-*2001*	0.834	0.348	0.334	Increasing
JSCT-*2002*	0.830	0.326	0.312	Increasing
JSCT-*2003*	0.828	0.344	0.367	Increasing
JSCT-*2004*	0.828	0.399	0.427	Increasing
JSCT-*2005*	0.828	0.427	0.456	Increasing
JSCT-*2006*	0.828	0.405	0.433	Increasing
JNCT-*2000*	0.822	0.068	0.074	Increasing
JNCT-*2001*	0.822	0.081	0.088	Increasing
JNCT-*2002*	0.822	0.239	0.259	Increasing
JNCT-*2003*	0.822	0.400	0.433	Increasing
JNCT-*2004*	0.829	0.575	0.623	Increasing
JNCT-*2005*	0.840	0.620	0.619	Increasing
JNCT-*2006*	0.869	0.743	0.743	Increasing
NSICT-*2000*	1.000	0.483	0.427	Increasing
NSICT-*2001*	1.000	0.692	0.612	Increasing
NSICT-*2002*	1.000	0.889	0.786	Increasing
NSICT-*2003*	0.988	0.916	0.916	Increasing
NSICT-*2004*	0.986	0.903	0.903	Increasing
NSICT-*2005*	0.996	0.975	0.975	Increasing
NSICT-*2006*	1.000	1.000	1.000	Constant

Appendix 23 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
SAGT-*2000*	1.000	0.507	0.231	Increasing
SAGT-*2001*	1.000	0.556	0.253	Increasing
SAGT-*2002*	0.968	0.791	0.334	Increasing
SAGT-*2003*	0.916	0.699	0.508	Increasing
SAGT-*2004*	0.875	0.673	0.673	Increasing
SAGT-*2005*	0.884	0.698	0.698	Increasing
SAGT-*2006*	1.000	1.000	1.000	Constant
MPE-*2000*	0.924	0.213	0.137	Increasing
MPE-*2001*	0.924	0.254	0.164	Increasing
MPE-*2002*	0.929	0.296	0.190	Increasing
MPE-*2003*	0.942	0.394	0.254	Increasing
MPE-*2004*	0.962	0.537	0.346	Increasing
MPE-*2005*	0.973	0.607	0.391	Increasing
MPE-*2006*	0.986	0.681	0.439	Increasing
T37-*2000*	1.000	0.446	0.260	Increasing
T37-*2001*	1.000	0.536	0.312	Increasing
T37-*2002*	1.000	0.566	0.329	Increasing
T37-*2003*	1.000	0.598	0.313	Increasing
T37-*2004*	0.893	0.671	0.309	Increasing
T37-*2005*	0.899	0.691	0.318	Increasing
T37-*2006*	0.904	0.707	0.325	Increasing
TT-*2000*	0.873	0.275	0.092	Increasing
TT-*2001*	0.873	0.314	0.106	Increasing
TT-*2002*	0.874	0.393	0.132	Increasing
TT-*2003*	0.894	0.524	0.185	Increasing
TT-*2004*	0.876	0.457	0.237	Increasing
TT-*2005*	0.885	0.555	0.288	Increasing
TT-*2006*	0.894	0.593	0.307	Increasing
DCT-*2000*	0.997	0.774	0.744	Increasing
DCT-*2001*	0.991	0.736	0.708	Increasing
DCT-*2002*	0.999	0.782	0.752	Increasing
DCT-*2003*	0.990	0.928	0.928	Increasing
DCT-*2004*	1.000	1.000	1.000	Constant
DCT-*2005*	1.000	1.000	1.000	Constant
DCT-*2006*	1.000	1.000	1.000	Constant
RSCT-*2000*	1.000	0.950	0.950	Increasing
RSCT-*2001*	1.000	1.000	1.000	Constant
RSCT-*2002*	1.000	0.955	0.872	Increasing
RSCT-*2003*	1.000	1.000	1.000	Constant
RSCT-*2004*	1.000	0.974	0.974	Increasing
RSCT-*2005*	1.000	1.000	1.000	Constant
RSCT-*2006*	1.000	0.995	0.995	Increasing

Appendix 23 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
TPCT-*2000*	0.889	0.585	0.220	Increasing
TPCT-*2001*	0.880	0.590	0.222	Increasing
TPCT-*2002*	0.881	0.591	0.222	Increasing
TPCT-*2003*	0.829	0.508	0.213	Increasing
TPCT-*2004*	0.881	0.610	0.255	Increasing
TPCT-*2005*	0.917	0.670	0.281	Increasing
TPCT-*2006*	0.979	0.755	0.316	Increasing
SPCT-*2000*	0.825	0.400	0.400	Increasing
SPCT-*2001*	0.847	0.475	0.475	Increasing
SPCT-*2002*	0.850	0.484	0.484	Increasing
SPCT-*2003*	0.942	0.800	0.800	Increasing
SPCT-*2004*	0.965	0.880	0.880	Increasing
SPCT-*2005*	1.000	1.000	1.000	Constant
SPCT-*2006*	0.988	0.960	0.960	Increasing
ASCT-*2000*	1.000	0.269	0.068	Increasing
ASCT-*2001*	1.000	0.280	0.071	Increasing
ASCT-*2002*	1.000	0.526	0.133	Increasing
ASCT-*2003*	1.000	0.611	0.155	Increasing
ASCT-*2004*	1.000	0.537	0.136	Increasing
ASCT-*2005*	1.000	0.581	0.147	Increasing
ASCT-*2006*	1.000	0.636	0.161	Increasing
SACT-*2000*	1.000	0.224	0.055	Increasing
SACT-*2001*	1.000	0.255	0.063	Increasing
SACT-*2002*	1.000	0.304	0.075	Increasing
SACT-*2003*	1.000	0.327	0.081	Increasing
SACT-*2004*	1.000	0.349	0.084	Increasing
SACT-*2005*	1.000	0.371	0.090	Increasing
SACT-*2006*	1.000	0.665	0.161	Increasing
VCT-*2000*	1.000	0.722	0.722	Increasing
VCT-*2001*	1.000	0.731	0.731	Increasing
VCT-*2002*	1.000	0.877	0.877	Increasing
VCT-*2003*	1.000	1.000	1.000	Constant
VCT-*2004*	1.000	0.964	0.964	Increasing
VCT-*2005*	1.000	0.868	0.868	Increasing
VCT-*2006*	1.000	0.881	0.881	Increasing
VT-*2000*	0.983	0.850	0.850	Increasing
VT-*2001*	0.992	0.935	0.935	Increasing
VT-*2002*	1.000	1.000	1.000	Constant
VT-*2003*	0.875	0.537	0.390	Increasing
VT-*2004*	0.879	0.552	0.400	Increasing
VT-*2005*	0.874	0.532	0.385	Increasing
VT-*2006*	0.882	0.573	0.415	Increasing

Appendix 23 (Continued)

Terminal-*year*	BCC-I	CCR-I	SE	RTS
LSCT-*2000*	1.000	1.000	1.000	Constant
LSCT-*2001*	1.000	0.901	0.468	Increasing
LSCT-*2002*	0.999	0.900	0.468	Increasing
LSCT-*2003*	1.000	0.915	0.596	Increasing
LSCT-*2004*	0.952	0.896	0.821	Increasing
LSCT-*2005*	0.945	0.880	0.806	Increasing
LSCT-*2006*	1.000	1.000	1.000	Constant
KCT-*2000*	1.000	0.411	0.181	Increasing
KCT-*2001*	0.936	0.500	0.293	Increasing
KCT-*2002*	0.940	0.483	0.277	Increasing
KCT-*2003*	1.000	0.827	0.487	Increasing
KCT-*2004*	0.927	0.819	0.583	Increasing
KCT-*2005*	0.936	0.853	0.822	Increasing
KCT-*2006*	1.000	1.000	1.000	Constant
CCT-*2000*	1.000	0.233	0.079	Increasing
CCT-*2001*	1.000	0.271	0.092	Increasing
CCT-*2002*	1.000	0.387	0.131	Increasing
CCT-*2003*	1.000	0.443	0.150	Increasing
CCT-*2004*	0.825	0.341	0.169	Increasing
CCT-*2005*	0.964	0.651	0.322	Increasing
CCT-*2006*	0.853	0.619	0.427	Increasing
MIT-*2000*	0.868	0.724	0.469	Increasing
MIT-*2001*	0.856	0.684	0.443	Increasing
MIT-*2002*	0.855	0.680	0.440	Increasing
MIT-*2003*	0.891	0.705	0.507	Increasing
MIT-*2004*	0.922	0.817	0.760	Increasing
MIT-*2005*	0.946	0.885	0.823	Increasing
MIT-*2006*	0.896	0.616	0.549	Increasing
PQIT-*2000*	1.000	0.429	0.096	Increasing
PQIT-*2001*	1.000	0.302	0.113	Increasing
PQIT-*2002*	1.000	0.350	0.099	Increasing
PQIT-*2003*	0.955	0.515	0.145	Increasing
PQIT-*2004*	1.000	0.766	0.216	Increasing
PQIT-*2005*	0.984	0.682	0.291	Increasing
PQIT-*2006*	1.000	0.794	0.339	Increasing
ACT-*2000*	1.000	0.909	0.572	Increasing
ACT-*2001*	1.000	0.842	0.530	Increasing
ACT-*2002*	1.000	0.756	0.756	Increasing
ACT-*2003*	1.000	0.801	0.801	Increasing
ACT-*2004*	1.000	0.889	0.889	Increasing
ACT-*2005*	1.000	0.913	0.913	Increasing
ACT-*2006*	1.000	1.000	1.000	Constant

Appendix 24: Efficiency Estimates for the Quay Site (Based on Panel-Data Input-Orientation)

Terminal-*year*	Average STS crane move/hr	BCC-I	CCR-I	BCC-O	CCR-O
CT3-*2000*	35.0	1.000	1.000	1.000	1.000
CT3-*2001*	35.0	1.000	0.997	1.003	1.003
CT3-*2002*	37.0	1.000	1.000	1.000	1.000
CT3-*2003*	40.0	1.000	1.000	1.000	1.000
CT3-*2004*	40.0	1.000	1.000	1.000	1.000
CT3-*2005*	40.0	1.000	1.000	1.000	1.000
CT3-*2006*	40.0	1.000	1.000	1.000	1.000
T8E-*2000*	30.0	1.000	0.811	1.233	1.233
T8E-*2001*	30.0	1.000	0.811	1.233	1.233
T8E-*2002*	30.0	1.000	0.811	1.233	1.233
T8E-*2003*	32.0	1.000	0.865	1.156	1.156
T8E-*2004*	33.0	1.000	0.892	1.121	1.121
T8E-*2005*	33.0	1.000	0.892	1.121	1.121
T8E-*2006*	37.0	1.000	1.000	1.000	1.000
MTL-*2000*	29.3	0.754	0.662	1.409	1.510
MTL-*2001*	30.5	0.770	0.690	1.354	1.450
MTL-*2002*	32.4	0.796	0.732	1.274	1.365
MTL-*2003*	32.9	0.803	0.744	1.255	1.344
MTL-*2004*	32.9	0.786	0.723	1.257	1.382
MTL-*2005*	32.1	0.775	0.706	1.288	1.417
MTL-*2006*	31.3	0.764	0.688	1.321	1.453
HIT-*2000*	30.0	0.774	0.667	1.412	1.499
HIT-*2001*	33.0	0.812	0.734	1.284	1.362
HIT-*2002*	35.0	0.838	0.778	1.210	1.285
HIT-*2003*	35.0	0.838	0.778	1.210	1.285
HIT-*2004*	35.0	0.779	0.732	1.215	1.365
HIT-*2005*	40.0	0.843	0.837	1.063	1.195
HIT-*2006*	40.0	0.843	0.837	1.063	1.195
SCT-*2000*	32.5	1.000	0.929	1.077	1.077
SCT-*2001*	35.0	1.000	1.000	1.000	1.000
SCT-*2002*	35.0	0.926	0.911	1.097	1.098
SCT-*2003*	37.0	0.966	0.963	1.038	1.038
SCT-*2004*	40.0	0.891	0.884	1.130	1.131
SCT-*2005*	38.0	0.854	0.840	1.189	1.191
SCT-*2006*	41.0	0.911	0.906	1.102	1.104
SKCT-*2000*	30.0	0.879	0.801	1.244	1.248
SKCT-*2001*	32.0	0.909	0.855	1.166	1.170
SKCT-*2002*	33.0	0.925	0.881	1.131	1.135
SKCT-*2003*	37.0	0.871	0.839	1.140	1.191
SKCT-*2004*	40.0	0.832	0.787	1.259	1.271
SKCT-*2005*	42.0	0.800	0.761	1.238	1.314
SKCT-*2006*	43.0	0.814	0.779	1.209	1.284

Appendix 24 (Continued)

Terminal-*year*	Average STS crane move/hr	BCC-I	CCR-I	BCC-O	CCR-O
YICT-*2000*	32.0	0.897	0.822	1.211	1.217
YICT-*2001*	32.0	0.897	0.822	1.211	1.217
YICT-*2002*	35.0	0.943	0.899	1.107	1.113
YICT-*2003*	37.0	0.973	0.950	1.047	1.052
YICT-*2004*	37.0	0.703	0.665	1.405	1.504
YICT-*2005*	43.0	0.781	0.773	1.209	1.294
YICT-*2006*	45.0	0.809	0.809	1.156	1.237
GCT-*2000*	35.0	0.790	0.738	1.259	1.355
GCT-*2001*	32.0	0.728	0.615	1.625	1.625
GCT-*2002*	52.0	1.000	1.000	1.000	1.000
GCT-*2003*	39.4	0.819	0.758	1.320	1.320
GCT-*2004*	40.6	0.836	0.781	1.281	1.281
GCT-*2005*	41.1	0.843	0.790	1.265	1.265
GCT-*2006*	45.0	0.896	0.865	1.156	1.156
HBCT-*2000*	28.0	0.847	0.646	1.506	1.549
HBCT-*2001*	22.7	0.847	0.655	1.485	1.527
HBCT-*2002*	19.6	0.848	0.655	1.478	1.527
HBCT-*2003*	21.1	0.848	0.712	1.358	1.404
HBCT-*2004*	21.9	0.867	0.777	1.256	1.287
HBCT-*2005*	33.7	0.851	0.832	1.181	1.201
HBCT-*2006*	36.0	0.808	0.780	1.261	1.282
PECT-*2000*	22.4	0.760	0.627	1.583	1.594
PECT-*2001*	21.0	0.760	0.648	1.532	1.542
PECT-*2002*	23.3	0.719	0.639	1.544	1.565
PECT-*2003*	23.9	0.749	0.677	1.477	1.478
PECT-*2004*	30.0	0.747	0.673	1.486	1.486
PECT-*2005*	35.9	0.798	0.748	1.337	1.337
PECT-*2006*	36.0	0.735	0.685	1.368	1.460
HGCT-*2000*	32.0	1.000	0.858	1.166	1.166
HGCT-*2001*	33.0	1.000	0.885	1.130	1.130
HGCT-*2002*	37.3	1.000	1.000	1.000	1.000
HGCT-*2003*	35.7	1.000	0.957	1.045	1.045
HGCT-*2004*	36.0	1.000	0.965	1.036	1.036
HGCT-*2005*	40.4	1.000	1.000	1.000	1.000
HGCT-*2006*	41.0	1.000	1.000	1.000	1.000
UCT-*2000*	21.1	1.000	0.789	1.116	1.267
UCT-*2001*	19.3	1.000	0.853	1.033	1.173
UCT-*2002*	19.5	1.000	0.881	1.000	1.135
UCT-*2003*	19.8	1.000	0.880	1.064	1.136
UCT-*2004*	23.6	1.000	0.893	1.049	1.120
UCT-*2005*	24.3	1.000	0.915	1.024	1.093
UCT-*2006*	30.0	1.000	0.936	1.000	1.068

Appendix 24 (Continued)

Terminal-*year*	Average STS crane move/hr	BCC-I	CCR-I	BCC-O	CCR-O
ECTD-*2000*	32.0	0.609	0.552	1.625	1.812
ECTD-*2001*	32.0	0.609	0.552	1.625	1.812
ECTD-*2002*	35.0	0.615	0.603	1.486	1.657
ECTD-*2003*	35.0	0.614	0.603	1.486	1.657
ECTD-*2004*	35.0	0.608	0.603	1.486	1.659
ECTD-*2005*	35.0	0.608	0.603	1.486	1.659
ECTD-*2006*	35.0	0.608	0.603	1.486	1.659
MDCT-*2000*	32.0	0.659	0.585	1.551	1.709
MDCT-*2001*	32.0	0.659	0.585	1.551	1.709
MDCT-*2002*	32.0	0.659	0.585	1.551	1.709
MDCT-*2003*	33.0	0.668	0.585	1.528	1.710
MDCT-*2004*	33.0	0.662	0.570	1.576	1.755
MDCT-*2005*	33.0	0.662	0.570	1.576	1.755
MDCT-*2006*	35.0	0.684	0.606	1.486	1.649
YCT-*2000*	25.0	0.802	0.595	1.662	1.681
YCT-*2001*	25.0	0.802	0.595	1.662	1.681
YCT -*2002*	25.0	0.802	0.595	1.662	1.681
YCT -*2003*	27.0	0.802	0.643	1.539	1.556
YCT -*2004*	27.0	0.802	0.643	1.539	1.556
YCT -*2005*	34.0	0.839	0.809	1.222	1.236
YCT -*2006*	30.0	0.802	0.714	1.385	1.400
BCT-*2000*	28.0	0.671	0.584	1.455	1.713
BCT-*2001*	28.0	0.671	0.584	1.455	1.713
BCT-*2002*	32.0	0.698	0.667	1.273	1.499
BCT-*2003*	35.0	0.729	0.700	1.249	1.428
BCT-*2004*	37.0	0.746	0.725	1.232	1.380
BCT-*2005*	37.0	0.746	0.725	1.232	1.380
BCT-*2006*	38.0	0.761	0.744	1.200	1.344
TTC-*2000*	30.0	0.784	0.691	1.302	1.448
TTC-200*1*	32.0	0.802	0.737	1.221	1.358
TTC-*2002*	33.0	0.811	0.760	1.184	1.316
TTC-2003	36.0	0.824	0.814	1.111	1.229
TTC-*2004*	39.0	0.912	0.882	1.026	1.134
TTC-2005	40.0	1.000	0.904	1.000	1.106
TTC-*2006*	38.0	0.860	0.859	1.053	1.164
CTH-*2000*	28.0	1.000	0.985	1.000	1.015
CTH-*2001*	28.0	1.000	0.985	1.000	1.015
CTH-*2002*	29.0	1.000	0.855	1.000	1.170
CTH-*2003*	27.0	1.000	0.796	1.074	1.256
CTH-*2004*	26.0	1.000	0.767	1.115	1.304
CTH-*2005*	29.0	1.000	0.855	1.000	1.170
CTH-*2006*	30.0	1.000	0.885	1.000	1.131

Appendix 24 (Continued)

Terminal-*year*	Average STS crane move/hr	BCC-I	CCR-I	BCC-O	CCR-O
JACT-*2000*	25.0	0.709	0.505	1.934	1.980
JACT-*2001*	27.0	0.709	0.545	1.790	1.833
JACT-*2002*	28.0	0.709	0.566	1.727	1.768
JACT-*2003*	29.0	0.709	0.586	1.667	1.707
JACT-*2004*	30.0	0.631	0.546	1.611	1.832
JACT-*2005*	30.0	0.588	0.504	1.733	1.983
JACT-*2006*	35.0	0.588	0.588	1.486	1.700
PRCT-*2000*	21.0	0.966	0.621	1.591	1.610
PRCT-*2001*	21.0	0.966	0.621	1.591	1.610
PRCT-*2002*	25.0	0.966	0.740	1.336	1.352
PRCT-*2003*	25.0	0.966	0.740	1.336	1.352
PRCT-*2004*	27.0	0.966	0.799	1.237	1.252
PRCT-*2005*	29.0	0.966	0.858	1.152	1.166
PRCT-*2006*	30.0	0.973	0.887	1.114	1.127
LBPF-*2000*	24.0	0.817	0.652	1.410	1.534
LBPF-*2001*	27.0	0.841	0.734	1.253	1.363
LBPF-*2002*	28.0	0.851	0.761	1.208	1.315
LBPF-*2003*	29.0	0.860	0.788	1.167	1.269
LBPF-*2004*	27.0	0.817	0.719	1.270	1.391
LBPF-*2005*	28.0	0.825	0.746	1.224	1.341
LBPF-*2006*	28.0	0.825	0.746	1.224	1.341
LBPT-*2000*	23.0	0.715	0.500	1.616	2.002
LBPT-*2001*	25.0	0.715	0.543	1.487	1.841
LBPT-*2002*	26.0	0.715	0.565	1.430	1.771
LBPT-*2003*	26.0	0.714	0.557	1.456	1.795
LBPT-*2004*	25.0	0.714	0.529	1.541	1.890
LBPT-*2005*	28.0	0.714	0.592	1.375	1.688
LBPT-*2006*	30.0	0.714	0.635	1.284	1.575
NPCT-*2000*	26.0	0.909	0.677	1.467	1.477
NPCT-*2001*	28.0	0.909	0.729	1.362	1.371
NPCT-*2002*	26.0	0.909	0.677	1.467	1.477
NPCT-*2003*	29.0	0.909	0.755	1.315	1.324
NPCT-*2004*	30.0	0.909	0.781	1.272	1.280
NPCT-*2005*	28.0	0.909	0.729	1.362	1.371
NPCT-*2006*	31.0	0.909	0.807	1.231	1.239
WPCT-*2000*	25	0.800	0.534	1.742	1.873
WPCT-*2001*	27	0.800	0.584	1.590	1.711
WPCT-*2002*	29	0.800	0.628	1.480	1.593
WPCT-*2003*	31	0.800	0.671	1.384	1.490
WPCT-*2004*	32	0.800	0.693	1.341	1.444
WPCT-*2005*	34	0.800	0.726	1.281	1.377
WPCT-*2006*	35	0.800	0.747	1.245	1.338

Appendix 24 (Continued)

Terminal-*year*	Average STS crane move/hr	BCC-I	CCR-I	BCC-O	CCR-O
QQCT-*2000*	40.0	1.000	0.667	1.500	1.500
QQCT-*2001*	45.0	1.000	0.750	1.333	1.333
QQCT-*2002*	60.0	1.000	1.000	1.000	1.000
QQCT-*2003*	70.0	1.000	1.000	1.000	1.000
QQCT-*2004*	78.0	1.000	0.982	1.000	1.018
QQCT-*2005*	80.0	0.994	0.984	1.006	1.016
QQCT-*2006*	82.0	1.000	1.000	1.000	1.000
PNTC-*2000*	24.0	0.933	0.708	1.402	1.412
PNTC-*2001*	24.0	0.933	0.708	1.402	1.412
PNTC-*2002*	25.0	0.933	0.738	1.346	1.355
PNTC-*2003*	27.0	0.882	0.732	1.330	1.366
PNTC-*2004*	27.0	0.882	0.731	1.346	1.368
PNTC-*2005*	29.0	0.828	0.725	1.284	1.380
PNTC-*2006*	29.0	0.828	0.725	1.284	1.380
PTP-*2000*	30.0	0.800	0.696	1.245	1.436
PTP-*2001*	32.0	0.800	0.743	1.167	1.346
PTP-*2002*	32.0	0.800	0.743	1.167	1.346
PTP-*2003*	34.0	0.800	0.789	1.098	1.267
PTP-*2004*	35.0	0.800	0.794	1.097	1.260
PTP-*2005*	36.0	0.820	0.816	1.067	1.225
PTP-*2006*	37.0	0.807	0.806	1.089	1.241
TOCT-*2000*	26.6	1.000	0.806	1.241	1.241
TOCT-*2001*	30.7	1.000	0.930	1.075	1.075
TOCT-*2002*	33.0	1.000	1.000	1.000	1.000
TOCT-*2003*	35.4	1.000	1.000	1.000	1.000
TOCT-*2004*	32.8	0.949	0.911	1.098	1.098
TOCT-*2005*	34.2	0.963	0.950	1.053	1.053
TOCT-*2006*	36.0	1.000	1.000	1.000	1.000
XNWT-*2000*	22.0	1.000	0.997	1.000	1.003
XNWT-*2001*	21.0	1.000	0.952	1.048	1.050
XNWT-*2002*	27.0	1.000	0.964	1.037	1.037
XNWT-*2003*	28.0	1.000	1.000	1.000	1.000
XNWT-*2004*	30.0	0.984	0.888	1.119	1.126
XNWT-*2005*	30.0	0.984	0.888	1.119	1.126
XNWT-*2006*	31.0	0.984	0.918	1.083	1.090
NP-*2000*	25.0	1.000	0.951	1.052	1.052
NP -*2001*	25.0	1.000	0.951	1.052	1.052
NP-*2002*	26.3	1.000	1.000	1.000	1.000
NP-*2003*	26.2	1.000	0.996	1.004	1.004
NP-*2004*	27.1	1.000	0.968	1.033	1.033
NP-*2005*	25.3	1.000	0.904	1.107	1.107
NP-*2006*	28.0	1.000	1.000	1.000	1.000

Appendix 24 (Continued)

Terminal-*year*	Average STS crane move/hr	BCC-I	CCR-I	BCC-O	CCR-O
TP-*2000*	28.0	0.800	0.678	1.277	1.474
TP-*2001*	28.0	0.800	0.678	1.277	1.474
TP-*2002*	28.0	0.800	0.678	1.277	1.474
TP-*2003*	28.0	0.800	0.678	1.277	1.474
TP-*2004*	28.0	0.800	0.678	1.277	1.474
TP-*2005*	28.0	0.800	0.678	1.277	1.474
TP-*2006*	28.0	0.800	0.678	1.277	1.474
NCB-*2000*	27.0	1.000	0.818	1.222	1.222
NCB-*2001*	28.0	1.000	0.848	1.179	1.179
NCB-*2002*	26.0	1.000	0.788	1.269	1.269
NCB-*2003*	29.2	1.000	0.885	1.130	1.130
NCB-*2004*	30.2	1.000	0.915	1.093	1.093
NCB-*2005*	33.0	1.000	1.000	1.000	1.000
NCB-*2006*	27.5	1.000	0.833	1.200	1.200
LCIT-*2000*	29.0	1.000	0.906	1.103	1.103
LCIT-*2001*	30.0	1.000	0.938	1.067	1.067
LCIT-*2002*	31.0	1.000	0.969	1.032	1.032
LCIT-*2003*	32.0	1.000	1.000	1.000	1.000
LCIT-*2004*	31.0	1.000	0.969	1.032	1.032
LCIT-*2005*	32.0	0.790	0.784	1.108	1.276
LCIT-*2006*	34.0	0.845	0.833	1.043	1.201
LCB1-*2000*	27.0	1.000	0.854	1.170	1.170
LCB1-*2001*	28.4	1.000	0.899	1.113	1.113
LCB1-*2002*	30.7	1.000	0.972	1.029	1.029
LCB1-*2003*	31.6	1.000	1.000	1.000	1.000
LCB1-*2004*	33.1	0.908	0.903	1.040	1.108
LCB1-*2005*	34.8	1.000	0.949	1.000	1.053
LCB1-*2006*	35.5	0.940	0.919	1.033	1.088
CTB-*2000*	28.0	0.868	0.730	1.331	1.370
CTB-*2001*	29.0	0.868	0.756	1.285	1.323
CTB-*2002*	30.0	0.828	0.719	1.263	1.392
CTB-*2003*	32.3	0.828	0.774	1.173	1.293
CTB-*2004*	32.3	0.774	0.736	1.240	1.358
CTB-*2005*	35.0	0.805	0.798	1.145	1.253
CTB-*2006*	33.0	0.774	0.752	1.214	1.329
NSCT-*2000*	26.0	0.939	0.785	1.263	1.275
NSCT-*2001*	27.0	0.939	0.815	1.216	1.227
NSCT-*2002*	27.0	0.939	0.815	1.216	1.227
NSCT-*2003*	32.0	0.965	0.928	1.075	1.078
NSCT-*2004*	34.0	0.986	0.986	1.011	1.015
NSCT-*2005*	33.0	0.974	0.955	1.042	1.047
NSCT-*2006*	36.0	1.000	1.000	1.000	1.000

Appendix 24 (Continued)

Terminal-*year*	Average STS crane move/hr	BCC-I	CCR-I	BCC-O	CCR-O
AMCT-*2000*	28.0	0.950	0.859	1.086	1.164
AMCT-*2001*	29.0	0.955	0.855	1.169	1.169
AMCT-*2002*	32.0	0.965	0.888	1.126	1.126
AMCT-*2003*	32.0	1.000	1.000	1.000	1.000
AMCT-*2004*	35.4	0.971	0.930	1.073	1.075
AMCT-*2005*	33.2	0.996	0.995	1.004	1.005
AMCT-*2006*	35.0	1.000	1.000	1.000	1.000
MCT-*2000*	23.0	1.000	0.966	1.000	1.035
MCT-*2001*	24.0	0.994	0.906	1.066	1.104
MCT-*2002*	25.0	1.000	1.000	1.000	1.000
MCT-*2003*	26.0	1.000	1.000	1.000	1.000
MCT-*2004*	27.0	1.000	1.000	1.000	1.000
MCT-*2005*	26.0	0.828	0.815	1.167	1.227
MCT-*2006*	28.0	0.795	0.758	1.255	1.319
MICT-*2000*	26.0	0.867	0.524	1.898	1.907
MICT-*2001*	28.0	0.864	0.508	1.959	1.969
MICT-*2002*	29.0	0.876	0.569	1.748	1.757
MICT-*2003*	33.0	0.886	0.608	1.638	1.646
MICT-*2004*	35.0	0.892	0.642	1.551	1.558
MICT-*2005*	34.0	0.893	0.647	1.540	1.547
MICT-*2006*	35.0	0.892	0.639	1.558	1.565
JSCT-*2000*	36.4	0.774	0.369	2.706	2.707
JSCT-*2001*	34.1	0.773	0.365	2.735	2.738
JSCT-*2002*	24.4	0.769	0.342	2.922	2.925
JSCT-*2003*	28.1	0.712	0.337	2.825	2.963
JSCT-*2004*	36.1	0.731	0.392	2.431	2.550
JSCT-*2005*	37.1	0.740	0.419	2.274	2.385
JSCT-*2006*	37.1	0.733	0.398	2.396	2.514
JNCT-*2000*	27.0	0.730	0.062	16.020	16.180
JNCT-*2001*	31.0	0.730	0.073	13.557	13.692
JNCT-*2002*	32.0	0.744	0.216	4.588	4.634
JNCT-*2003*	33.0	0.768	0.361	2.743	2.770
JNCT-*2004*	34.0	0.805	0.519	1.906	1.925
JNCT-*2005*	32.0	0.839	0.618	1.602	1.618
JNCT-*2006*	32.0	0.885	0.742	1.335	1.348
NSICT-*2000*	26.0	0.947	0.481	1.841	2.080
NSICT-*2001*	28.0	0.974	0.689	1.284	1.451
NSICT-*2002*	30.0	1.000	0.885	1.000	1.130
NSICT-*2003*	30.0	0.976	0.916	1.092	1.092
NSICT-*2004*	32.0	0.972	0.903	1.107	1.107
NSICT-*2005*	33.0	0.993	0.975	1.025	1.025
NSICT-*2006*	33.0	1.000	1.000	1.000	1.000

Appendix 24 (Continued)

Terminal-*year*	Average STS crane move/hr	BCC-I	CCR-I	BCC-O	CCR-O
SAGT-*2000*	26.0	1.000	0.929	1.077	1.077
SAGT-*2001*	28.0	1.000	1.000	1.000	1.000
SAGT-*2002*	28.0	0.847	0.846	1.064	1.182
SAGT-*2003*	31.0	0.751	0.725	1.161	1.379
SAGT-*2004*	31.0	0.732	0.673	1.297	1.487
SAGT-*2005*	32.0	0.736	0.694	1.257	1.440
SAGT-*2006*	34.0	0.750	0.738	1.183	1.356
MPE-*2000*	29.0	0.788	0.643	1.453	1.555
MPE-*2001*	29.0	0.788	0.643	1.453	1.555
MPE-*2002*	30.0	0.791	0.665	1.404	1.503
MPE-*2003*	32.0	0.797	0.709	1.316	1.410
MPE-*2004*	32.0	0.797	0.709	1.316	1.410
MPE-*2005*	32.0	0.797	0.709	1.316	1.410
MPE-*2006*	31.0	0.794	0.687	1.359	1.455
T37-*2000*	38.2	0.995	0.965	1.037	1.037
T37-*2001*	35.8	0.987	0.904	1.106	1.106
T37-*2002*	39.6	1.000	1.000	1.000	1.000
T37-*2003*	39.7	1.000	1.000	1.000	1.000
T37-*2004*	37.0	0.852	0.850	1.146	1.177
T37-*2005*	42.4	1.000	0.974	1.000	1.027
T37-*2006*	32.4	0.830	0.744	1.309	1.344
TT-*2000*	26.0	0.872	0.810	1.155	1.235
TT-*2001*	26.0	0.872	0.810	1.155	1.235
TT-*2002*	28.0	0.875	0.872	1.072	1.146
TT-*2003*	29.0	0.856	0.855	1.078	1.169
TT-*2004*	30.0	0.840	0.766	1.220	1.306
TT-*2005*	30.0	0.840	0.763	1.259	1.311
TT-*2006*	31.0	0.845	0.788	1.218	1.268
DCT-*2000*	22.0	0.882	0.518	1.854	1.930
DCT-*2001*	22.0	0.882	0.518	1.854	1.930
DCT-*2002*	25.0	0.882	0.589	1.631	1.698
DCT-*2003*	26.0	0.848	0.588	1.594	1.700
DCT-*2004*	28.0	0.851	0.634	1.481	1.578
DCT-*2005*	26.0	0.848	0.588	1.594	1.700
DCT-*2006*	29.0	0.855	0.656	1.429	1.524
RSCT-*2000*	23.0	1.000	0.785	1.261	1.275
RSCT-*2001*	25.0	1.000	0.853	1.160	1.173
RSCT-*2002*	29.0	1.000	0.989	1.000	1.011
RSCT-*2003*	32.0	1.000	1.000	1.000	1.000
RSCT-*2004*	29.0	1.000	0.906	1.103	1.103
RSCT-*2005*	31.0	1.000	0.969	1.032	1.032
RSCT-*2006*	31.0	1.000	0.969	1.032	1.032

Appendix 24 (Continued)

Terminal-*year*	Average STS crane move/hr	BCC-I	CCR-I	BCC-O	CCR-O
TPCT-*2000*	24.0	0.800	0.660	1.409	1.515
TPCT-*2001*	25.0	0.742	0.654	1.353	1.529
TPCT-*2002*	23.0	0.742	0.602	1.470	1.662
TPCT-*2003*	24.0	0.709	0.581	1.453	1.720
TPCT-*2004*	28.0	0.717	0.672	1.298	1.488
TPCT-*2005*	29.0	0.712	0.673	1.253	1.485
TPCT-*2006*	29.2	0.713	0.678	1.245	1.475
SPCT-*2000*	27.0	0.675	0.521	1.570	1.920
SPCT-*2001*	27.0	0.675	0.521	1.570	1.920
SPCT-*2002*	28.0	0.675	0.540	1.514	1.852
SPCT-*2003*	30.0	0.682	0.579	1.413	1.728
SPCT-*2004*	31.0	0.686	0.598	1.368	1.673
SPCT-*2005*	30.0	0.682	0.579	1.413	1.728
SPCT-*2006*	32.0	0.690	0.617	1.325	1.620
ASCT-*2000*	25.0	1.000	0.893	1.120	1.120
ASCT-*2001*	25.0	1.000	0.893	1.120	1.120
ASCT-*2002*	24.0	1.000	0.857	1.167	1.167
ASCT-*2003*	26.0	1.000	0.929	1.077	1.077
ASCT-*2004*	28.0	1.000	1.000	1.000	1.000
ASCT-*2005*	27.0	1.000	0.964	1.037	1.037
ASCT-*2006*	28.0	1.000	1.000	1.000	1.000
SACT-*2000*	25.0	1.000	0.893	1.120	1.120
SACT-*2001*	25.0	1.000	0.893	1.120	1.120
SACT-*2002*	25.0	1.000	0.893	1.120	1.120
SACT-*2003*	27.0	1.000	0.964	1.037	1.037
SACT-*2004*	27.0	1.000	0.964	1.037	1.037
SACT-*2005*	28.0	1.000	1.000	1.000	1.000
SACT-*2006*	28.0	1.000	1.000	1.000	1.000
VCT-*2000*	28.0	0.691	0.522	1.514	1.917
VCT-*2001*	27.0	0.689	0.503	1.570	1.988
VCT-*2002*	27.0	0.689	0.503	1.570	1.988
VCT-*2003*	29.0	0.694	0.540	1.462	1.851
VCT-*2004*	27.0	0.689	0.503	1.570	1.988
VCT-*2005*	28.0	0.691	0.522	1.514	1.917
VCT-*2006*	29.0	0.694	0.540	1.462	1.851
VT-*2000*	25.0	0.724	0.561	1.531	1.783
VT-*2001*	25.0	0.724	0.561	1.531	1.783
VT-*2002*	27.0	0.724	0.606	1.418	1.651
VT-*2003*	29.0	0.724	0.571	1.420	1.751
VT-*2004*	28.0	0.720	0.552	1.470	1.813
VT-*2005*	29.0	0.724	0.571	1.420	1.751
VT-*2006*	29.0	0.724	0.571	1.420	1.751

Appendix 24 (Continued)

Terminal-*year*	Average STS crane move/hr	BCC-I	CCR-I	BCC-O	CCR-O
LSCT-*2000*	26.0	0.852	0.789	1.189	1.267
LSCT-*2001*	28.0	0.765	0.717	1.225	1.395
LSCT-*2002*	29.0	0.772	0.743	1.183	1.347
LSCT-*2003*	30.0	0.780	0.768	1.143	1.302
LSCT-*2004*	31.0	0.795	0.794	1.106	1.260
LSCT-*2005*	31.0	0.795	0.794	1.106	1.260
LSCT-*2006*	33.0	0.789	0.787	1.114	1.271
KCT-*2000*	22.0	0.812	0.499	1.833	2.003
KCT-*2001*	23.1	0.810	0.502	1.817	1.991
KCT-*2002*	24.0	0.810	0.522	1.749	1.916
KCT-*2003*	24.5	0.810	0.531	1.714	1.882
KCT-*2004*	23.2	0.810	0.503	1.810	1.987
KCT-*2005*	23.1	0.753	0.461	1.835	2.167
KCT-*2006*	21.7	0.753	0.434	1.954	2.307
CCT-*2000*	20.0	0.839	0.570	1.659	1.756
CCT-*2001*	21.2	0.784	0.576	1.565	1.736
CCT-*2002*	23.2	0.784	0.630	1.430	1.586
CCT-*2003*	22.0	0.784	0.598	1.508	1.673
CCT-*2004*	26.0	0.771	0.650	1.375	1.537
CCT-*2005*	29.0	0.724	0.685	1.233	1.459
CCT-*2006*	30.2	0.729	0.658	1.323	1.519
MIT-*2000*	26.0	0.771	0.569	1.571	1.756
MIT-*2001*	25.0	0.771	0.548	1.634	1.826
MIT-*2002*	23.0	0.771	0.504	1.776	1.985
MIT-*2003*	25.0	0.771	0.548	1.634	1.826
MIT-*2004*	28.0	0.771	0.583	1.460	1.714
MIT-*2005*	29.0	0.776	0.604	1.409	1.655
MIT-*2006*	33.0	0.793	0.683	1.285	1.465
PQIT-*2000*	23.0	1.000	0.844	1.000	1.185
PQIT-*2001*	25.3	1.000	0.893	1.000	1.120
PQIT-*2002*	24.6	0.999	0.868	1.028	1.152
PQIT-*2003*	26.0	0.875	0.815	1.147	1.226
PQIT-*2004*	25.0	0.873	0.784	1.193	1.275
PQIT-*2005*	28.0	0.832	0.747	1.271	1.339
PQIT-*2006*	29.0	0.835	0.774	1.227	1.292
ACT-*2000*	24.0	1.000	0.802	1.042	1.247
ACT-*2001*	25.0	1.000	0.836	1.000	1.197
ACT-*2002*	32.6	1.000	1.000	1.000	1.000
ACT-*2003*	22.0	1.000	0.675	1.482	1.482
ACT-*2004*	25.0	1.000	0.767	1.304	1.304
ACT-*2005*	26.5	1.000	0.813	1.230	1.230
ACT-*2006*	27.0	1.000	0.828	1.207	1.207

Appendix 25: Efficiency Estimates for the Yard Site (Based on Panel-Data Input-Orientation)

Terminal-*year*	Average dwell time (days)	BCC-I	CCR-I
GCT-*2000*	6	0.812	0.661
GCT-*2001*	6	0.803	0.608
GCT-*2002*	5.7	0.882	0.8
GCT-*2003*	5.4	0.833	0.741
GCT-*2004*	5	0.94	0.78
GCT-*2005*	5	0.963	0.8
GCT-*2006*	4.7	0.955	0.79
HBCT-*2000*	7.5	0.9	0.444
HBCT-*2001*	7	0.668	0.434
HBCT-*2002*	7	0.75	0.458
HBCT-*2003*	7	0.882	0.49
HBCT-*2004*	6	0.916	0.598
HBCT-*2005*	5.2	0.9	0.72
HBCT-*2006*	5	0.843	0.719
HGCT-*2000*	5	0.94	0.686
HGCT-*2001*	5.8	0.966	0.708
HGCT-*2002*	4	1	0.8
HGCT-*2003*	4	1	0.8
HGCT-*2004*	4	1	0.8
HGCT-*2005*	4.3	1	0.8
HGCT-*2006*	4	1	0.8
WPCT-*2000*	5	0.868	0.386
WPCT -*2001*	5.3	0.776	0.424
WPCT -*2002*	5.5	0.758	0.49
WPCT -*2003*	5.3	0.7221	0.536
WPCT -*2004*	5.3	0.668	0.574
WPCT -*2005*	5.5	0.625	0.536
WPCT -*2006*	5	0.839	0.603
PTP-*2000*	5	0.867	0.576
PTP -*2001*	4.8	0.88	0.654
PTP -*2002*	4.5	0.91	0.703
PTP -*2003*	4	0.982	0.8
PTP -*2004*	4	0.792	0.776
PTP-*2005*	3.5	0.966	0.8
PTP -*2006*	3.3	0.966	0.8

Appendix 25 (Continued)

Terminal-*year*	Average dwell time (days)	BCC-I	CCR-I
JSCT-*2000*	8.5	0.79	0.579
JSCT -*2001*	8.5	0.79	0.552
JSCT -*2002*	9.3	0.853	0.452
JSCT -*2003*	9	0.814	0.48
JSCT -*2004*	8.5	0.822	0.488
JSCT -*2005*	8.3	0.828	0.501
JSCT -*2006*	8.3	0.825	0.501
SAGT-*2000*	5.6	0.895	0.743
SAGT -*2001*	4.5	0.966	0.8
SAGT -*2002*	5.2	0.934	0.767
SAGT -*2003*	6	0.826	0.683
SAGT -*2004*	6	0.803	0.624
SAGT -*2005*	6.2	0.811	0.645
SAGT -*2006*	5	0.792	0.784
T37-*2000*	5	0.981	0.772
T37-*2001*	5	0.968	0.739
T37-*2002*	4.3	0.9	0.8
T37-*2003*	4.3	0.9	0.8
T37-*2004*	5.8	0.877	0.734
T37-*2005*	4	0.925	0.8
T37-*2006*	6	0.866	0.706
SPCT-*2000*	5.5	0.85	0.554
SPCT -*2001*	5.5	0.86	0.559
SPCT -*2002*	5.5	0.891	0.577
SPCT -*2003*	5	0.82	0.724
SPCT -*2004*	5	0.835	0.768
SPCT -*2005*	4.3	0.955	0.8
SPCT -*2006*	4.3	0.965	0.8
KCT-*2000*	6	0.855	0.74
KCT -*2001*	5	0.97	0.8
KCT -*2002*	4.7	0.94	0.866
KCT -*2003*	9.3	0.672	0.49
KCT -*2004*	7.2	0.877	0.602
KCT -*2005*	6	0.827	0.727
KCT -*2006*	5	0.88	0.8

Appendix 26: DEA Supply Chain Oriented Efficiency for Export Operations (Based on CCR-I Panel Data)

Observation / DMU	CSI spatial configuration			24-hourr rule spatial configuration		
	Site efficiency		Network efficiency	Site efficiency		Network efficiency
	Gate	*Yard & Quay*		*Gate & Yard*	*Quay*	
GCT-*2000*	0.780	1.000	0.697	0.850	0.850	0.850
GCT-*2001*	0.879	0.987	0.846	0.987	0.850	0.821
GCT-*2002*	0.825	0.990	0.841	0.990	0.831	0.788
GCT-*2003*	1.000	1.000	1.000	1.000	0.850	1.000
GCT-*2004*	0.904	0.754	0.666	0.754	0.840	0.816
GCT-*2005*	0.897	0.812	0.703	0.812	0.850	0.846
GCT-*2006*	0.911	0.900	0.796	0.900	0.850	0.851
HBCT-*2000*	0.911	1.000	0.904	1.000	0.740	0.682
HBCT-*2001*	0.928	0.980	0.905	0.980	0.830	0.639
HBCT-*2002*	0.777	0.955	0.720	0.955	0.819	0.868
HBCT-*2003*	0.725	0.974	0.759	0.974	0.850	0.822
HBCT-*2004*	0.818	0.670	0.555	0.670	0.850	0.868
HBCT-*2005*	0.870	0.866	0.752	0.866	0.830	0.867
HBCT-*2006*	0.910	0.937	0.914	0.937	0.839	0.884
HGCT-*2000*	1.000	1.000	1.000	1.000	0.844	0.902
HGCT-*2001*	0.949	1.000	0.922	1.000	0.761	0.828
HGCT-*2002*	1.000	1.000	1.000	0.977	0.964	0.917
HGCT-*2003*	1.000	1.000	1.000	0.722	0.815	0.645
HGCT-*2004*	0.893	0.674	0.590	0.690	0.820	0.665
HGCT-*2005*	0.867	0.760	0.698	0.754	0.820	0.719
HGCT-*2006*	1.000	0.921	0.885	1.000	1.000	1.000
WPCT-*2000*	0.867	0.842	0.780	0.836	0.778	0.748
WPCT -*2001*	0.872	0.776	0.762	0.847	0.787	0.727
WPCT -*2002*	0.898	0.822	0.792	0.900	0.866	0.732
WPCT -*2003*	0.746	0.884	0.684	0.917	0.900	0.789
WPCT -*2004*	0.825	0.727	0.619	0.683	0.915	0.657
WPCT -*2005*	0.887	0.695	0.662	0.672	0.928	0.619
WPCT -*2006*	0.945	0.715	0.694	0.705	0.941	0.618
PTP-*2000*	1.000	0.989	0.966	0.817	1.000	0.796
PTP -*2001*	1.000	0.945	0.921	1.000	1.000	1.000
PTP -*2002*	1.000	1.000	1.000	1.000	0.996	0.921
PTP -*2003*	0.969	1.000	0.936	0.985	1.000	0.944
PTP -*2004*	0.945	1.000	0.890	0.887	1.000	0.851
PTP-*2005*	0.994	1.000	0.977	0.912	0.988	0.814
PTP -*2006*	1.000	1.000	1.000	0.966	1.000	0.953

Appendix 26 (Continued)

JSCT-*2000*	0.752	0.783	0.767	0.833	0.950	0.801
JSCT -*2001*	0.765	0.794	0.775	0.941	0.889	0.880
JSCT -*2002*	0.815	0.851	0.822	0.818	0.941	0.776
JSCT -*2003*	0.697	0.776	0.721	0.881	1.000	0.850
JSCT -*2004*	0.723	0.740	0.735	0.950	1.000	0.928
JSCT -*2005*	0.713	0.727	0.719	0.889	0.968	0.870
JSCT -*2006*	0.722	0.792	0.738	0.916	1.000	0.885
SAGT-*2000*	0.786	0.560	0.673	0.550	0.689	0.522
SAGT -*2001*	0.686	0.576	0.631	0.634	0.650	0.601
SAGT -*2002*	0.614	0.673	0.620	0.624	0.667	0.611
SAGT -*2003*	0.627	0.722	0.678	0.600	0.740	0.604
SAGT -*2004*	0.729	0.421	0.566	0.429	0.768	0.538
SAGT -*2005*	0.773	0.675	0.714	0.498	0.850	0.557
SAGT -*2006*	0.771	0.800	0.766	0.755	0.929	0.734
T37-*2000*	0.873	0.922	0.855	0.907	0.529	0.502
T37-*2001*	0.928	0.989	0.977	0.979	0.788	0.766
T37-*2002*	1.000	1.000	1.000	1.000	0.941	0.968
T37-*2003*	0.964	1.000	0.942	0.785	0.954	0.733
T37-*2004*	0.839	0.677	0.714	0.729	1.000	0.753
T37-*2005*	0.891	0.626	0.657	0.794	1.000	0.823
T37-*2006*	0.900	0.675	0.773	0.828	1.000	0.858
SPCT-*2000*	1.000	0.847	0.823	0.847	0.928	0.885
SPCT -*2001*	1.000	0.897	0.871	0.897	0.924	0.937
SPCT -*2002*	0.927	0.879	0.812	0.945	0.934	0.873
SPCT -*2003*	0.997	0.945	0.977	0.945	0.967	0.977
SPCT -*2004*	0.956	0.788	0.668	0.553	0.965	0.498
SPCT -*2005*	1.000	0.747	0.698	0.580	1.000	0.544
SPCT -*2006*	1.000	0.800	0.765	0.652	1.000	0.637
KCT-*2000*	0.752	0.783	0.767	0.833	0.950	0.801
KCT -*2001*	0.765	0.794	0.775	0.941	0.889	0.880
KCT -*2002*	0.815	0.851	0.822	0.818	0.941	0.776
KCT -*2003*	0.697	0.776	0.721	0.881	1.000	0.850
KCT -*2004*	0.723	0.740	0.735	0.950	1.000	0.928
KCT -*2005*	0.713	0.727	0.719	0.889	0.968	0.870
KCT -*2006*	0.722	0.792	0.738	0.916	1.000	0.885

Appendix 27: Malmquist Productivity Index: Year-by-Year TFP Change

Terminal	2000-01				2001-02				2002-03				2003-04				2004-05				2005-06			
	MPI	PEC	SEC	TC	MPI	PEC	SEC	TC	MPI	PEC	SEC	TC	MPI	PEC	SEC	TC	MPI	PEC	SEC	TC	MPI	PEC	SEC	TC
CT3	1.054	1.000	1.000	1.054	1.062	1.000	1.000	1.062	1.972	1.000	1.309	1.506	1.994	1.000	1.453	1.373	3.769	1.000	3.296	1.144	0.488	1.000	0.505	0.965
T8E	1.085	1.000	1.021	1.063	0.853	1.000	0.942	0.906	1.016	1.000	1.008	1.008	0.795	1.000	0.892	0.892	0.850	1.000	0.922	0.922	1.188	1.000	1.090	1.090
MTL	0.965	1.000	1.000	0.965	0.988	1.000	1.000	0.988	0.807	1.000	0.905	0.892	1.266	1.075	1.167	1.009	0.767	0.955	0.858	0.936	0.852	0.974	0.904	0.967
HIT	1.065	1.000	1.000	1.065	0.939	1.000	1.000	0.939	1.290	1.000	1.136	1.136	0.859	1.000	0.897	0.958	0.930	1.000	0.965	0.964	0.943	1.000	0.971	0.971
SCT	1.130	1.000	1.068	1.058	0.996	1.000	1.062	0.938	0.865	1.000	0.897	0.964	0.873	1.000	0.952	0.917	1.025	1.000	1.001	1.024	0.961	1.002	0.987	0.971
SKCT	0.960	0.992	0.914	1.058	0.861	0.968	0.926	0.961	0.884	0.953	0.782	1.185	1.485	1.131	1.333	0.985	1.279	1.122	1.201	0.949	1.118	1.008	1.141	0.973
YICT	0.795	0.922	0.895	0.964	0.922	1.000	1.000	0.922	0.816	1.000	0.911	0.896	1.184	1.000	1.107	1.070	1.364	1.000	1.257	1.085	0.785	1.000	0.882	0.890
GCT	0.920	0.977	0.933	1.010	0.850	1.000	0.975	0.872	0.858	1.000	0.907	0.945	1.002	1.026	0.960	1.018	0.898	0.974	0.940	0.981	1.252	1.058	1.199	0.987
HBCT	1.127	1.006	1.109	1.010	0.829	0.970	0.903	0.947	0.865	0.985	0.955	0.919	0.615	0.945	0.644	1.010	1.098	1.127	0.978	0.997	0.982	1.018	0.978	0.986
PECT	0.973	0.979	0.943	1.053	0.881	0.988	0.902	0.988	0.912	1.007	0.970	0.934	0.840	0.967	0.881	0.986	1.042	0.992	0.969	1.084	1.171	1.086	1.086	0.993
HGCT	0.893	1.000	0.850	1.051	0.856	1.000	0.884	0.968	1.076	1.000	0.988	1.089	0.912	1.000	0.935	0.975	1.340	1.000	1.451	0.924	1.050	1.000	0.987	1.063
UCT	0.698	1.000	0.707	0.987	0.891	1.000	0.906	0.983	0.958	1.000	0.949	1.010	1.013	1.000	0.970	1.044	0.981	1.000	0.952	1.031	1.038	1.000	1.054	0.985
ECTD	0.455	0.691	0.635	1.035	1.000	1.035	1.006	0.960	1.235	1.103	1.136	0.986	1.048	1.008	1.078	0.965	1.105	1.031	1.159	0.925	0.732	0.932	0.806	0.974
MDCT	0.967	1.000	0.923	1.047	0.320	0.860	0.388	0.959	0.835	0.955	0.861	1.015	1.181	1.019	1.218	0.951	0.937	0.992	0.980	0.964	0.800	0.987	0.861	0.942
YCT	0.909	0.988	0.895	1.028	0.906	0.984	0.905	1.017	0.794	0.989	0.856	0.937	0.832	0.945	0.898	0.981	0.911	0.966	0.943	1.001	0.895	1.003	0.968	0.922
BCT	0.957	0.979	0.957	1.020	0.934	0.954	1.004	0.976	1.350	1.071	1.374	0.918	0.977	0.903	0.856	1.263	0.970	1.000	0.985	0.985	0.804	1.000	0.897	0.897
TTC	0.975	0.988	0.946	1.043	0.955	0.975	1.009	0.970	0.964	0.992	0.958	1.014	0.683	0.949	0.711	1.012	0.861	0.976	0.921	0.958	0.802	0.980	0.882	0.928
CTH	1.015	0.998	1.040	0.978	1.305	1.003	1.384	0.940	0.500	0.914	0.594	0.919	0.828	0.977	0.882	0.962	0.798	0.987	0.830	0.975	1.361	1.012	1.381	0.974
JACT	0.885	1.000	0.835	1.059	0.812	0.878	0.990	0.935	0.627	0.918	0.724	0.943	0.733	0.978	0.835	0.898	1.181	0.990	1.202	0.993	0.904	0.968	0.966	0.968
PRCT	0.912	0.980	0.914	1.019	0.900	0.958	0.963	0.976	0.831	0.990	0.863	0.973	0.837	0.987	0.939	0.904	0.974	0.995	0.940	1.041	0.819	0.986	0.855	0.971
LBPF	1.036	0.994	0.986	1.056	0.963	0.976	0.910	1.084	1.247	0.933	0.915	1.461	1.106	0.997	1.134	0.979	1.097	1.046	1.013	1.035	0.851	1.006	0.881	0.961
LBPT	0.913	0.971	0.929	1.013	0.986	0.968	1.047	0.973	1.014	1.022	1.007	0.985	0.642	0.951	0.743	0.909	0.758	0.869	0.752	1.160	0.717	0.920	0.810	0.962
NPCT	0.964	0.971	0.935	1.061	0.886	0.971	0.953	0.957	0.952	1.002	0.980	0.970	0.773	0.935	0.884	0.935	1.050	1.005	1.026	1.018	0.959	1.014	0.995	0.950
WPCT	0.705	0.992	0.669	1.063	0.711	0.912	0.813	0.959	0.976	0.966	0.861	1.174	0.754	0.945	0.850	0.939	0.814	1.005	0.865	0.936	0.686	0.920	0.751	0.992
QQCT	0.784	0.971	0.764	1.058	0.692	0.940	0.782	0.941	1.508	0.979	1.515	1.017	1.654	1.288	1.352	0.949	0.802	0.974	0.853	0.965	0.709	0.912	0.805	0.965
PNTC	0.929	0.984	0.903	1.045	0.933	0.995	0.977	0.960	1.508	0.999	1.604	0.941	0.724	1.009	0.740	0.969	1.298	1.033	1.217	1.032	0.854	0.990	0.935	0.924
PTP	0.816	0.977	0.873	0.956	0.771	0.948	0.853	0.952	0.561	0.918	0.699	0.875	1.021	0.970	1.014	1.038	0.941	0.986	0.949	1.005	0.935	0.977	0.989	0.968
TOCT	0.920	0.998	0.936	0.985	0.764	0.981	0.801	0.972	0.627	1.000	0.620	1.011	1.388	0.978	1.362	1.042	0.837	0.994	0.847	0.994	0.960	0.998	0.971	0.990
XNWT	0.921	1.000	0.880	1.046	0.764	1.000	0.801	0.954	0.705	1.000	0.679	1.038	1.502	1.000	1.367	1.099	0.904	1.000	0.950	0.952	0.770	1.000	0.863	0.892
NP	0.536	0.996	0.550	0.978	0.715	0.991	0.796	0.906	0.717	0.986	0.785	0.926	1.050	0.975	1.018	1.057	0.920	0.996	0.897	1.030	0.873	0.988	0.912	0.968

Appendix 27 (Continued)

Terminal	2000-01				2001-02				2002-03				2003-04				2004-05				2005-06			
	MPI	PEC	SEC	TC	MPI	PEC	SEC	TC	MPI	PEC	SEC	TC	MPI	PEC	SEC	TC	MPI	PEC	SEC	TC	MPI	PEC	SEC	TC
TP	0.845	0.981	0.820	1.050	1.063	1.001	1.110	0.956	0.961	0.971	0.935	1.059	0.853	0.971	0.901	0.975	0.955	0.999	0.953	1.003	1.174	1.020	1.186	0.970
NCB	1.000	1.000	0.967	1.035	1.059	1.000	1.116	0.949	1.017	1.000	1.012	1.005	1.062	1.000	0.926	1.147	0.879	1.000	0.932	0.943	1.126	1.000	1.287	0.875
LCIT	0.757	1.000	0.720	1.051	0.730	1.000	0.755	0.968	0.869	1.000	0.827	1.050	0.714	1.000	0.845	0.845	2.269	1.134	1.770	1.131	0.982	1.007	1.001	0.975
LCB1	0.918	1.000	0.866	1.059	0.942	1.000	0.977	0.964	1.033	1.000	0.883	1.169	2.935	1.189	2.482	0.995	1.086	1.003	1.026	1.056	0.745	1.001	0.773	0.964
CTB	0.748	0.969	0.755	1.024	1.225	0.995	1.264	0.974	0.629	0.936	0.702	0.957	1.363	1.092	1.072	1.164	0.774	0.989	0.834	0.938	0.906	1.000	0.958	0.945
NSCT	0.871	0.952	0.948	0.965	0.832	0.935	0.927	0.959	0.988	1.036	1.067	0.893	0.740	0.903	0.780	1.051	0.941	1.031	0.917	0.995	1.036	1.018	1.045	0.974
AMCT	1.048	1.000	1.000	1.048	0.963	1.000	1.000	0.963	0.789	1.000	0.888	0.888	1.241	1.000	1.053	1.178	0.856	1.000	0.927	0.924	0.974	1.000	0.986	0.988
MCT	1.066	1.000	1.038	1.027	0.969	1.000	1.038	0.934	0.940	1.000	0.940	1.001	0.876	1.000	0.951	0.922	2.202	1.287	1.765	0.970	1.156	1.059	1.139	0.958
MICT	1.032	0.993	1.033	1.007	0.892	0.975	1.007	0.909	0.837	0.965	0.893	0.971	0.902	0.985	0.933	0.981	0.976	1.003	0.995	0.979	1.031	1.009	1.021	1.001
JSCT	1.012	0.993	0.970	1.050	1.068	1.006	1.119	0.949	0.955	1.035	0.961	0.961	0.817	0.983	0.847	0.981	0.982	1.033	0.966	0.985	1.098	1.007	1.061	1.027
JNCT	0.846	1.000	0.834	1.015	0.338	0.987	0.368	0.931	0.583	1.000	0.598	0.975	0.651	0.969	0.674	0.998	0.870	0.985	0.882	1.001	0.742	0.937	0.780	1.015
NSICT	0.697	0.958	0.712	1.022	0.779	0.970	0.845	0.950	0.971	1.000	0.933	1.041	1.025	1.003	1.017	1.005	0.914	0.997	0.923	0.993	0.951	1.000	0.975	0.975
SAGT	0.912	1.000	0.864	1.055	0.747	1.181	0.641	0.986	1.879	1.009	1.560	1.193	1.099	1.011	1.069	1.017	1.032	0.990	0.954	1.093	0.556	0.910	0.635	0.962
MPE	0.836	0.980	0.807	1.057	0.861	1.006	0.906	0.944	0.706	0.965	0.724	1.011	0.678	0.988	0.725	0.947	0.857	0.985	0.871	0.998	0.855	0.996	0.889	0.966
T37	0.833	0.990	0.829	1.016	0.947	0.997	0.973	0.977	1.035	1.000	1.064	0.973	1.146	1.091	1.127	0.933	1.057	0.995	0.966	1.100	0.975	1.018	0.995	0.962
TT	0.875	0.999	0.861	1.017	0.799	0.947	0.855	0.988	0.861	0.980	0.768	1.144	1.425	1.016	1.339	1.048	1.075	0.992	0.913	1.186	0.904	1.011	0.946	0.945
DCT	1.051	1.000	1.000	1.051	0.941	1.000	1.000	0.941	0.702	1.000	0.834	0.842	0.861	1.000	0.928	0.928	0.904	1.000	0.888	1.018	0.897	1.000	0.937	0.957
RSCT	0.950	1.000	1.000	0.950	0.994	1.000	1.000	0.994	0.816	1.000	0.911	0.895	1.061	1.000	0.986	1.076	0.949	1.000	0.974	0.974	1.010	1.000	1.005	1.005
TPCT	0.992	0.992	1.006	0.994	0.998	1.068	0.959	0.975	1.086	1.034	1.058	0.993	0.855	1.017	0.941	0.893	0.781	0.874	0.802	1.114	0.846	0.997	0.886	0.958
SPCT	0.842	0.963	0.866	1.011	0.980	1.021	1.038	0.925	0.399	0.839	0.509	0.935	0.792	0.924	0.840	1.021	0.791	0.982	0.864	0.932	1.159	1.013	1.123	1.019
ASCT	0.963	1.000	0.955	1.008	0.532	1.000	0.534	0.996	0.900	1.000	0.859	1.047	1.182	1.000	1.138	1.039	0.987	1.000	0.925	1.067	0.880	1.000	0.914	0.963
SACT	0.879	1.000	0.882	0.996	0.838	1.000	0.880	0.953	0.983	1.000	0.928	1.060	0.922	1.000	0.933	0.989	1.024	1.000	0.941	1.088	0.544	1.000	0.557	0.977
VCT	0.988	0.963	1.023	1.003	0.833	0.940	0.923	0.961	0.760	0.991	0.869	0.883	1.056	1.029	1.067	0.961	1.236	1.093	1.214	0.931	0.999	1.036	1.021	0.945
VT	0.909	1.000	0.983	0.924	0.935	1.000	1.000	0.935	1.494	1.108	1.302	1.035	0.952	1.016	0.989	0.947	0.951	1.007	1.045	0.904	0.868	1.005	0.933	0.926
LSCT	1.139	1.000	1.092	1.043	1.001	1.000	1.040	0.962	1.065	1.052	1.018	0.995	1.095	1.073	1.047	0.975	1.016	0.979	0.996	1.042	0.975	0.977	1.041	0.959
KCT	0.802	1.000	0.810	0.990	1.089	1.023	1.125	0.946	0.497	0.978	0.572	0.888	0.966	1.000	1.013	0.953	0.839	1.091	0.828	0.928	0.858	0.966	0.940	0.945
CCT	0.861	1.000	0.829	1.040	0.700	1.000	0.716	0.977	0.875	1.000	0.873	1.002	1.913	1.219	1.554	1.010	0.473	0.918	0.483	1.066	1.203	1.091	1.115	0.989
MIT	1.059	0.996	1.032	1.030	1.005	0.952	1.052	1.004	0.956	0.988	0.884	1.094	0.798	0.966	0.830	0.995	0.906	0.957	0.884	1.070	2.128	1.106	1.945	0.989
PQIT	1.439	1.000	1.404	1.025	0.896	1.000	0.915	0.979	0.683	1.000	0.698	0.979	0.618	1.000	0.674	0.917	1.807	1.000	1.681	1.075	0.830	1.000	0.859	0.967
ACT	1.080	1.000	1.022	1.057	0.987	1.000	1.015	0.972	1.084	1.000	0.943	1.150	0.909	1.000	0.901	1.009	0.952	1.000	0.974	0.977	0.913	1.000	0.913	1.000

Appendix 28: Malmquist Productivity Index: Regulatory-Period TFP Change

Terminals	2000-2006				2000-2004				2004-2006			
	MPI	PEC	SEC	TC	**MPI**	PEC	SEC	TC	**MPI**	PEC	SEC	TC
CT3	3.293	1.000	1.596	2.064	1.997	1.000	1.059	1.886	3.110	1.000	1.507	2.064
T8E	0.837	1.000	0.962	0.870	0.832	1.000	0.962	0.866	0.870	1.000	1.000	0.870
MTL	0.920	1.000	1.000	0.920	1.070	1.075	1.040	0.958	0.823	0.931	0.961	0.920
HIT	0.897	1.000	1.000	0.897	0.991	1.000	1.000	0.991	0.897	1.000	1.000	0.897
SCT	0.986	1.002	1.115	0.882	0.977	1.000	1.128	0.867	0.874	1.002	0.989	0.882
SKCT	1.128	1.170	0.924	1.044	0.715	1.035	0.614	1.125	1.775	1.131	1.504	1.044
YICT	0.707	0.922	0.895	0.857	0.705	0.922	0.895	0.855	0.857	1.000	1.000	0.857
GCT	0.968	1.033	1.058	0.886	0.833	1.003	0.927	0.896	1.042	1.031	1.141	0.886
HBCT	0.783	1.042	0.836	0.898	0.869	0.908	1.068	0.896	0.807	1.147	0.783	0.898
PECT	0.867	1.015	0.828	1.031	0.717	0.943	0.832	0.914	1.105	1.077	0.995	1.031
HGCT	0.839	1.000	0.751	1.117	0.735	1.000	0.678	1.084	1.237	1.000	1.107	1.117
UCT	0.582	1.000	0.555	1.049	0.579	1.000	0.561	1.033	1.037	1.000	0.988	1.049
ECTD	0.451	0.764	0.700	0.842	0.543	0.795	0.733	0.932	0.773	0.961	0.955	0.842
MDCT	0.274	0.820	0.369	0.905	0.301	0.837	0.381	0.945	0.859	0.980	0.969	0.905
YCT	0.588	0.881	0.753	0.887	0.625	0.909	0.715	0.961	0.904	0.969	1.052	0.887
BCT	0.844	0.904	0.942	0.991	0.967	0.904	0.942	1.135	0.991	1.000	1.000	0.991
TTC	0.592	0.867	0.727	0.940	0.658	0.906	0.727	0.999	0.898	0.956	1.000	0.940
CTH	0.801	0.893	1.069	0.839	0.851	0.894	1.071	0.889	0.837	0.999	0.998	0.839
JACT	0.492	0.755	0.751	0.868	0.469	0.788	0.710	0.838	0.879	0.958	1.058	0.868
PRCT	0.560	0.900	0.709	0.878	0.684	0.917	0.868	0.859	0.703	0.981	0.817	0.878
LBPF	0.834	0.950	0.590	1.487	0.879	0.903	0.594	1.638	1.555	1.053	0.993	1.487
LBPT	0.553	0.730	0.868	0.874	0.810	0.913	1.015	0.873	0.597	0.799	0.855	0.874
NPCT	0.791	0.900	0.987	0.891	0.789	0.883	0.969	0.921	0.924	1.019	1.018	0.891
WPCT	0.282	0.763	0.360	1.026	0.402	0.826	0.433	1.123	0.789	0.925	0.832	1.026
QQCT	0.339	1.022	0.387	0.859	0.507	1.151	0.454	0.970	0.649	0.888	0.851	0.859
PNTC	0.629	1.010	0.713	0.873	0.767	0.987	0.819	0.948	0.777	1.023	0.870	0.873
PTP	0.496	0.795	0.693	0.902	0.516	0.825	0.697	0.898	0.864	0.964	0.994	0.902
TOCT	0.273	0.950	0.269	1.070	0.320	0.957	0.316	1.057	0.902	0.992	0.849	1.070
XNWT	0.562	1.000	0.589	0.955	0.671	1.000	0.610	1.100	0.922	1.000	0.965	0.955
NP	0.267	0.935	0.324	0.881	0.300	0.950	0.359	0.879	0.782	0.984	0.901	0.881

Appendix 28(Continued)

Terminals	2000-2006				2000-2004				2004-2006			
	MPI	PEC	SEC	TC	**MPI**	PEC	SEC	TC	**MPI**	PEC	SEC	TC
TP	0.888	0.944	0.933	1.008	0.801	0.927	0.835	1.036	1.148	1.019	1.118	1.008
NCB	1.192	1.000	1.276	0.934	0.993	1.000	0.877	1.132	1.359	1.000	1.455	0.934
LCIT	0.607	1.141	0.504	1.056	0.386	1.000	0.428	0.903	1.418	1.141	1.176	1.056
LCB1	1.220	1.193	0.920	1.111	1.549	1.189	1.196	1.089	0.858	1.004	0.769	1.111
CTB	0.763	0.974	0.791	0.990	0.957	0.985	0.858	1.132	0.902	0.989	0.922	0.990
NSCT	0.634	0.874	0.822	0.883	0.690	0.832	0.911	0.909	0.836	1.050	0.902	0.883
AMCT	0.946	1.000	1.000	0.946	1.043	1.000	1.000	1.043	0.946	1.000	1.000	0.946
MCT	1.316	1.363	1.136	0.851	0.970	1.000	1.038	0.934	1.269	1.363	1.094	0.851
MICT	0.799	0.932	1.004	0.854	0.796	0.921	0.991	0.872	0.876	1.012	1.013	0.854
JSCT	0.898	1.057	0.956	0.888	0.924	1.017	0.990	0.918	0.892	1.040	0.965	0.888
JNCT	0.095	0.882	0.112	0.968	0.119	0.956	0.135	0.919	0.737	0.923	0.825	0.968
NSICT	0.465	0.929	0.504	0.993	0.510	0.932	0.539	1.016	0.926	0.997	0.936	0.993
SAGT	0.535	1.085	0.393	1.256	0.825	1.205	0.553	1.238	0.804	0.901	0.710	1.256
MPE	0.313	0.923	0.368	0.920	0.396	0.940	0.441	0.955	0.753	0.982	0.834	0.920
T37	0.667	1.089	0.668	0.917	0.740	1.076	0.754	0.911	0.822	1.012	0.886	0.917
TT	0.521	0.944	0.428	1.290	0.642	0.941	0.582	1.173	0.952	1.003	0.736	1.290
DCT	0.724	1.000	1.000	0.724	0.773	1.000	1.000	0.773	0.724	1.000	1.000	0.724
RSCT	0.903	1.000	1.000	0.903	0.926	1.000	1.000	0.926	0.903	1.000	1.000	0.903
TPCT	0.731	0.971	0.822	0.915	0.881	1.114	0.944	0.838	0.695	0.872	0.871	0.915
SPCT	0.520	0.757	0.747	0.918	0.455	0.762	0.668	0.893	1.021	0.994	1.119	0.918
ASCT	0.423	1.000	0.377	1.122	0.501	1.000	0.459	1.092	0.923	1.000	0.822	1.122
SACT	0.334	1.000	0.316	1.057	0.637	1.000	0.641	0.994	0.522	1.000	0.493	1.057
VCT	0.874	1.044	1.156	0.724	0.749	0.922	0.992	0.818	0.955	1.132	1.165	0.724
VT	1.354	1.139	1.524	0.780	1.328	1.126	1.340	0.880	0.898	1.012	1.137	0.780
LSCT	1.438	1.079	1.337	0.997	1.617	1.128	1.386	1.034	0.920	0.956	0.965	0.997
KCT	0.491	1.054	0.659	0.706	0.773	1.054	1.038	0.706	0.498	0.635	1.000	0.784
CCT	0.351	1.220	0.299	0.962	0.696	1.219	0.559	1.020	0.515	1.001	0.534	0.962
MIT	1.053	0.958	0.989	1.111	0.828	0.905	0.842	1.087	1.381	1.058	1.174	1.111
PQIT	0.595	1.000	0.623	0.955	0.618	1.000	0.653	0.947	0.911	1.000	0.954	0.955
ACT	0.849	1.000	0.691	1.227	0.951	1.000	0.760	1.251	1.116	1.000	0.909	1.227

Appendix 29: A Generic Model for Assessing the Cost-Benefit of Security Investment

One of the major issues in the current port security framework is the existence of a plethora of regulations targeting at container port operating and management systems. Most of these regulations are overlapping in both scope and nature, but both researchers and regulators justify this overlap by the need to establish a multi-layer regulatory system in an effort to fill potential security gaps (Flynn, 2004; Willis and Ortiz, 2004; CBP, 2006). The problem with overlapping security regulations is that many of them duplicate similar security requirements, which creates confusion as to which security regulation to select and implement in order to improve a terminal's security.

Using the frameworks and methods developed in this thesis and as a guide for the port industry to embark on new security measures, we propose a general efficiency model, which is also suitable for implementing and managing the current security framework. The proposed model translates various security regulations into a set of security components, the categorisation and prioritisation of which depend on their relative performance in reducing costs and risk exposure and/or optimising commercial rewards, operational efficiency, and competitive advantage.

Port operators invest an ***M*** amount of security input (equipment, technology, labour, etc.) to produce an ***S*** amount of security output (lower risk exposure, improved security, reduced cargo dwell time, lesser physical inspections, fast-lane treatment, etc.). Therefore, the assessment of a terminal's security performance can be analysed by estimating an efficiency production frontier whereby the terminal seeks to maximise security rewards from a given amount of security investments and/or minimise security investment to achieve a particular or standard security objective. Because of different operational and management features (type of trade, types of ships serviced, size of operations, etc.) terminal operators or DMUs, will choose different bundles of security components in order to achieve the desired and/or required security output. The efficient frontier in Figure 41 represents the relationship between the input (***M***) and output (***S***) of security. As we move along the efficiency frontier, we observe that terminals A, B and C are all efficient in their security investments although each of them chooses a different bundle of security regulations. Conversely, terminal D is inefficient because it lies below the efficiency frontier. For terminal D to be efficient, it has either to increase its security output to the level achieved by terminal C or decrease its security inputs to a level similar to that of terminal B.

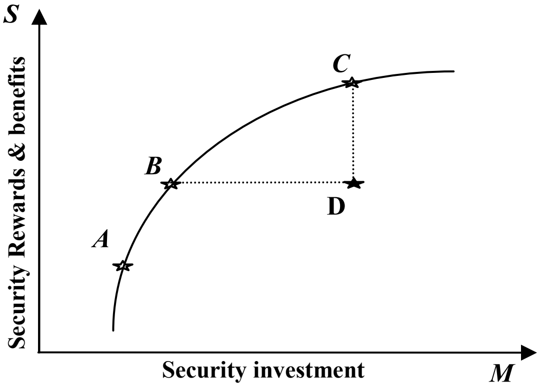


Figure 41: Security investment efficiency frontier

Assuming a set of security regulations and procedures, it is then possible to disaggregate them into a series of security components each with a different proportion of costs or investments ($M = m_0, m_1, \dots, m_n$) versus corresponding amounts of benefits or rewards ($S = s_0, s_1, \dots, s_n$). Let $M = [m_0, m_1, m_2, \dots, m_{15}]$ be the set of security components for Terminal A as shown in table 39.

Table 39: Security components for terminal A

Security Component	Description
M1	Security management system (ISO 28000)
M2	Port security officer (ISPS)
M3	Port security plan (ISPS)
M4	Security training drills (ISPS)
M5	security alarms - general (ISPS/ CSI)
M6	security alarms- terminal sheds (ISPS/ CSI)
M7	Control access to terminal (ISPS/ CSI)
M8	Security patrol (ISPS/ CSI)
M9	security patrol cargo areas (ISPS/ CSI)
M10	monitoring restricted areas (ISPS/ CSI)
M11	Auto CCTV terminal and cargo (ISPS/ CSI)
M12	Physical inspection (ISPS/ CSI)
M13	Scanning and screening equipment (CSI)
M14	Container seals/ reading equipment (ISPS/ CSI)
M15	Automated manifest systems (24-hr rule)

Based on the feedbacks from terminal managers of CT3 in Hong Kong (CT3 is being operated by DP World and is therefore ISO 28000 compliant), a hypothetical simulation of terminal ‘A’ security components’ performance is shown in Table 40. The simulation shows that for a number of different prescribed potential security incidents in terminal operations, the security management system (M1) was successful in deterring 45.8% of all security incidents on average while container scanning and screening (M13) was able to detect 43.5% of security incidents. Note that a detailed performance analysis integrating all aspects of security benefits (not just the deterrence of security incidents) is beyond the scope of this study.

Table 40: Simulation of terminal 'A' security component performance

	S	
Security Components	Mean	Standard Deviation
M1	.458	.264
M2	.340	.574
M3	.254	.535
M4	.121	.392
M5	.213	.217
M6	.283	.237
M7	.153	.134
M8	.216	.392
M9	.187	.141
M10	.138	.185
M11	.256	.315
M12	.354	.371
M13	.435	.123
M14	.175	.154
M15	.341	.116

Using data on investments in security equipment and procedures, it is possible to construct an efficiency frontier that shows the relationship between the cost and benefit of terminal security. This can be analysed empirically by applying the same analytical frontier technique, i.e. DEA, used in this study. In the context of this thesis, the model can be used to examine which bundle of security components can achieve the highest productive efficiency while still complying with regulatory requirements. It can also be used as a decision and management tool for evaluating the relative efficiency of terminal operators in investing in and/or implementing new security initiatives and regulations. This can be particularly useful for future security initiatives such as the US secure freight initiative (SFI).