TERMINAL EXPANSION MODEL FOR A CONTAINER PORT FOR JOHOR PORT

LOKE KENG BIN

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To my beloved family

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ABSTRACT

At present, container terminal's expansion models did not consider small changes in commercial viability with small changes in expansion size over time. This study intends to develop an alternative container terminal's expansion model based on marginal approach. The treatment of each of these variables should be done separately for the increase in demand that may require one variable to be immediately expanded while other variables may have cope with and sustain the increase in demand. An algorithm's expansion model is generated to calculate the expansion size, expansion time, interval of expansion and significant of expansion for each of the expansion variables, respectively. A case study was performed in Johor Port Berhad to validate the practicability and workability of the algorithm model. The initial result shows that the subsequent expansion for rubber tyred gantry crane starts in the year 2021. The expansion size of quay crane and rubber tyred gantry crane is one unit per time. The expansion size of prime mover is two units per time. The first expansion time for quay crane is in the year 2023, and the interval period is four to five years. The first expansion time for rubber tyred gantry crane is in the year 2021, and the interval period is one to two years. The first expansion time for prime mover is in the year 2025, and the interval period is one to two years. The reason for the one year allowance of the interval period is because the expansion size is based on the unit of infrastructure purchase and not based on 20-foot equivalent unit capacity. All the expansion stage is positive for the net present value. On the other hand, the algorithm model shows that the berth capacity requirement, container park area, container freight station and terminal other areas are sustainable over the planning time horizon and not based on expansion required. The research has successfully identified five key infrastructural components of the container terminal, and developed a generic mathematical model to calculate the marginal expansion required.

ABSTRAK

Pada masa ini, model pengembangan kontena terminal tidak mempertimbangkan perubahan kecil dengan keupayaan komersial dalam ukuran saiz pengembangan sepanjang masa. Kajian ini bertujuan untuk membangunkan model alternatif pengembangan kontena terminal berdasarkan pendekatan berjidar. Kajian terhadap setiap pembolehubah pengembangan harus dilakukan secara berasingan bagi setaip peningkatan dengan permintaan. Satu pembolehubah pengembangan mungkin memerlukan pengembangan segera manakala pembolehubah pengembangan lain mungkin dapat menampung dan mengekalkannya dengan peningkatan dalam permintaan. Model pengembangan algoritma dihasilkan untuk mengira saiz pengembangan, masa pengembangan, selang pengembangan dan pengembangan signifikan masing-masing bagi setiap pembolehubah pengembangan. Satu kajian kes telah dilakukan di Johor Port Berhad untuk mengesahkan secara praktik dan kebolehan pelaksanaannya. Keputusan menunjukkan bahawa pengembangan kren gantri bertayar getah bermula pada tahun 2021. Saiz pengembangan kren dermaga dan kren gantri bertayar getah adalah satu unit untuk setiap kali pembelian. Saiz pengembangan lori adalah dua unit untuk setiap kali pembelian. Masa pengembangan pertama bagi kren dermaga adalah pada tahun 2023, dan tempoh selang adalah empat hingga lima tahun. Masa pengembangan pertama bagi kren gantri bertayar getah adalah pada tahun 2021, dan tempoh selang adalah satu hingga dua tahun. Masa pengembangan pertama bagi lori adalah pada tahun 2025, dan tempoh selang adalah satu hingga dua tahun. Tempoh selang selama satu tahun lazim diberikan kerana saiz pengembangan adalah berdasarkan unit pembelian infrastruktur dan tidak berdasarkan kepada saiz kontena. Semua peringkat pengembangan adalah positif bagi nilai bersih terkini. Seterusnya, model algoritma menunjukkan bahawa bilangan dermaga kren, tempat letak kontena, stesen gudang dan kawasan terminal lain adalah mampan di sepanjang masa perancangan dan tiada pengembangan diperlukan. Kajian ini telah berjaya mengenal pasti lima infrastruktur komponen utama bagi kontena terminal dan membangunkan satu model matematik generik untuk mengira pengembangan secara berjidar.

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LIST OF ABBREVIATIONS

bcr	-	Berth Capacity Requirement
bdr	-	Berth-Day Requirement
Bhd.	-	Berhad
cfs	-	Container Freight Station
chs	-	Container Handling System
cpa	-	Container Park Area
cte	-	Container Terminal Expansion
dQ	-	Change In Demand
DM1	-	First Decision Making
DM2	-	Second Decision Making
EDI	-	Electronic Data Interchange
EOQ	-	Economic Order Quantity
et. al.	-	And Co-Workers
FCL	-	Full-Container-Load
ha	-	Hectare
i^{th}	-	Number Of Year
ITU	-	Intermodal Transport Units
LCL	-	Less-Than-Container-Load
n	-	Multiple Units
NA	-	Non-Applicable
NPV	-	Net Present Value
m	-	Minimum Purchase Unit
MPH	-	Move Per Hour
PC	-	Personal Computer
pm	-	Prime Mover
qc	-	Quay Crane
RM	-	Ringgit Malaysia

rtg	-	Rubber-Tyred Gantry Crane
sc	-	Straddle Carrier
sct	-	Ship’ Cost At Terminal
TEU	-	Twenty-Foot Equivalent Units
toa	-	Terminal Other Area

LIST OF SYMBOLS

%	-	Percentage
λ	-	Economy’s scale factors
γ_{ct}	-	Gradient from the plot of demand growths for container throughput
γ_{gt}	-	Gradient from the plot of demand growths for cargo throughput
γ_{lt}	-	Gradient from the plot of demand growths for lorry throughput
γ_{vt}	-	Gradient from the plot of demand growths for vessel throughput
$\$_{bcr=1}$	-	First of the investment cost for bcr
$\$_{bcr=2}$	-	Second of the investment cost for bcr
$\$_{bcr=n}$	-	Thereafter expansion times of the investment cost for bcr
$\$_{cfs=1}$	-	First of the investment cost for cfs
$\$_{cfs=2}$	-	Second of the investment cost for cfs
$\$_{cfs=n}$	-	Thereafter expansion times of the investment cost for cfs
$\$_{cpa=1}$	-	First of the investment cost for cpa
$\$_{cpa=2}$	-	Second of the investment cost for cpa
$\$_{cpa=n}$	-	Thereafter expansion times of the investment cost for cpa
$\$_{pm=1}$	-	First of the investment cost for pm
$\$_{pm=2}$	-	Second of the investment cost for pm
$\$_{pm=n}$	-	Thereafter expansion times of the investment cost for pm
$\$_{qc=1}$	-	First of the investment cost for qc
$\$_{qc=2}$	-	Second of the investment cost for qc
$\$_{qc=n}$	-	Thereafter expansion times of the investment cost for qc

$\$_{rtg=1}$	-	First of the investment cost for rtg
$\$_{rtg=2}$	-	Second of the investment cost for rtg
$\$_{rtg=n}$	-	Thereafter expansion times of the investment cost for rtg
$\$_{toa=1}$	-	First of the investment cost for toa
$\$_{toa=2}$	-	Second of the investment cost for toa
$\$_{toa=n}$	-	Thereafter expansion times of the investment cost for toa
A	-	Time horizon demand
a	-	Expected profits generated over the next n year
AOH_{bcr}	-	Average operation hour of vessel
AOH_{toa}	-	Average operation hour of lorry
bcr	-	Berth capacity requirement
bcr_{future}	-	Total unit required of bcr for the future demand
bcr_{now}	-	Current supply of berth
C	-	Cost per unit of infrastructure
C_{bcr}	-	Cost of the expanded part of bcr (except the initial investment cost)
C_{cfs}	-	Cost of the expanded part of cfs (except the initial investment cost)
C_{cpa}	-	Cost of the expanded part of cpa (except the initial investment cost)
C_{pm}	-	Cost of the expanded part of pm (except the initial investment cost)
C_{qc}	-	Cost of the expanded part of qc (except the initial investment cost)
C_{rtg}	-	Cost of the expanded part of rtg (except the initial investment cost)
C_{toa}	-	Cost of the expanded part of toa (except the initial investment cost)
cfs	-	Container freight station
cfs_{future}	-	Total unit required of cfs for the future demand (ground slot)
cfs_{now}	-	Current supply of cfs (ground slot)
chs	-	Container handling system
cpa	-	Container park area
cpa_{future}	-	Total unit required of cpa for the future demand (ground slot)

cpa_{now}	-	Current supply of cpa (ground slot)
cte	-	Container terminal expansion
D_{bcr}	-	Dues collected from that particular expansion of bcr
D_{bcrt}	-	Total dues collected after expansion of bcr
D_{cfs}	-	Dues collected from that particular expansion of cfs
D_{cfst}	-	Total dues collected after expansion of cfs
D_{cpa}	-	Dues collected from that particular expansion of cpa
D_{cpat}	-	Total dues collected after expansion of cpa
D_i	-	Interval time
D_{pm}	-	Dues collected from that particular expansion of pm
D_{pmt}	-	Total dues collected after expansion of pm
D_{qc}	-	Dues collected from that particular expansion of qc
D_{qct}	-	Total dues collected after expansion of qc
D_{rtg}	-	Dues collected from that particular expansion of rtg
D_{rtgt}	-	Total dues collected after expansion of rtg
D_{toa}	-	Dues collected from that particular expansion of toa
D_{toat}	-	Total dues collected after expansion of toa
dt_{cfs}	-	Dwell time of cargo in cfs
dt_{cpa}	-	Dwell time of container in cpa
FP_{bcr}	-	Fees (e.g. salary) paid to berth operator in time t
FP_{cfs}	-	Fees (e.g. salary) paid to cfs operator in time t
FP_{cpa}	-	Fees (e.g. salary) paid to cpa operator in time t
FP_{pm}	-	Fees (e.g. salary) paid to pm operator in time t
FP_{qc}	-	Fees (e.g. salary) paid to qc operator in time t
FP_{rtg}	-	Fees (e.g. salary) paid to rtg operator in time t
FP_{toa}	-	Fees (e.g. salary) paid to gate operator in time t
I	-	Estimation of total net income per power δT_t from the new Investment
I_{bcr}	-	Net income from that particular expansion of bcr
I_{cfs}	-	Net income from that particular expansion of cfs
I_{cpa}	-	Net income from that particular expansion of cpa
I_i	-	Investment cost
I_{pm}	-	Net income from that particular expansion of pm
I_{qc}	-	Net income from that particular expansion of qc

I_{rtg}	-	Net income from that particular expansion of rtg
I_{toa}	-	Net income from that particular expansion of toa
IRP_t	-	Investment recovery period
$K_{e,i}$	-	Capacity expansion
m	-	Minimum purchasing unit/minimum construction unit
M_{bcr}	-	Tariff per service of vessel throughput in berth
M_{cfs}	-	Tariff per service of cargo throughput in cfs
M_{cpa}	-	Tariff per service of container throughput in cpa
M_{pm}	-	Tariff per service of container throughput of pm
M_{qc}	-	Tariff per service of container throughput of qc
M_{rtg}	-	Tariff per service of container throughput of rtg
M_{toa}	-	Tariff per service of lorry throughput in toa
MC_{bcr}	-	Berth maintenance costs in time t
MC_{cfs}	-	cfs maintenance costs in time t
MC_{cpa}	-	cpa maintenance costs in time t
MC_{pm}	-	pm maintenance costs in time t
MC_{qc}	-	qc maintenance costs in time t
MC_{rtg}	-	rtg maintenance costs in time t
MC_{toa}	-	toa maintenance costs in time t
MIT_{bcr}	-	Berth mitigation (other costs) costs in time t
MIT_{cfs}	-	cfs mitigation (other costs) costs in time t
MIT_{cpa}	-	cpa mitigation (other costs) costs in time t
MIT_{pm}	-	pm mitigation (other costs) costs in time t
MIT_{qc}	-	qc mitigation (other costs) costs in time t
MIT_{rtg}	-	rtg mitigation (other costs) costs in time t
MIT_{toa}	-	toa mitigation (other costs) costs in time t
MPH_{pm}	-	Move Per Hour for prime mover
MPH_{qc}	-	Move Per Hour for quay crane
MPH_{rtg}	-	Move Per Hour for rubber-tyre gantry crane
n	-	Number unit/duplicate of m
NPV	-	Net present value
NPV_{bcr}	-	Net present value for the investment return of berth capacity requirement

NPV_{cfs}	-	Net present value for the investment return of container freight system
NPV_{cpa}	-	Net present value for the investment return of container park area
NPV_{pm}	-	Net present value for the investment return of prime mover
NPV_{qc}	-	Net present value for the investment return of quay crane
NPV_{rtg}	-	Net present value for the investment return of rubber-tyred gantry crane
NPV_{toa}	-	Net present value for the investment return of terminal other areas
N_{bcr}	-	Number of bcr capacity requirement
$N_{bcr=1}$	-	First total requested expansion of bcr
$N_{bcr=2}$	-	Second total requested expansion of bcr
$N_{bcr=n}$	-	Thereafter expansion times of total requested expansion of bcr
N_{cfs}	-	Number of cfs capacity requirement
$N_{cfs=1}$	-	First total requested expansion of cfs
$N_{cfs=2}$	-	Second total requested expansion of cfs
$N_{cfs=n}$	-	Thereafter expansion times of total requested expansion of cfs
N_{cpa}	-	Number of cpa capacity requirement
$N_{cpa=1}$	-	First total requested expansion of cpa
$N_{cpa=2}$	-	Second total requested expansion of cpa
$N_{cpa=n}$	-	Thereafter expansion times of total requested expansion of cpa
N_{pm}	-	Number of pm capacity requirement
$N_{pm=1}$	-	First total requested expansion of pm
$N_{pm=2}$	-	Second total requested expansion of pm
$N_{pm=n}$	-	Thereafter expansion times of total requested expansion of pm
N_{qc}	-	Number of qc capacity requirement
$N_{qc=1}$	-	First total requested expansion of qc
$N_{qc=2}$	-	Second total requested expansion of qc
$N_{qc=n}$	-	Thereafter expansion times of total requested expansion of qc
N_{rtg}	-	Number of rtg capacity requirement
$N_{rtg=1}$	-	First total requested expansion of rtg
$N_{rtg=2}$	-	Second total requested expansion of rtg

$N_{rtg=n}$	-	Thereafter expansion times of total requested expansion of rtg
N_{toa}	-	Number of toa capacity requirement
$N_{toa=1}$	-	First total requested expansion of toa
$N_{toa=2}$	-	Second total requested expansion of toa
$N_{toa=n}$	-	Thereafter expansion times of total requested expansion of toa
OC_{bcr}	-	Berth operating costs in time t
OC_{cfs}	-	cfs operating costs in time t
OC_{cpa}	-	cpa operating costs in time t
OC_{pm}	-	pm operating costs in time t
OC_{qc}	-	qc operating costs in time t
OC_{rtg}	-	rtg operating costs in time t
OC_{toa}	-	toa operating costs in time t
OI_{bcr}	-	Berth operator's investment (e.g. training) spend in time t
OI_{cfs}	-	cfs operator's investment (e.g. training) spend in time t
OI_{cpa}	-	cpa operator's investment (e.g. training) spend in time t
OI_{pm}	-	pm operator's investment (e.g. training) spend in time t
OI_{qc}	-	qc operator's investment (e.g. training) spend in time t
OI_{rtg}	-	rtg operator's investment (e.g. training) spend in time t
OI_{toa}	-	toa operator's investment (e.g. training) spend in time t
P	-	Estimation of total principal investment over the planning time horizon
pf	-	Peak factor
Pi	-	Capital investment costs
Pi_{bcr}	-	Principal berth investment cost for that particular expansion time
Pi_{cfs}	-	Principal cfs investment cost for that particular expansion time
Pi_{cpa}	-	Principal cpa investment cost for that particular expansion time
Pi_{pm}	-	Principal pm investment cost for that particular expansion time
Pi_{qc}	-	Principal qc investment cost for that particular expansion time
Pi_{rtg}	-	Principal rtg investment cost for that particular expansion time
Pi_{toa}	-	Principal toa investment cost for that particular expansion time
pm	-	Prime mover

pm_{future}	-	Total unit required of pm for the future demand
pm_{now}	-	Current supply of prime mover
Q_0	-	Quantity demand at time = 0
Q_{c0}	-	Initial quantity demand of container throughput
Q_{ct}	-	Container throughput forecasting in time t
Q_{g0}	-	Initial quantity demand of cargo throughput
Q_{gt}	-	Cargo throughput forecasting in time t
Q_h	-	Quantity demand at time = h
Q_{l0}	-	Initial quantity demand of lorry throughput
Q_{lt}	-	Lorry throughput forecasting in time t
$Q_{bcr=1}$	-	First total handling capacity for the marginal expansion of bcr
$Q_{bcr=2}$	-	Second total handling capacity for the marginal expansion of bcr
$Q_{bcr=n}$	-	Thereafter expansion times of total handling capacity for the marginal expansion of bcr
Q_{bcrEOQ}	-	Optimal order quantity of bcr that a company should hold as a serving infrastructure
$Q_{cfs=1}$	-	First total handling capacity for the marginal expansion of cfs
$Q_{cfs=2}$	-	Second total handling capacity for the marginal expansion of cfs
$Q_{cfs=n}$	-	Thereafter expansion times of total handling capacity for the marginal expansion of cfs
Q_{cfsEOQ}	-	Optimal order quantity of cfs that a company should hold as a serving infrastructure
$Q_{cpa=1}$	-	First total handling capacity for the marginal expansion of cpa
$Q_{cpa=2}$	-	Second total handling capacity for the marginal expansion of cpa
$Q_{cpa=n}$	-	Thereafter expansion times of total handling capacity for the marginal expansion of cpa
Q_{cpaEOQ}	-	Optimal order quantity of cpa that a company should hold as a serving infrastructure
$Q_{pm=1}$	-	First total handling capacity for the marginal expansion of pm

$Q_{pm=2}$	-	Second total handling capacity for the marginal expansion of pm
$Q_{pm=n}$	-	Thereafter expansion times of total handling capacity for the marginal expansion of pm
Q_{pmEOQ}	-	Optimal order quantity of pm that a company should hold as a serving infrastructure
$Q_{qc=1}$	-	First total handling capacity for the marginal expansion of qc
$Q_{qc=2}$	-	Second total handling capacity for the marginal expansion of qc
$Q_{qc=n}$	-	Thereafter expansion times of total handling capacity for the marginal expansion of qc
Q_{qcEOQ}	-	Optimal order quantity of qc that a company should hold as a serving infrastructure
$Q_{rtg=1}$	-	First total handling capacity for the marginal expansion of rtg
$Q_{rtg=2}$	-	Second total handling capacity for the marginal expansion of rtg
$Q_{rtg=n}$	-	Thereafter expansion times of total handling capacity for the marginal expansion of rtg
Q_{rtgEOQ}	-	Optimal order quantity of rtg that a company should hold as a serving infrastructure
Q_{ti}	-	Demand quantity
$Q_{toa=1}$	-	First total handling capacity for the marginal expansion of toa
$Q_{toa=2}$	-	Second total handling capacity for the marginal expansion of toa
$Q_{toa=n}$	-	Thereafter expansion times of total handling capacity for the marginal expansion of toa
Q_{toaEOQ}	-	Optimal order quantity of toa that a company should hold as a serving infrastructure
Q_t	-	Quantity demand at time = t
Q_{v0}	-	Initial quantity demand of vessel throughput
Q_{vt}	-	Vessel throughput forecasting in time t
qc	-	Quay crane
qc_{future}	-	Total unit required of qc for the future demand

qc_{now}	-	Current supply of quay crane
R	-	Holding costs as a percentage
r	-	Discount rate
RM_{bcr}	-	Dollar requirement per unit of berth
RM_{cfs}	-	Dollar requirement per unit of cfs
RM_{cpa}	-	Dollar requirement per unit of cpa
RM_{pm}	-	Dollar requirement per unit of pm
RM_{qc}	-	Dollar requirement per unit of qc
RM_{rtg}	-	Dollar requirement per unit of rtg
RM_{toa}	-	Dollar requirement per unit of toa
rtg	-	Rubber-tyred gantry crane
rtg_{future}	-	Total unit required of rtg for the future demand
rtg_{now}	-	Current supply of rubber-tyred gantry crane
$T_{bcr=1}$	-	First expansion time for the marginal expansion of bcr
$T_{bcr=2}$	-	Second expansion time for the marginal expansion of bcr
$T_{bcr=n}$	-	Thereafter expansion times for the marginal expansion of bcr
$T_{cfs=1}$	-	First expansion time for the marginal expansion of cfs
$T_{cfs=2}$	-	Second expansion time for the marginal expansion of cfs
$T_{cfs=n}$	-	Thereafter expansion times for the marginal expansion of cfs
$T_{cpa=1}$	-	First expansion time for the marginal expansion of cpa
$T_{cpa=2}$	-	Second expansion time for the marginal expansion of cpa
$T_{cpa=n}$	-	Thereafter expansion times for the marginal expansion of cpa
$T_{pm=1}$	-	First expansion time for the marginal expansion of pm
$T_{pm=2}$	-	Second expansion time for the marginal expansion of pm
$T_{pm=n}$	-	Thereafter expansion times for the marginal expansion of pm
$T_{qc=1}$	-	First expansion time for the marginal expansion of qc
$T_{qc=2}$	-	Second expansion time for the marginal expansion of qc
$T_{qc=n}$	-	Thereafter expansion times for the marginal expansion of qc
$T_{rtg=1}$	-	First expansion time for the marginal expansion of rtg
$T_{rtg=2}$	-	Second expansion time for the marginal expansion of rtg
$T_{rtg=n}$	-	Thereafter expansion times for the marginal expansion of rtg
$T_{toa=1}$	-	First expansion time for the marginal expansion of toa
$T_{toa=2}$	-	Second expansion time for the marginal expansion of toa

$T_{toa=n}$	-	Thereafter expansion times for the marginal expansion of toa
$TGS_{cfsfuture}$	-	Total ground slot of cfs required for the future demand
$TGS_{cpafuture}$	-	Total ground slot of cpa required for the future demand
t	-	Number of year
T_1	-	Fist investment
t_n	-	Number of year with planning time horizon
T_t	-	Maximum planning time horizon
T_{pth}	-	Maximum time for the planning time horizon
toa	-	Terminal other areas
toa_{future}	-	Total unit required of toa for the future demand
toa_{now}	-	Current supply of terminal other areas
rtg	-	Rubber-tyred gantry crane
rtg_{future}	-	Total unit required of rtg for the future demand
rtg_{now}	-	Current supply of rubber-tyred gantry crane
S	-	Cost per setup
SH_{cfs}	-	Stacking height of cfs level
SH_{cpa}	-	Stacking height of cpa level
toa_{now}	-	Current supply of entry gate
ut	-	Maximum utilisation rate of equipment

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Ninety percent of cargoes are likely to be containerised (Branch, 1986). In highly-developed trades, it is estimated that seventy percent of containers move in Full-Container-Load (FCL) basis; and the remaining by Less-Than-Container-Load (LCL) shipments. Likewise, more than 90% of international trades move through seaports and 80% of sea cargoes move in containers through major seaports. It proves that the worldwide container throughput increases approximately 11% annually (Won and Yong, 1999). Thereafter, world container throughput increased by 14.49% to 540 million 20-foot equivalent units (TEU) in 2010 (UNCTAD, 2012). Hence, the development and expansion of container terminal have become crucial in order to meet the demand of container traffic.

As its level of importance and needs increase, a lot of studies based on scientific methods have been proposed to solve the port development and expansion problems. This study underlines and elaborates the details on port development and expansion, past and current design approaches.

1.2 Research Background

The objective of port development and expansion is to provide terminal service and support future demand. Different parties have different ideas and intentions of port development and expansion; namely economic point of view, service efficiency, social factors, environmental issues, and etc.

1.2.1 Intention for Port Development and Expansion

The intention of port development and expansion is to maximize the net profit or minimize the cost of expenses (Frankel, 1987). In economic point of view, a port authority should meet the port service provided with minimum cost and as much profit as possible. With limited resources and supplies, port authority should plan the development and expansion needs that depends on the availability of resource's allocation.

Apart from economic factors, port development and expansion also express the service sufficiency level and social factors. Service sufficiency level is based on capacity, technology, working hours available; port effectiveness, and, etc. Social factors are looking at employment opportunities, trade-off effects, environmental impact, community development, stabilization of socioeconomic factors, and, etc. In short; the essential of port development and expansion is to support the internal and external requirements.

1.2.2 Basic Definitions on Port Development and Expansion

Mettam and Butcher (1988) highlighted that some of the port development and expansion planning focuses on engineering, economic, management, financial, or operation respectively. It does not have a proper aspect of port development an expansion plan. The varying focusing aspects are proposed for different objectives.

Dekker and Verhaeghe (2008) stress that port need development and expansion when the demand has achieved a certain number or increment. It is related to an adjustment of particular supply capacity at a certain point of time. UNCTAD (1985) described that port development and expansion planning is a series of method to calculate the requirement of capacity of a terminal to fulfil the current and future terminal traffic demand throughput. It uses the amount of twenty-foot equivalent units (TEU) to calculate the demand capacity, and then the ship's cost at a terminal to determine the acceptability of an expansion plan.

1.2.3 Basic Elements on Port Development and Expansion

There are numerous elements need to be considered during master planning, to select a suitable location for new development of port or extension of current port facilities; there is deep safe water at berthing points and approach channels; sufficient land area, and labour force, good connection to road, rail and waterway routes (UNCTAD, 1985).

To meet the container terminal's development and expansion requirement, the layout of a physical port is one of the important aspects that needed to be taken into account. To ensure a good coordination, reliability of operation, in favour for profit and benefit, the port layout or networking must be designed to fix the expected future demand (Chalid, 2009). To be successful in supporting the additional capacity throughput, features of port expansion normally include extra shipping berths, terminal land, depth of dredging area, road and rail connection, additional facilities and, etc.

Container handling system, area requirement, berth occupancy, information systems, schedule-day, container feeder services, and types of container handling equipment are the major considerations in container terminal planning. Area requirement has been analysed by UNCTAD (1985) and Frankel (1987) by determining the size of container park area and container freight station. Then, the berth occupancy has been figured out by berth-day requirement and ship cost. Financial aids also must be evaluated for any investment decision, to verify the impact upon the investment for that port for the financial health. Dekker (2008) extends the study on financial investigation by using the marginal approach.

1.2.4 Past and Current Models for Port Development and Expansion

UNCTAD (1985) used the planning chart concept to lead the different facilities or infrastructure. The formula has been converted into a chart for immediate use. Frankel, 1987 employed mathematical techniques to be familiar with the issues and methods of port planning and development. Thomas (1999) specified in the container handling system, by given significant efficiency and competence to the container terminal selected. Mohd Zamani (2006) utilized fuzzy methods to develop a planning model. He tried to improve the lack of human modes in planning approaches. Dekker and Verhaeghe, 2008 applied marginal approach to determine when, size and interval expansion time in such method. Figure 1.1 shows the existing and current port development and expansion approaches. The details of the models are described in Chapter 2.

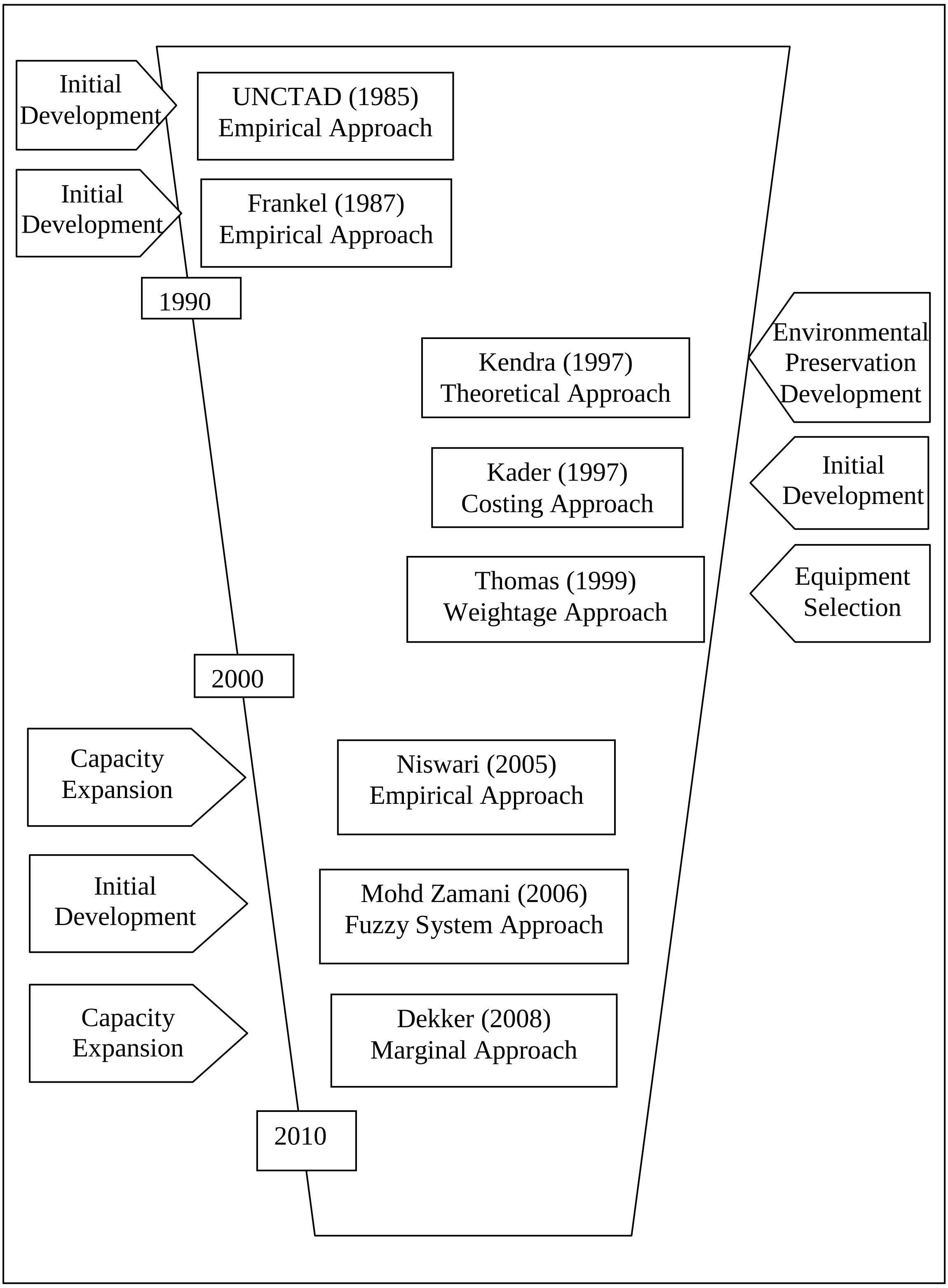

Figure 1.1 Existing and current port development and expansion approaches and stages

Table 1.1 Discrepancy between existing and current port development and expansion models

S/N	Approaches / Models	Applied	Features
1	Empirical Approach		
	i. UNCTAD, 1985	Initial Development	Capacity Planning
	ii. Frankel, 1987	Initial Development	Capacity Planning
	iii. Niswari, 2005	Expansion Estimation	Capacity Planning
2	Theoretical Approach		
	i. Kendra, 1997	Environmental Preservation	Environment Protection
3	Costing Approach		
	i. Kader, 1997	Development and Expansion	Cost Estimation
4	Weightage Approach		
	i. Thomas, 1999	Equipment Selection	Approximation Multi Container Decision Making
5	Fuzzy System Approach		
	i.Mohd Zamani, 2006	Initial Development	Uncertainly Approximation
6	Marginal Approach		
	i. Dekker, 2008	Expansion Estimation	Cost Optimum Control

Table 1.1 shows the discrepancy between existing and current port development and expansion models. UNCTAD Model (1985), Frankel Model (1987), and Mohd Zamani Model (2006) are special for initial port set up. Niswari Model (2005) and Dekker Model (2008) are particular for port expansion estimation. However, Kader Model (1997) is used for port initial development and expansion planning. But, it is unique for inland water way designs. On the other hand, Kendra Model (1997) and Thomas Model (1999) are specific for environment protection during port development and approximation multi container decision making respectively.

1.2.5 Marginal Approach in Port Development and Expansion

Roger (2004) describes that marginal cost is an increment of cost in producing an extra unit of output or cost saving by producing one unit less. Consequently, marginal approach is a method of decomposing of an investment plan into several investment sections that consider the support capacity with demand throughput and financial viability.

Dekker and Verhaeghe (2008) uses of marginal approach to optimise the investment which consider the economics of scale and utilisation rate. Dekker (2008) tries to determine the expansion time and size as well as the interval of expansion capacity. It uses Net Present Value (NPV) to control the marginal benefit.

1.3 Problem Statements

Most of the existing container terminal's expansion models are focused on the fulfillment of future throughput demand. The purpose of expansion is only to describe the overall terminal expansion with respect to increase in demand. At this moment, container terminal's expansion models are not considering small changes in commercial viability as well as in expansion magnitude over time.

Therefore, Dekker and Verhaeghe (2008) drew attention to marginal approach in container terminal's expansion planning. He proposed the use of NPV to calculate the significance of expansion in every single expansion step. However, his study only draws interest in total expansion in TEU, and neglected the expansion of the actual port infrastructure.

The expansion cost for expansion variables (actual infrastructure) is based upon the change in demand (dQ), but some expansion variables could sustain dQ but others may not. For example, storage area may need to be expanded while the number of quay crane can still be maintained. This sustaining period will continue until dQ increase to a new level to justify the next expansion, eg. storage and quay crane. Container terminal expansion will be more accurate if dQ and periods of sustaining for each expansion variable could be identified so that the expansion of infrastructure is at correct size and at the correct time.

Therefore, this study intends to look at the alternative ways of a container terminal's expansion model. It expands from existing approaches by translating the TEU as a variable into a group of practical variables; namely, container handling system (chs), berth capacity requirement (bcr), container part area (cpa), container freight station (cfs), and terminal other area (toa). Thereafter, this research uses NPV to evaluate the increment requirement for future throughput demand. The positive NPV represents the significance of increment of the expansion variables and size respectively for each expansion period. The purpose of using the marginal approach is to ensure a sustainable and economically effective expansion plan.

1.4 Research Objective

The main objective of this study is to develop a generic container terminal expansion model based on marginal approach. Therefore, this research embarks on the following objectives.

i. To identify the key infrastructural components of a port terminal that should be expanded based on marginal approach.

ii. To develop a generic mathematical model for the infrastructural expansion of port terminal based on marginal approach.

1.5 Significance of the Study

World seaborne trade via containers is continuously expanding and developing countries are expanding their container terminal facilities to cope with the demand. The current approach in handling the requirement of expansion is relying too much on textbook guidelines for port development. Terminal expansion is better if it is planned by using the marginal approach. The terminal expansion variables (e.g. infrastructure, equipment, area, and, etc.) should be identified and blended with elements that constrain terminal expansion. The main task is to transform input data into logical mathematical expressions. The final expression is mathematical algorithm, and it serves as a model for the expansion of the decision making tools to assist port expansion planners.

1.6 Scope of Study

Towards achieving the objectives, the research has to chase on the following scopes.

i. The container terminal expansion and not total port expansion.

ii. It embarks from currently accepted words on terminal expansion such as container handling system (chs), berth capacity requirement (bcr), container park area (cpa), container freight station (cfs), and terminal other area (toa), and marginal expansion model

iii. The expansion sizes for each expansion variable in each increment of container traffic demand.

iv. Sustenance period and expansion period for each expansion variable in each increment of container traffic demand.

v. An expansion model which combine the various common sectors of container terminal into consideration such as the expansion variables, size and time.

1.7 Conceptual Framework

Several studies and approaches have been used to evaluate and organize the port development and expansion model between 1985 and 2008. Mohd Zamani (2006) established fuzzy expert system to assess the container terminal development planning. He adapted the expansion variables from UNCTAD (1985), Frankel (1987), and Thomas (1999). Dekker and Verhaeghe (2008) established marginal approach to determine maximum capacity extension in TEU/year. However, it did not deal with the expansion variables (infrastructure) individually. Some of the infrastructure can sustain the throughput demand, but some may not, therefore, this research extent from Dekker model and deal with its limitation. This research revises the marginal approach model with expansion variables focusing on expansion time, and expansion size. Figure 1.2 shows the formulation of a conceptual framework for container terminal expansion model by the marginal approaches that deal with expansion variables.

Kendra (1997) focused on environmental control and Kader (1997) model focused on inland waterway transport system. Both of the models are not related to container seaport operation needs. Niswari (2005) model focused on berth and yard expansion needs only. It did not consider the entire container terminal operation requirement. As a result, three of these models are not included in this study.

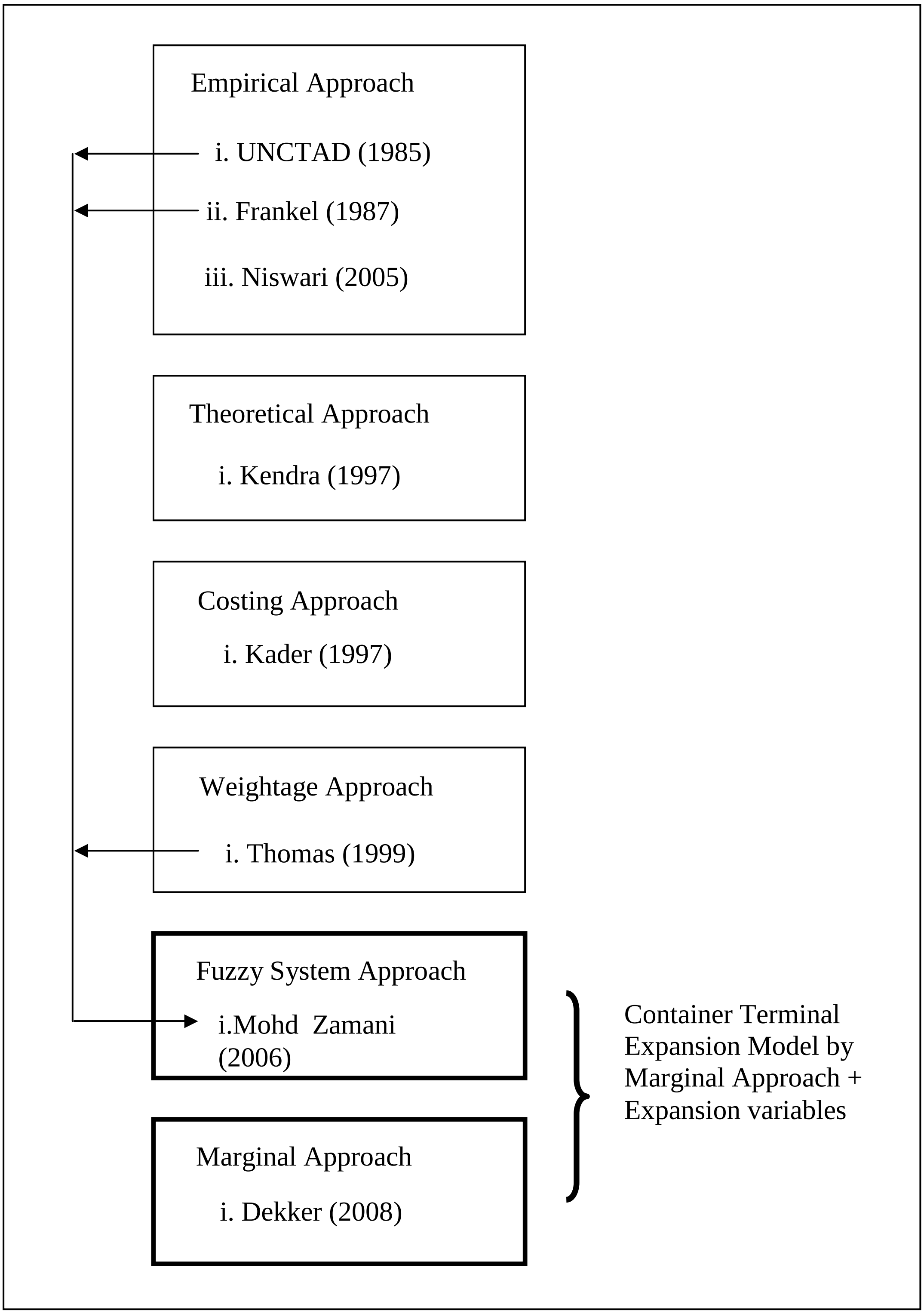

Figure 1.2 Formulation of conceptual framework for container terminal expansion model by marginal approach

1.8 Summary

This chapter briefs the importance and objective of research. The research background highlights the intention of research, basic definition, basic elements, past and current models, and marginal approach. It also generally briefs on shortage of the previous study and the intention of the current study to overcome the problem. The objectives of research, significance of study, scope of study, and formulation of conceptual framework are describes in this chapter.

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