LLOYD'S PRACTICAL SHIPPING GUIDES

PORT OPERATIONS, PLANNING AND LOGISTICS

Author: **KHALID BICHOU**

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BY

KHALID BICHOU

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ABOUT THE AUTHOR

Dr Khalid Bichou is a transport logistics and port consultant and is the co-founder of the Port Operations Research and Technology Centre (PORTeC) at Imperial College London. He has over 17 years of international experience in the port, maritime, transport and logistics industries including periods in senior positions and as Consultant and Adviser to global operators, financial institutions, governments and international agencies. His expertise spans port and maritime operations, transport economics and infrastructure, freight and distribution logistics, trade facilitation and supply chain security.

Following a career which has included periods as Transport Economist in a global shipping company, Transport Investment Analyst in a European bank, Head of Strategy and Business Development in two Nordic ports, Head of Port Infrastructure and Investment in a governmental agency, Director of Ports and Maritime Administration, and Senior Port and Transport Logistics Specialist in two international agencies, he has operated for the last five years as an Independent Consultant. He has been involved in around 40 consultancy projects and advisory services in over 32 countries. He has also been active in professional training and capacity building and has designed and delivered over 25 training courses and seminars for the maritime, transport and logistics industries.

He is a chartered member of the Institute of Transport and Logistics, Director of Logistics-Ports and Maritime at AVCONET, International Advisor to the Supply Chain and Logistics Group, and member and adviser of several other professional and academic associations in the field. He was recently appointed Specialist Port Adviser to the UK House of Commons and Transport Logistics Adviser to the EU Parliament. He has published two books and over 30 papers and policy reports. He is visiting academic and lecturer at several universities and research institutions, both in the UK and abroad.

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CHAPTER 1

INTRODUCTION

Ports are critical infrastructure resources and serve a key role in the transportation of freight and people. With more than 80% of international trade by volume being carried by sea, ports are vital for seaborne trade and international commerce. Ports are the critical nodal interfaces where maritime transport connects with other modes of transport and where trading, distribution and logistics activities can take place. Efficient port operations significantly lower maritime and trade costs whereas delays in ports impose costs on logistics and supply chains through the cost of warehousing and inventory. Ports also serve as economic catalysts for the markets and regions they serve, where the aggregation of port services and activities generates socio-economic wealth and benefits.

There are no confirmed statistics on the number of ports in the world. Some sources estimate the total figure to vary between 2,000 and 30,000 ports and terminal facilities. In 2008, it was estimated that world ports handled over 8 billion tons of international seaborne trade of goods loaded (UNCTAD, 2008). Because of trade imbalances, transhipment practices and other operational considerations, the global port throughput and handling activity would have exceeded the volume of seaborne trade. For instance, 143 million twenty-foot equivalent units (TEUs) were handled by world ports and terminals for an estimated 1.24 billion tons of global container trade in 2007 (UNCTAD, 2008).

A port can range from a small quay for berthing a ship to a very large-scale centre with many terminals and a cluster of industries and services. Ports are dissimilar in their assets, operations, roles and functions, and even within a single port the activities and services performed are, or could be, broad in scope and nature. This situation has led to a variety of operational, management, organisational and institutional approaches to ports, and it is almost impossible to find a worldwide uniform definition for them. There is indeed a variety of terms describing ports such as interfaces between sea and land, nodes in the multimodal and inter-modal transport network, distribution and logistics centres, maritime gateways and corridors, distriparks and maritime clusters, and free zones and trading hubs.

Ports are not just seaports. In some countries such as the USA, the term port usually includes airports and sometimes inter-modal facilities such as railway and road connections. Today, ports are not only a transfer point between sea and land but also serve as distribution, logistics and production centres. Ports can also serve leisure, fishing and/or military ships, thus deviating from traditional commercial cargo-ship activities. In some ports, non-sea-related activities can also fall under the wider definition of ports. For instance, dry ports are inland logistics centres not directly linked to sea or waterway connections. For the purposes of this book, we will restrict most of our discussion to the seaport, hereafter simply called the port, and defined as:

"The interface between land and a sea or a waterway connection providing facilities and services to commercial ships and their cargo, as well as the associated multimodal, distribution and logistics activities."

1 PORTS AND THE MARITIME BUSINESS

Traditionally, ports have been regarded as a sub-system of the shipping and maritime industry, with their main roles being restricted to the provision of services to ships and their cargoes. Shipping or maritime business is mainly concerned with the transport of goods by sea and/or waterway connections. The economic approach treats maritime transport as a *derived demand* from international trade. The term *shipping* is a generic term often used interchangeably, and may be reduced to the sole provision of sea transportation or expanded to the provision of other logistics and trading services. Shipping markets may be divided into four main segments:

- the *freight market:* trades sea transport,
- the *new building market:* trades new ships,
- the *sales and purchase market:* trades second hand ships, and
- the *demolition or scrap market:* trades old and obsolete ships.

Shipping services are usually determined by the nature of trade, or traffic, and more specifically by the type of cargo or commodity transported. The term *commodity* is frequently used in international shipping and port management, and denotes situations where there is little qualitative difference between the products of different suppliers. Unlike branded products, the markets of commodity products have little or no differentiation between them and are considered equivalent regardless of their supply base. Examples of commodity products include basic bulk products such as oil, grain, coal and iron ore. In shipping and ports, many segments run the risk of *commoditisation*, for instance, in the case of container shipping and transhipment terminals. This has several implications on the competitive, pricing and marketing strategies of shipping and port services.

Year	**Liquid cargo**	**Dry cargo (million ton)**		**Total**
		Bulk	**Break bulk and unitised**	
1970	1442	448	676	2566
1980	1871	796	1037	3704
1990	1755	968	1285	4008
2000	2163	1288	2533	983
2007	2681	1997	3344	8022

Table 1.1: Growth of world seaborne trade in million tons (compiled from UNCTAD)

Year	**World traffic**	**World throughput**	**Full**	**Empty**	**Transhipment**
1990	28.7	88.0	70.2	17.8	15.5
1995	46.0	145.5	118.7	26.8	31.4
2000	68.4	236.2	186.1	50.1	60.9
2005	115.5	397.9	315.4	82.5	106.6
2007	142.4	496.6	392.6	104.0	136.4

Table 1.2: Growth of world container seaborne trade and throughput in million EUs (compiled from Drewry and Containerisation International)

Typically, seaborne trade is categorised into bulk, break-bulk and general cargo trades, and this categorisation has also been used to classify different types of ships (see Table 1.3). Other criteria for ship classification include type of packaging (eg containers: containerships; trailers: roll-on roll-off or Ro-Ro ships); ship's size (eg Panamax versus post-Panamax vessels, very large crude carriers (VLCC) versus ultra-large crude carriers (ULCC)); technological specifications (eg conventional versus cellular containerships, single-deck versus double-deck ships); and safety and security records (eg safety class for vessels, ISPS ship security levels).

As with a ship's specialisation, modern port layout and operating systems are increasingly designed to serve a particular trade, ship or cargo type, although many ports around the world still operate multipurpose facilities. For instance,

Table 1.3: International classification of ships

<table>
<tr><td rowspan="10">Marine structures</td><td colspan="5">Non-ship structures</td></tr>
<tr><td colspan="5">Naval and military crafts</td></tr>
<tr><td rowspan="8">Merchant ships</td><td rowspan="5">Liquid</td><td>1</td><td>Oil tanker</td><td>Crude oil
Crude products
Oil products
Oil/chemical</td></tr>
<tr><td>2</td><td colspan="2">Chemical tanker</td></tr>
<tr><td>3</td><td>Liquefied gas carrier</td><td>LNG
LPG
Other liquefied</td></tr>
<tr><td>4</td><td>Tank barge</td><td>Single hull
Double hull
Double-side
Double-bottom
Other tank barge</td></tr>
<tr><td>5</td><td>Other tanker</td><td>Asphalt, bitumen
Molasses
Vegetable oil
Other tankers</td></tr>
<tr><td rowspan="3">Dry bulk</td><td>6</td><td>Bulk/oil carrier</td><td>Ore/bulk/oil
Ore/oil
Bulk/oil</td></tr>
<tr><td>7</td><td>Bulk carrier</td><td>Ore
Bulk/container
Other bulk</td></tr>
<tr><td>8</td><td>Specialised carrier</td><td>Barge carrier
Chemical carrier
Irradiated fuel carrier
Livestock carrier
Other specialised carrier</td></tr>
</table>

(Continued)

Table 1.3: International classification of ships (*Continued*)

Marine structures	Merchant ships	**Non-ship structures**			
		Naval and military crafts			
		Other dry cargo	9	Container ships	
			10	General cargo ships	Ro-Ro passenger
			11		Ro-Ro containers Other Ro-Ro cargo
			12		Reefer
			13		General cargo/passenger
			14		General cargo/single deck
			15		General cargo/containers General cargo multi-deck
			16	Dry cargo barge	Deck barge Hopper barge Lash/sea-bee barge Open dry cargo barge Covered dry cargo barge Other dry cargo barge
			17	Passenger ship	Cruise
			18		Other passenger
		Miscellaneous	19	Fish catching and processing	Fish processing Fish catching
			20	Off-shore production and support	Off-shore drilling Off-shore support
			21	Tow-boats and tugs	Tug Push-boat
			22	Other ship types	Research/survey
			23		Dredger
			24		Other

Source: International Association of Classification Societies (IACS).
LNG: liquefied natural gas; LPG: liquefied petroleum gas; Ro-Ro: roll-on roll-off.

a bulk port provides berthing, cargo handling and processing facilities for ships carrying bulk (liquid or dry) cargo, while a container port consists of a set of berths, yards, gates and, sometimes, extended landside connections solely designed to accommodate containerships and their cargoes. Seaports must not be confused with terminals; the latter are specialised units within ports (see Figure 1.1).

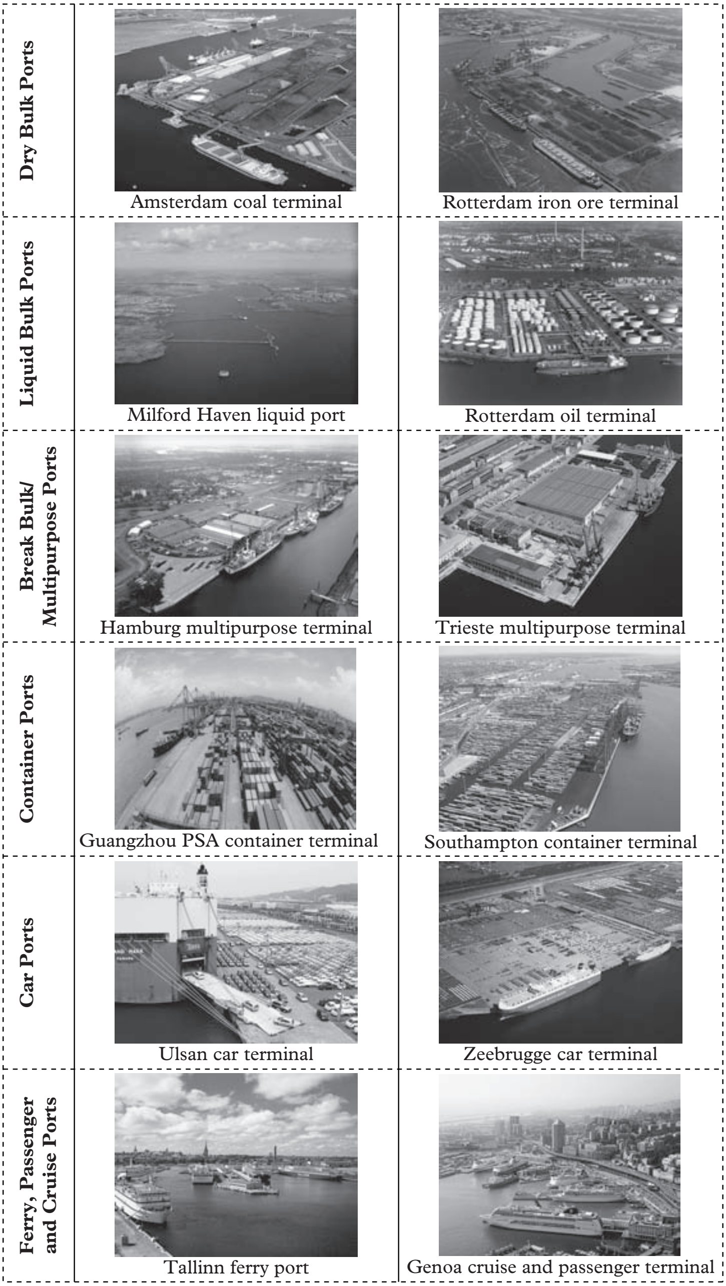

Fig. 1.1: Selection of ports and terminals

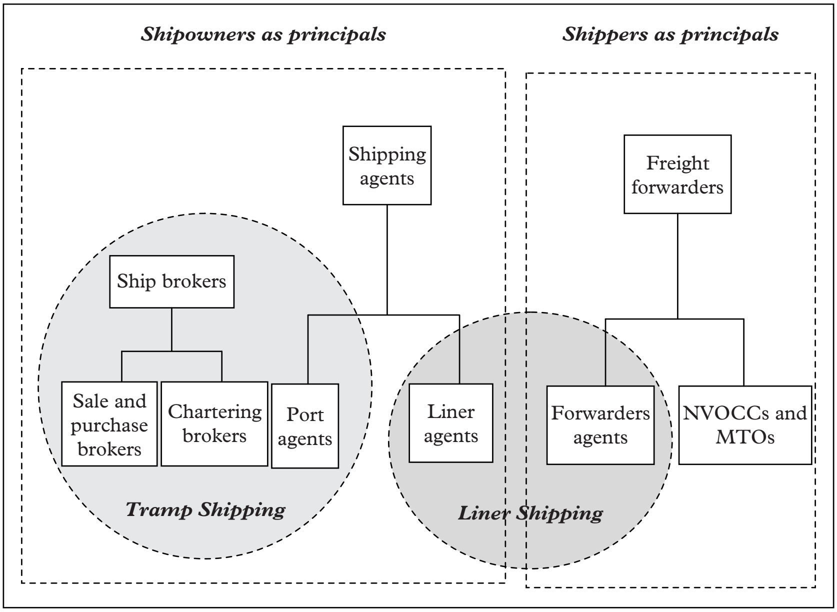

Fig. 1.2: Main agents and intermediaries in international shipping
MTOs, multimodal transport operators; NVOCCs, non-vessel operating common carriers.

When shippers (cargo owners, senders or receivers) outsource the transport of their cargo by sea or water, shipping services are usually divided into *liner shipping* and *tramp shipping*. While liner shipping plies regular routes and ports according to published sailing schedules, tramp shipping is irregular in both time and space. Sometimes, shipping services are performed directly by the shipper (*industrial shipping*), for instance, in the case of vertically integrated global oil firms and car manufacturing companies. Industrial operators may use their own fleet and/or charter in vessels, usually on a *voyage charter*, a *time charter* or a *bareboat (demise) charter*. Generally, industrial shipping is treated as a separate market although it can account for as much as 35% of the world's seaborne trade.

Both tramp and liner operators may be regarded as third-party transport operators. Traditional third-party operators have focused their services on a single logistics operation (eg transport, warehousing, information management, audit and payment, and so on). Modern transport operators offer more than just transport services and can therefore be considered as *third-party logistics* (3PL) providers. Core activities of 3PL, also called *logistics outsourcing* or *contract logistics*, include transport, warehousing, inventory management, information systems, consolidation and distribution, freight management and consulting services. Other functions include value-added capabilities such as labelling, packaging and telemarketing. A distinction should be made between asset-based logistics (3PL) and non-asset-based logistics (*fourth-party logistics* (4PL)). The latter is performed by providers who do not have tangible assets or equipment. Instead, they offer management skills to the shipper, for example, by facilitating shipping documentation and coordinating inter-modal services. Finally, *integrators* are those 3PL providers who provide integrated services such as in the courier and express market.

A key feature in shipping and port markets is the use of *intermediaries* either between carriers or between carriers and shippers. The use of intermediaries may add unnecessary costs to cargo transport and logistics, but is often justified by the advantages of specialisation and efficiency. Depending on the services they provide, intermediaries may be called ship brokers, ship agents, freight forwarders, multimodal transport operators (MTOs), non-vessel operating common carriers (NVOCCs), export management houses, etc. In the context of logistics management, shipping and port intermediaries may be assimilated to 4PL providers.

Unlike tramp ships, the *voyages* of which can link two or more ports at any time, liner ships operate between designated trade routes or *lanes*. Typically, trade lanes follow cargo, commodity and/or geographical classifications, for instance, containerised versus non-containerised routes, inter-continental versus intra-regional routes, deep-sea versus short-sea routes, etc. Within the same route, ships are *deployed* to perform multiple consecutive trips between a series of ports, sometimes called *shipping string* which includes both loading and unloading ports. Because of significant economies of scale of ships (increasing ship size), their physical constraints (draft, length, width, etc), cost structure (operating costs, time in port, space utilisation, etc), trade imbalance and other factors, different *logistical patterns* of liner routing have evolved through the years. These include double-dipping, pendulum and hub-and-spoke services, among others.

Another way to look at the maritime business in general, and at ports in particular, is to consider freight transport (or the transport of goods) as an integral part of the logistics system. Unlike the economic and trade approach where maritime transport and ports are perceived as a *derived demand* from trade, the logistics and supply chain approach integrates the transport function with other business components of the firm such as purchasing, production, storage and inventory management. In this approach, ports are categorised according to their logistical and locational status within international shipping and trade patterns, to their positioning and alignments within supply chain systems and configurations, and/or to the nature and extent of logistics and value-added services they provide (see Section 2.3). A thorough discussion on logistics and supply chain issues in port operations and management is provided in Chapter 10 of this book.

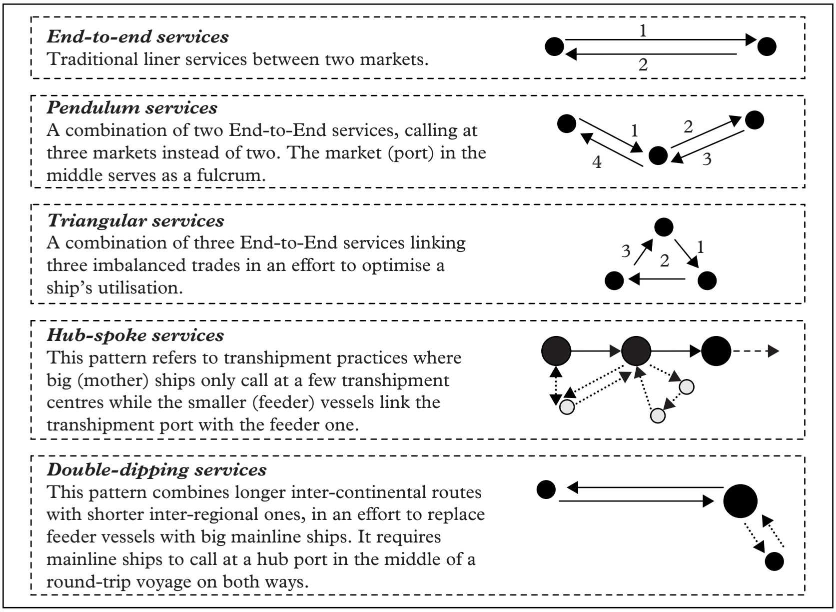

Fig. 1.3: Description of selected operational patterns of liner shipping

As far as shipping services and trading routes are concerned, ports may be classified as network ports, transhipment ports, direct-call ports and/or feeder ports. However, this taxonomy is neither exhaustive nor comprehensive for modern port logistics.

- *Network ports* provide high value-added services to both ships and cargo and generate traffic from/to the port and its hinterland and foreland. Given their extensive channels of distribution, network ports are commercially attractive and offer low unit cost per ship.
- *Transhipment ports* provide high value-added services to ships but low value-added services to cargo. They are mainly dedicated to ship–shore operations and provide fast turnaround times for ships. They are also suitable for cargo concentration and distribution.
- *Direct-call ports* provide low value-added services to ships but high value-added services to cargo. They are particularly attractive to tramp shipping and some forms of liner shipping.
- *Feeder ports* provide low value-added services to ships but not necessarily to cargo. They are not physically, or possibly, economically suitable for direct call and need to be linked to network or transhipment ports.

An alternative way to classify ports is to look at their geographical and spatial markets, specifically the extent of the land area a port can serve, commonly called the *hinterland*. Here ports can be classified as local, regional, national or international. The size of the hinterland may vary considerably from one port to another due to several factors such as the scope of shipping services and port traffic, the quality of port facilities and services, the size and efficiency of the inland transport network, and the number of competing ports for the same hinterland. A good example of port competition for the same hinterland can be found in the US Midwest region, the seaborne trade of which is the subject of intense competition between East, West and the Great Lakes US ports. In Europe, the main ports in the Le Havre–Hamburg range (also called the Banana range)—Le Havre, Antwerp, Rotterdam, Bremen/Bremerhaven and Hamburg—compete for the same hinterland. Ports can serve a wider spatial region beyond their immediate hinterland. This is often called the *foreland* and denotes the geographical area a hub or a network port serves through networking with other feeder ports or through an extended inland transport system. Here again, several ports can compete for the same foreland.

From a spatial and geographical perspective, the relationship between freight flows and port development is better understood through the concepts of gateways, articulation points, freight corridors and distribution centres:

- *Gateways* are locations that bring together different modes of transportation along with warehousing, freight forwarding, customs broking and other logistics services. Many textbooks differentiate between *transport gateways* as hubs for major regions and *freight gateways* which serve cities and regional areas. An illustration of this categorisation may be found in the port of New York/New Jersey as an industrial and logistics hub (freight gateway) which is joined by the inland port of Albany (transportation gateway) designated to receive freight containers barged from the main hub port.
- *Articulation points* are nodal locations interfacing several spatial systems and serving as gateways between spheres of production and consumption, and may include terminal facilities, distribution, warehousing and trading centres. The difference between gateways and articulation points is that the latter are viewed from an urban perspective, whereas gateways do not necessarily need to be located at city interfaces. From this perspective, seaports are seen as hard terminals since they are immoveable, whereas inland terminals dispose of a great degree of locational flexibility.
- *Freight corridors* represent transport links of freight transportation supported by an accumulation of transport infrastructures and activities servicing these flows. Traditionally, flows in freight corridors tended to be fragmented and segmented since each mode tried to exploit its own advantages in terms of cost, service, reliability and safety. Hence, maritime corridors may be assimilated to geographical trade routes. However, evolving routing patterns, such as hub-and-spoke and transhipment networks, currently reduce the capacity of maritime corridors to accommodate operational and logistics patterns of maritime transport.

Criterion	**Port category**
Cargo/commodity type	Dry bulk port, liquid bulk port, general cargo port, etc
Ship type	Ferry port, Ro-Ro port, multipurpose port, LNG port, etc
Trade type	Import port, export port, transhipment port, transit port, etc
Institutional model	Landlord port, tool port, service port, etc
Ownership model	Private port, public port, semi-public port, etc
Management model	Trust port, corporatised port, autonomous port, etc
Organisational model	Centralised port, decentralised port, devolved port, etc
Geographical scope	Gateway port, local port, coastal port, inland port, etc
Logistics status	Feeder port, hub port, transhipment port, network port, etc

Table 1.4: Different classifications of ports
LNG: liquefied natural gas; Ro-Ro: roll-on roll-off.

- *Freight distribution centres* serve as locations for cargo transfer and distribution to regional or extended markets, depending on corridor capacity and articulation point links. Traditionally, many distribution centres were located close to central areas mainly as a factor of market proximity, but are currently relocating to peripheral areas. Functionally, a freight distribution is the combination of a freight corridor and an articulation point or a gateway.

Another popular way to categorise ports is to classify them in terms of ownership and institutional structure. Here ports can be classified by type of ownership (private port, public port, etc), institutional structure (landlord port, tool port, service port, etc) and/or a combination of these and other criteria. A detailed review of these models and others is provided in Chapter 2.

2 MULTI-DISCIPLINARY APPROACHES TO PORT OPERATIONS AND MANAGEMENT

The literature on approaches to port operations and management is quite extensive as it cuts across various subjects and disciplines. It is noticeable in the current body of port literature that the conceptualisation of the port business has taken place at different disciplinary levels without producing a comprehensive and structured port management discipline. Much of the current literature on ports has been developed by international organisations and institutions in the field (UNCTAD, IAPH, the World Bank, etc), and a resulting terminology has evolved depicting specific concepts hardly understood by professionals and academics outside the field (see Chapter 2). On the other hand, many areas of port operations and management still remain unexplored, and there are few references outlining the different features of operational, logistics and strategic management in ports. Generally, the activities and operations of ports have been studied from three main perspectives: an economic approach, an engineering/operations approach, and an evolving logistics and supply chain management (SCM) approach.

2.1 The Economic Approach

Standard economic approaches and theories on international trade and development, production output and capacity, geography and spatial organisation, market structures and industrial organisation, and policy and regulation have been applied to the economic activity of ports and terminals along with other transport infrastructures. A central tenant in the economic approach to ports is that freight and maritime transport is a *derived demand* from trade, essentially international trade. In other words, there will be no need for transport if no trade takes place. Key economic characteristics of the port industry include, but are not limited, to the following: multi-product/multi-output system, multi-agent system, externalities, spillovers and wider effects, natural monopoly and economies of scale and scope, location and network structure, requirements for market, safety and environmental regulation, and long-life assets and long lead times for planning and project completion.

2.1.1 Multi-product/multi-output system

Port production, in economic terms, is highly heterogeneous with many attributes. This is because most ports handle different cargo and ship categories, hence providing different types of port services. Even within specialised ports or terminals, different port services may be provided such as in terms of services to ships and services to cargo, or in terms of nautical services, cargo handling services and value added services. Traditionally, port services have been categorised into services to ships (pilotage, towage, mooring, bunkering, ship repair, etc) and services to cargo (eg loading and unloading, stacking and storage), but other complimentary and value-added services, such as consolidation and break bulk, packaging and labelling, repositioning and distribution, may also be carried out in ports or around their vicinity. Chapter 2 reviews the organisational structure of ports and lists the different functions and roles of modern ports and terminals.

Because of the multi-output nature of port operations, the application of the single-productive theory to ports is clearly unsatisfactory; but it was not until the last decade or so that the port literature started recognising the multi-productive nature of port processes. Despite this, little consensus seems to have been reached among port researchers on the factors of production that should be considered in a production function, or on the related costs and factor prices that should be considered in a cost function. There is also little consensus on the extent to which non-controllable or exogenous variables should be included in the analysis. A detailed review of cost and production functions in ports and of the techniques for analysing port productive efficiency is provided in Chapter 9.

2.1.2 Multi-agent system

From a microeconomic perspective, ports are seen as entities producing private goods for which the levels of supply and demand and relative prices are determined by agents' behaviour, market mechanisms and regulatory requirements. From a macroeconomic approach, ports are critical infrastructure producing public goods that are hardly captured in market transactions but which create direct benefits to port operators as well as indirect effects, be they positive or negative.

Traditional microeconomic port models limit port agents to two main actors: ports and port operators, representing the supply side, versus ocean carriers and shipping lines, representing the demand side. On the supply side, port services facilities may be provided by a single entity or by a myriad of firms and organisations. A key agent in port operations and management is the port authority whose role may be limited to the provision of basic nautical and operational infrastructure (landlord port) or extended to the provision, operation and management of all port facilities and services (public service port). However, with the growing scope and intervention of private sector participation in ports, some or all of port activities and services are increasingly being performed by the private sector. A detailed review and analysis of port ownership and institutional models is provided in Chapter 2. On the demand side, port economics has traditionally focused on the study of the economic behaviour of shipping lines and ocean carriers. This is usually conducted in terms of a cost-minimising exercise for shipping lines as opposed to a revenue-maximising exercise for ports, but sometimes a game simulation between the two objectives is undertaken.

Nonetheless, in a typical port setting several agents and stakeholders may influence decisions on port choice and on the selection of freight transport and shipping services. By way of illustration, a typical international movement of a container box is estimated to involve 25 parties on average. While not all these parties have a direct impact on ports, some actors such as shippers (cargo owners), 3PL providers, freight forwarders and NVOCCs certainly influence port demand, choice and selection. The extent to which those actors are involved in port management is described in the chapters on port operations (Chapter 6) and marketing and competition (Chapter 9).

As for modelling the economic behaviour of port agents, much emphasis has been placed on the analysis of port demand and on the study of the competitive dynamics of port markets. For the former, the bulk of the literature on the subject has focused on the modelling of the behaviour of shipping lines, and more recently on the modelling of port choice and selection from the perspectives of shippers and other port agents. For the latter, the contemporary literature has focused on the growing intensity of competition and contestability within and between different port markets. The interactions between port demand and supply are at the core of the study of port planning, pricing and competition, and these aspects will be thoroughly discussed in Chapters 3, 5 and 9, respectively.

2.1.3 Requirements for market, safety and environmental regulation

Since ports are public goods, port policy becomes an integral part of the country's general economic, trade and social policy. Generally, port policy is formulated based on two understandings: (i) the role of ports in the development of the country and (ii) the set of policy measures that are needed in order to support and further promote this role. It is these measures that constitute the components of a port policy. Key to port economics is the extent to which governments and public regulators are involved in the process of port planning and development, and in the aspects of safety, economic and market regulation. Governments and public authorities can use a range of policy instruments to either promote or hinder the development of port and shipping services, for instance, in terms of a protection-oriented, market-oriented or market-regulated port policy. Even in situations where public agents adopt a neutral view of port planning and development, the market mechanisms through which the port sector is functioning may not be completely free or independent from the influence of the process of public decision making. For instance, in their quest to reduce congestion and promote environmental sustainability, governments may favour one transport mode over another or simply one port over another. Sometimes, port development and policy decisions are usually beyond the remit of a single public agent especially where local, national and supra-national decisions interact, and sometimes conflict, in the shaping of port policy and development. The recent trend of globalisation of port operations and services suggest that many aspects of port policy will now be dealt with at international level.

A central tenet of modern port policy is to ensure effective competition between and within ports so as to provide users with real choice. While modern port management in which commercial investment, whether private or public, drives port development is becoming the norm across many ports and terminals in the world, the regulatory intervention from governments and other public authorities should aim at remedying potential or demonstrable market failures and other hindrances to the wider economic, social, safety and environmental objectives. Port market regulation may also include such aspects as port prices and user's charging, market access, mergers and acquisitions, concessions and private sector participation, incentives and subsidy programmes, and efficiency and yard-stick benchmarking. Another important element of policy intervention is the assessment of port capacity and whether or not industry and market mechanisms alone should plan and finance current and future capacity of the port system.

Other issues of policy and regulatory intervention in ports are safety, security and environmental sustainability. Examples of regulated activities in ports include port state control, harbour and traffic management, hazardous materials (HAZMAT) the handling of storage, port safety and security, environmental protection and impact assessment, health and occupational safety, etc. Several regulatory standards have been developed to ensure the safety, security and environmental sustainability of ports and port operations. Many of these regulations are set at international or regional levels such as through the International Maritime Organization (IMO), the European Union's (EU) Maritime Safety Agency, the World Customs Organization (WCO), the World Trade Organization (WTO), International Labour Organization (ILO), etc. International and regional professional associations in the field (eg the International Association of Ports and Harbours (IAPH), the American Association of Port Authorities (AAPA), the European Sea-Port Organisation (ESPO) and the International Association of Ports and Cities (IAPC/AIPC) also set professional standards for safety, security and environmental sustainability. These will be discussed in Chapters 11, 12 and 13, respectively.

2.1.4 Externalities, spillovers and wider effects

Externalities are indirect effects that can be passed on to third parties, other interests and the wider economy beyond port firms and investors. External microeconomic benefits of ports include the improvement of the efficiency of the productive and trade-logistic system and the reduction of congestion and generalised port costs, which can then be transferred to port users (eg shipping lines) and their clients (eg shippers). External macroeconomic benefits include spatial spillover effects (eg higher accessibility, agglomeration economies, regeneration and redistribution), socio-economic and multiplier effects (eg increases in employment, earnings and consumption), and innovation and technological progress. Port externalities may also be negative, arising from the costs of congestion, safety hazards, environmental degradation and pollution, as well as negative location effects on certain industries such as tourism and real estate development.

An important aspect in the study of the wider effects on port infrastructure is the direction of causation between economic growth and the port activity. Most studies assume that growth is caused by port infrastructure, but as economies spend more on port infrastructure, the latter may follow growth as well. Another key point is the level of excludability from indirect effects where, for instance, some third parties cannot be prevented from enjoying the effects of direct investments made by port firms and operators. Equally important are the market, regulatory and pricing mechanisms that determine how much port users (and non-users) should pay for using port facilities and enjoying their wider benefits, but also for recovering the costs imposed by negative effects.

2.1.5 Natural monopoly and economies of scale and scope

Ports have large sunk assets and therefore tend to exhibit increasing returns to scale (cost per unit traffic tends to fall as a port expands) and increasing returns to scope or density (cost per unit traffic usually falls when more vessels and cargo are handled by existing facilities). Sometimes, economies of scale are defined as being associated with the efficiencies associated with supply-side changes of a single product type such as increasing or decreasing scale of production; for instance, when a port achieves higher container throughput. On the other hand, economies of scope are often defined as being associated with demand-side changes of multiple products such as increasing or decreasing scope of distribution and marketing; for instance, when port facilities are used to handle more than one type of cargo or when ports offer various port services (eg handling, storage, cargo consolidation and so on). While in the single-output case economies of scale are a sufficient condition for the verification of a natural monopoly, in the multi-output case, they are neither necessary nor sufficient. Economies of scope are, however, a necessary condition.

Traditionally, ports have been viewed as natural monopolies, justifying public involvement in both the provision (to ensure adequate investment) and the operation (to prevent monopoly exploitation) of port services and facilities. Nevertheless, not all port assets entail a long-lived and largely sunk cost structure. Several port facilities, such as port equipment and superstructure, can be easily assigned to specific port users and may therefore attract private investors and bring about competitive market features. Kessides (2004) refers to the example of towing and related port services where most of the capital costs relate to tugs. As there is an active international market for tugs, these may be bought, sold or leased quite easily. Thus, towing is a contestable activity as the cost of acquiring a tug is not a significant barrier to entry. Furthermore, the multi-product character of modern ports creates greater scope for unbundling and competition. Even when some ports have natural monopoly characteristics, several port segments and services may be perfectly competitive.

2.1.6 Location and network structure

Ports are immovable assets and their exclusive location attribute has been used to explain the monopolistic nature of ports, although this is no longer the case in modern port systems where the traditional captive hinterland is now being contested by different ports as well as other transport infrastructure systems.

An equally important aspect in port economics is the network structure of the port system. Here ports may be viewed as infrastructure facilities which are part of a wider transportation economic network for moving goods and people. From a network economics approach, the port network is comprised of network users (port users), service providers (ports and port operators) and the rest of the economy. This should not be confused with the engineering approach of network systems where transport networks are defined as flow (eg traffic) networks of links (mode and path) and nodes. In a simple presentation of a marine transport system, the mode represents maritime transport, the path corresponds to the maritime route and the node represents the port or terminal. A third definition of network systems is given by the SCM theory whereby a supply chain network is comprised of a series of firms and organisations that pass goods and materials forward from upstream suppliers to downstream customers, but also sometimes backward (reverse logistics) such as in the case of full export containers returning as empties. From this perspective, the port and marine transportation network is an integral part of the total supply chain network (see Section 2.3).

A central feature of network economics is the creation of network effects (i.e. the effect that one users) of certain goods or services has on the value of those goods to other users). This is particularly the case in network industries (telecommunication, electricity, transport, etc) where the more people that use a product or a service, the more valuable that product or service becomes to each user. In this sense, network effects correspond to positive network externalities but network effects may sometimes lead to negative externalities such as congestion. The study of congestion effects and increased queuing in ports is particularly important since it directly affects decisions and strategies of port planning, operations and competition. Network effects are sometimes confused for economies of scale and economies of scope, but the latter refer to the efficiencies associated with the supply-side and demand-side changes, respectively.

2.1.7 Long-life assets and long lead times for planning and project completion

The long-term strategy for port planning and project completion also affects the determinants of economic decision making in ports. The long lead time for port construction, including a lengthy planning and design period, and for superstructure and equipment procurement has always meant that short-term matching of the supply of port facilities to the expected demand is difficult to achieve, particularly in times of uncertainty and for unstable port markets. Port assets, in terms of both infrastructure and superstructure, have a long economic life and therefore entail a long pay-back period for investment and project appraisal.

2.2 The Operations Approach

From the engineering and operations approach, ports are seen as fixed assets and operations systems. Engineering applications in ports are mainly associated with the aspects of port design, construction, modelling, planning, operations, maintenance, optimisation and performance measurement. The sub-branches of engineering that are mostly concerned with port operations, planning and logistics include transportation engineering, environmental engineering and industrial engineering. The last sub-branch is often used to study ports using a systems and process approach, and is therefore closely related to the fields of logistics and SCM. The conceptualisation of ports as logistics and supply chain systems forms the basis of a new approach to ports, which is introduced in the next section and discussed extensively in Chapter 10.

A system is often defined as a set of components standing in inter-relations among themselves and with the environment. A port's internal system is composed of at least four components: physical assets (infrastructure and superstructure), labour and human resources, technology and information systems, and management and workflow processes. Because of the complex nature of port operations, relevant research on the subject is usually undertaken at disaggregated operational levels (eg terminal, site, equipment, technology and so on). A further distinction is also made between the types of engineering and operations decisions. The latter can be categorised into strategic, tactical or operational decisions according to their scope and time horizon.

Outside the nautical infrastructure, key port operations that have been mostly examined in the literature include ship and berth scheduling, stowage plans and quay-crane efficiency, vehicle-flow dispatching and scheduling, staking and storage in the yard, empty container management, automated operating systems, and inter-modal transport operations. A good review of these and other operations problems in terminal operations is provided in Chapter 6. Despite this, many operational features of port systems remain under-researched including aspects such as network structure, reliability and interoperability.

2.2.1 Network structure

Most transport and freight distribution systems follow a node-link network structure, although the nature and properties of the network differ greatly between and within systems. For instance, unlike rail and road systems, maritime links may be established between any two or more seaport locations subject to a number of infrastructural (ports, canals, locks, etc), operational (volume, capacity, price, etc) and organisational (liner shipping versus tramp shipping) constraints.

From an engineering and operations perspective, ports are a central node of the maritime and inter-modal transport networks. Mathematically, a transport network can be represented by a graph consisting of a set of *links* (edges) and a set of *nodes* (vertices). The links represent the transport movements between the nodes, which in turn represent points (eg ports) in space and sometimes in time as well. A *path* is a collection of links and nodes specifying both the route and the mode(s) of transport. In the graph theory, a network is pure when only topology and connectivity properties are considered. When flow properties are considered as well, a network is then referred to as a flow network, in which case capacity constraints and other related factors become key features of network analysis. Random graphs are one of the earliest and most extensively studied network models. They are defined as networks where nodes and links are assigned at random. On the opposite side of the network model spectrum, one encounters regular networks where link creation adheres to strict rules.

Most of the models and concepts developed in the graph and network theory can be applied to ports, at least in two separate areas of interest depending on how ports are perceived as network structures. When ports are viewed as nodes of the shipping and inter-modal transport network, the graph theory can be used to study certain shipping and related port aspects such as path flow estimation (freight flow modelling and traffic forecasting), network equilibrium (deterministic or stochastic user equilibrium), port and depot location, and route and mode choice (traffic assignment). When ports are analysed as individual spatial networks, the graph theory can be used to study several issues of port operations and short-term (operational) planning such as the routing, deployment and scheduling of port equipment and vehicles as well as labour and manpower. The network structure can also be applied to port planning, design and construction through the study of project networks and industrial scheduling.

The study of a port's network topology is also relevant to port operations and logistics, but the literature on the subject is relatively scarce. This may be due to the conventional thinking that the location of ports in spatial networks is exogenous (ie ships follow ports). On the other hand, the more specific study of the topology of port and shipping networks (eg scale-free networks, complex networks and small world networks) has received little attention from academics and professionals. Traditionally, port planning and capacity expansion schemes have relied on their volume/capacity ratio to identify highly congested links resulting in localised solutions. In a similar vein, international shipping networks have followed a trade-led pattern where new routes are opened and operated to link two or multiple markets, but traffic and operational constraints have forced shipping lines to develop new operational patterns in an effort to optimise ship utilisation and efficiency. As a result, the issue of liner network routing has been reduced to a ship's scheduling problem. The key point is that port and maritime network patterns have evolved from micro-level and fragmented decisions that do not always consider global network performance and system-wide impacts. With the evolving complex shipping networks (transhipment routes, hub-and-spoke systems, increasing use of hierarchical networks and multiple line bundling arrangements, etc) and the recent trends in port choice and logistics (shifts in global distribution patterns, changes in supply chain segmentation and planning processes, the general trends in outsourcing and the emergence of global terminal operators, etc), network design and capacity in shipping and ports require a new approach and systemisation.

2.2.2 Reliability

Another area of interest in network analysis is network reliability, which studies the vulnerability and robustness of a transportation network including topics of connectivity, link failure, disruption and redundancy, vulnerability and security. However, reliability in ports include aspects that go beyond the field of transport network reliability, for instance, terminal reliability, capacity reliability, operational reliability, transit (travel time) reliability and encounter reliability.

A widely accepted definition of reliability is the one provided by Wakabayashi and Iida (1992) who define reliability as "the probability of a device performing its purpose adequately for the period of time under the operating conditions encountered". Obviously, the extent to which a system or device is reliable depends on the interests and perceptions of different users, for instance, between those who focus on cost reliability versus those who favour time reliability, or simply between high risk averse users versus less risk averse users.

The potential sources of disruption to port systems and networks are numerous, ranging from routine events such as congestion and equipment failure to exceptional disasters such as earthquakes, terrorist attacks, ship collisions and other major accidents. The cause, scale, impact and frequency of such events will vary extensively, but it is possible to design and manage port systems and operations in ways that enhance the predictability of such events, minimise the disruptions they may cause, and improve the robustness and redundancy of the port system against such disruptions. Here, the concept of risk assessment and management becomes a key element in the study of a system's reliability. Risk assessment and evaluation is a well-established engineering process for identifying hazards, their probabilities and consequences, assessing the acceptability of risks and taking remedial action to address unacceptable risks. Vulnerability is another concept closely related to risk in that it encompasses both probability and consequences. Generally, vulnerability is defined as the likelihood of severe adverse consequences. Therefore, vulnerability may be interpreted as being the opposite of reliability.

Superior port design and redundancy improves a system's reliability. For instance, enhancing the methods and execution of port planning, operations and maintenance would improve the quality of services provided with a view to satisfying users' expectations. In a similar vein, developing systems and processes with quick recovery and resilience in the event of failure reduces the adverse consequences of disruption. Therefore, both the design and redundancy components of port equipment, operational procedures and management systems must be taken into account when assessing port safety and security. However, while port safety is based on the assumption of unintentional human and system behaviour to cause harm, port security involves a high degree of malevolence. Current maritime transport and port networks have been designed to respond to an extensive set of market and operational requirements, but their robustness and reliability vis-à-vis random or targeted failures have long been taken for granted. In the post-9/11 era, the robustness and survivability of the maritime network against node or port failures is a high priority. Despite this, the topic of network reliability in ports is surprisingly under-researched and only a few relevant works on the subject exist. The topics of port safety and security will be discussed in more detail in Chapters 11 and 12, respectively.

2.2.3 Interoperability

Interoperability refers to the capability of diverse systems and organisations to operate and work together. In seaports, interoperability must be achieved at operational, communication and technology levels. Operational interoperability refers to the ability of port operators to handle various types and sizes of ships and their cargoes. While some ports have a higher interoperable capability, many ports have lesser interoperability for conforming to operating requirements and working standards, for instance, in terms of equipment and labour capability. The ability to integrate various inter-modal systems is also a key to achieving a high degree of operational interoperability in ports. Communication and business process interoperability between various members of the port community is a key to successful port operations. The use of standard communication systems, such as vessel traffic services (VTS), electronic data interchange (EDI), EDI for Administration, Commerce and Transport (EDIFACT) and enterprise resource planning (ERP) systems, ensures the exchange of documentation, data and information in interoperable semantics, communication protocols and file formats. In the areas of port safety, security and environmental protection, interoperability communication between various port stakeholders and public agencies is the key to a successful management response during wide-scale emergencies. From an economic perspective, a lack of interoperability creates conditions for negative network externalities such as monopolistic behaviour, market failure and congestion effects.

2.3 The Logistics and Supply Chain Management Approach

Logistics had long been exclusively used by the military and was only integrated into operations and business management in the mid-1960s. There are almost as many definitions of logistics as the number of books and articles written on the subject. This, to some extent, reflects the underlying characteristics of logistics, which has been undergoing a constant evolution during the last three decades or so. The basis of logistics management is the integration and optimisation of a firm's functions and processes for the dual purpose of overall cost reduction and customer satisfaction. Logistics seeks to deliver the right product or service, in the right quantity and condition, at the right price, to the right place and for the right customer. Typically, the logistics process encompasses inbound, in-house and outbound logistics and spans the flows of goods, services, people and information from point of origin until point of consumption (forward logistics) and vice versa (reverse logistics). Logistics functions are usually categorised into two main components: materials management and physical distribution, and may include a range of activities such as purchasing, planning, production control, inventory management, materials handling, storage and warehousing, transport and distribution and sales and marketing. Most concepts of logistics and SCM also apply to ports. They include the following.

2.3.1 Customer service

Much of the emphasis of business logistics is placed on effective customer service which, combined with the objective of cost reduction, opposes business logistics to military logistics. The concept of customer service associates many aspects of logistics closely with marketing. It can be broadly described as the measure of how well the logistics system satisfies its customers and their expected levels of service. Customer service must be viewed as an integral part of the design and operation of any logistics system. In ports, much of the debate to date has been on how to perform efficient operations while still satisfying a wide range of port users and customers.

In SCM, the concept of customer service takes on another dimension since it assumes that the network of organisations in a port supply chain should work collaboratively in order to ensure superior customer service and competitive advantage vis-à-vis other supply chains. This means that port competition is moving to a further level: ports are not only competing against other ports on the basis of operational efficiency, price and location, but also, and more importantly, on the basis that they are embedded in quality supply chains that offer shippers, shipping lines and other customers a greater value than alternative ports, routes and supply chains. Today competitive advantage depends less on a port's internal capabilities but rather on its supply chain competitive potential whereas long-term success depends upon the competitiveness of the entire port supply network.

2.3.2 Value added

In logistics, the term value added is closely related to customer satisfaction. The most appropriate customer service level is the one that gives the customer the maximum value added. The performance of a logistics system is assessed based on how well it performs in creating value-added benefits to the customer in a cost-effective way. While the value of port services to shipping lines may be reduced to the aspects of operational efficiency and turnaround time, the value of port services to shippers may be extended to the aspects of product conversion, process decoupling, inventory management, market customisation, postponed manufacturing, modal shift and regional distribution.

Value added also means the value newly created or added to traditional services. Logistics activities are key elements in the value chain, and thus contribute greatly in the creation of value added. Apart from their traditional function as a sea–land interface, ports are a good location for value-added logistics activities such as consolidation and break bulk, sequencing and order processing, packing and packaging, postponement and customisation, promotion and market intelligence, facilitation of contacts and procedures, and so on. From a logistics approach, ports should be conceived of as logistics and distribution centres that not only optimise the movement of goods and services within the maritime and multimodal transport system, but also provide complementary services and add value to members of the larger logistics and supply chain network. The role of ports as logistics centres has been fully recognised in recent years with many ports worldwide expanding their activities into a wide range of logistics and value-added services. Thus, the port system not only serves as an integral component of the transport system, but is also a major sub-system of the broader logistics and supply chain systems.

2.3.3 Process and integrated approach

Much of the logistics philosophy is based on a process approach to business. This means that logistics is not an isolated activity, but rather a series of continuous and inter-related activities whereby planning, organisation, operation and management apply. One of the main benefits of logistics is that it offers an integrated approach to a range of activities and functions (eg purchasing, production, transport, warehousing and so on), and enables manufacturers and other organisations to identify the total cost of the system, and balances (or trades off) one aspect against another.

Over the past two decades or so, the integration of the international logistics chain has become a focal issue in developing strategic plans and long-term objectives for 3PL, shipping lines and even port operators. Today, 3PL providers offer packages that include full coverage of logistics services from origin to destination. In a similar vein, advances in containerisation, inter-modal integration and information technology have allowed shipping lines to extend the scope of their activities from traditional sea transport services to integrated door-to-door transport and logistics services including such activities as inland transportation, consolidation, freight forwarding and even cargo handling and port services. Yet, total logistics integration is achieved by few mega-carriers, while most shipping lines limit their services to sea transport and related shore-based operations. In ports, the process of port privatisation and deregulation being widely implemented during the last two decades or so has gradually lifted the barriers against logistics integration in the port industry. Nowadays, many port operators are capable of offering a range of logistics services beyond the traditional package of services to ships and cargo. There is also a growing trend on the part of ocean carriers, logistics service providers and even shippers towards port ownership and management. Recent strategies of vertical and horizontal integration evolving around port ownership and operations have produced new institutional port structures capable of offering integrated port and logistics services.

2.3.4 Total costs and cost trade-off analysis

A key element of integrated logistics is total cost analysis. The essence of logistics is to minimise the total cost rather than the cost of individual activities. Any change made in one aspect of an organisation is likely to affect other aspects as well as the total cost of the entire logistics system. Cost trade-off analysis is a key feature of total logistics costs and consists of comparing different combinations of cost elements so as to achieve an overall optimal solution. Examples of cost trade-off analysis include transport costs against inventory costs, warehousing costs against transport costs and production costs against inventory costs. It is obvious that these costs are inherently inter-related with each other. Cost trade-off analysis is also a useful tool for strategic decisions. A typical illustration is when a firm decides to move production to a cheaper place in order to reduce the cost per unit of the product at the factory, but the new production site would imply an increase in transport and other related costs.

While the objective of shipping lines is to minimise total door-to-door transport costs, including cargo handling and port costs, shippers seek to minimise total logistics costs, which include transportation costs, warehousing costs, order processing and information costs, lot quantity costs and inventory costs. Despite this, the literature on port planning, choice and freight flow modelling often overlooks the costs of shippers and limits the analysis to a trade-off exercise between a cost-minimisation for shipping lines versus a revenue-maximising objective for ports.

2.3.5 Ports as logistics systems

Despite the widespread recognition of the logistics and supply chain dimension of ports, the bulk of the practical and theoretical literature on ports has studied port systems from either an economic approach or an operations approach. However, these approaches neither fully justify the evolution of port systems nor integrate various functional port units into the wider freight logistics and supply chain network:

- On the one hand, the economic approach treats freight and maritime transport as a derived demand from trade. Here, maritime transport and port activities are perceived as an afterthought; that is, something which is considered only after the main activities of the firm such as purchasing, production and inventory have been undertaken. We believe that the economic and trade approach justifies only part of the evolution of freight distribution systems. The focus on the nature, origins and destinations of freight movements disintegrates port management from logistics and supply chain structures.
- On the other hand, the operations approach disaggregates the port system into individual units and components and seeks to optimise their individual operations rather than that of an overall port system. Here, operational fragmentation may result in conflicting objectives and disintegrated port operations. An integrative approach is therefore required.
- The logistics approach integrates both transport and cargo handling functions with other logistics components such as purchasing, production, storage and inventory management, promotion and marketing. In this approach, ports should be conceived as logistics and distribution centres that not only optimise the movement of goods and services within the entire transport and logistics chain, but also provide and add value to ultimate customers and users. Chapter 10 introduces a new conceptualisation of seaports as logistics and supply chain systems and discusses its implications on various port decisions such as planning, operations, marketing, competition, choice and selection.

2.3.6 Ports and international logistics

Most of the logistics concepts discussed above are also relevant in the international sphere. However, there is a great degree of complexity and uncertainty in international logistics compared with domestic logistics. The areas of complexity listed below also apply to international port and terminal management:

- *International trade complexities*: Different terms of sale and documentation, terms of payment, problems with the use of different currencies and the fluctuations of the exchange rate, etc.
- *The international and changing nature of markets*: involvement of supranational trading blocs (EU, North American Free Trade Agreement (NAFTA), Association of Southeast Asian Nations (ASEAN), etc), different national/regional tastes, languages, traditions, regulations, etc.

- *The nature of international supply chains, procurement and sourcing*: multiple choice of production, inventory location and management; difficulty of control over deliveries and inventories; different expectations for customer service.
- *The involvement of multinational and global corporations*: aspects of channel control and power, footloose strategies and risk of mobility, the growth of intra-firm trading, etc.
- *The general trend of outsourcing transport and logistics activities*: through contracting out with 3PL/4PL providers.
- *The frequent use of transport agents and intermediaries*: including brokers, agents, NVOCCs, freight forwarders and other intermediaries.

As the world economy becomes more integrated through an accelerated process of globalisation of production, consumption and services, the market place for an increasing number of port users and customers is now simply the globe. In international logistics, the relentless striving for greater economies of scale, global coverage, higher efficiency and improved service quality have leveraged port competition for cargo and shipping services to a global market level. Logistics integration and network orientation in the port and maritime industry have redefined the functional role of ports in value chains and have generated new patterns of freight distribution and new approaches to port hierarchy. Successful ports have realised that in order to survive and prosper in today's business environment, they have to adopt a global view. Today, many port operators have reached a global status by extending their activities to international port markets. The international consolidation of the port industry will be discussed in detail in Chapter 10.

2.3.7 Ports and supply chain management

Supply chain management extends the logistics concept of integration to a network of organisations by advocating trust, closer collaboration and partnership arrangements. SCM corresponds to external integration where a systems approach is used for managing the entire flow of information, materials and services from raw materials' suppliers through factories, warehouses, distribution centres and retailers to the final customer or end user. Key SCM decisions include supply chain configuration, planning and forecasting, suppliers' selection, process and product design, plant and warehouse location, demand management, supply chain risk and security, IT integration and enterprise systems, ecommerce and electronic markets, etc. Partnership arrangements in SCM require an abatement of conflictual attitudes in favour of long-term trust and cooperative relationships. Nevertheless, traditional relationships in the international logistics and shipping industry, including ports, have been more adversative than collaborative and where arm's length arrangements seem to prevail over integration.

2.4 Marketing Channels and Port Management

In marketing management, a channel is defined as the network of organisational contacts a firm operates to achieve its distribution objectives. In other words, it is the physical route taken by goods from producer to consumer or the route of the transfer of ownership (or title) of the goods. Sometimes, the two routes are the same, but often they are not, particularly in international trade where payment, information and sometimes ownership may be associated with entities other than the exporter and the importer. A marketing channel can be identified by the types of institutions associated with the *ownership and transaction* of goods. For instance, merchants (buyers and sellers) have the ownership of the goods and agents act on behalf of merchants, but sometimes negotiate the ownership. On the other hand, transport and logistics providers do not take ownership of the goods but only facilitate their efficient passage through the channel. As such, logistics operators/providers are not members of the marketing channel.

The literature on channel management has its roots in marketing management, and of late in logistics and SCM. A channel can be loosely defined as a set of organisations that have banded together for trade, distribution and/or marketing purposes. In logistics management, channels are often reduced to the physical routes taken by goods as they move from producers to customers. In marketing management, a channel may be defined as the network of organisational *contacts* a firm operates to achieve its distribution objectives. Members of the marketing channel are entities that take part in the various marketing flows including title, information, promotion and payment, while members of the supply chain include all the organisations involved in the sourcing, production, transport, storage, delivery, sales and even return of the product or the service. Two distinctive features of the marketing channel approach are worth underlining: (i) its focus on channel *control* and (ii) the appreciation of *conflict* between organisations. Such features differentiate the marketing channel approach from the supply chain approach, the latter requiring cooperative relationships and integration of organisations.

Another distinction between the two approaches stem from the way each of them focuses on inter-organisational relationships. The marketing channel approach deals with the control of the channel and focuses mainly on external organisational arrangements. The SCM approach, on the other hand, seeks optimal efficiency by focusing on organisational integration including internal arrangements within a single company. In either case, it is crucially important not to confuse between *institutions* and *functions*. Institutions refer to channel members (shippers, ocean carriers, ports, freight forwarders, regulators, etc) while functions describe what channel members do (production, transport, cargo handling, storage, regulation, etc). Often, this distinction is blurred given that many functions of port management are operated by channel members other than ports, for instance, when a shipper or a shipping line owns or operates ports and terminals. A thorough discussion of channel structure and design in ports from marketing and supply chain perspectives is provided in Chapters 9 and 10 respectively.

3 RATIONALE OF THE BOOK

From the above discussion, it is clear that ports are complex and dynamic entities, often dissimilar from each other, and where various services and activities are carried out by and for the account of different actors and organisations. Such a multi-faceted situation has led to a variety of operational, organisational and strategic management approaches to port systems.

It is noticeable in the current body of port literature that the conceptualisation of the port business has taken place at different disciplinary levels without producing a comprehensive and structured port operations and management discipline. Furthermore, many areas of port operations and management still remain unexplored, and there are few theoretical and practical references outlining the different features of operational, strategic and logistics management in ports.

Port Operations, Planning and Logistics is designed to offer a comprehensive, integrated, and detailed analysis of the complex and multi-faceted port system. As shown in Figure 1.4, the port system is portrayed in terms of four core

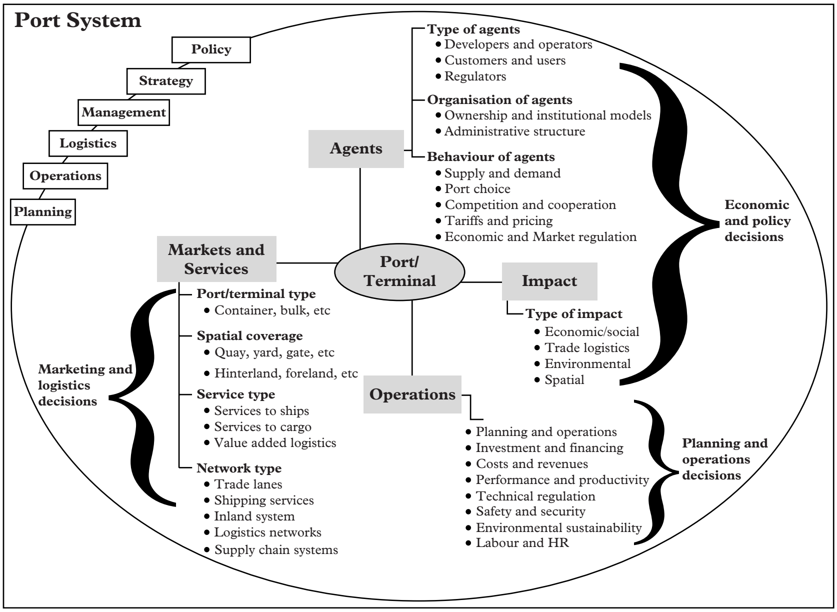

Fig. 1.4: Scope of this book

components: agents, operations, markets and services and impact. The focus of the book is on the interplay between those components and on the types of decisions they generate, namely planning and operations decisions, marketing and logistics decisions, and economic and policy decisions. The book provides a unique and multi-disciplinary reference that cuts across different research fields: economics, engineering, operations, technology, management, logistics, strategy and policy.

3.1 Contents of the Book

This book reviews theoretical and practical applications in port operations, planning and logistics and addresses the various needs, challenges and risks in port operations and management. The book explores various port topics: planning, operations, logistics, institutional organisation, investment and financing, pricing and asset management, efficiency and performance benchmarking, marketing and competition, information and communication technology, human resource management, safety and security, and environmental management, each supported with case studies, practical examples and illustrations of the latest developments in the field.

Chapter 1 points out the link between ports and the maritime business and presents alternative ways of port definitions and classifications. In particular, it outlines the different approaches to modern port systems and highlights the current and future trends in port operations and management. Chapter 2 reviews various port roles and functions and examines the traditional and evolving forms of port organisation, institutional structure and development. Chapter 3 reviews the various topics and elements of port planning—operational, strategic and long-term planning—while analysing the issue of port capacity in terms of both capacity planning and capacity management. It goes on to describe in detail the different models of port demand modelling, network design and traffic forecasting. Chapter 4 deals with port investment and finance with particular emphasis on port costs and costing, economic and financial appraisal of port investment, and the nature and modes of private sector participation in ports.

Chapter 5 introduces the subject of port pricing, lists the different port dues and charges, and reviews the different approaches to port pricing and user charging. Chapter 6 discusses various aspects of port operations: queuing and congestion, terminal configurations, terminal processes and procedures, equipment and handling systems, and maintenance and repair, with particular emphasis on containerised operations. Chapter 7 is dedicated to the subject of port productivity, performance and benchmarking. The various approaches and methods for measuring and benchmarking port performance and efficiency are described in detail supported by theoretical applications and practical case studies. Chapter 8 investigates the use of information and communication technology applications in ports from EDI and port community systems to radio frequency identification (RFID) and automation. Chapter 9 addresses the issues of port competition and marketing, focusing on the topics of market structure and analysis, competition and cooperation strategies in ports, port choice and selection, tools for port marketing and promotion, and instances of channel conflict and power in ports.

Chapter 10 investigates the logistics and supply chain dimensions of ports and discusses their applications and wider implications on inland systems and supply chain strategies. Chapters 11, 12 and 13 review the subjects of port safety, security and environmental management, respectively. Throughout these three chapters, the operational, economic and policy frameworks technical regulation in ports are discussed and their contemporary impacts on port operations and planning are assessed and analysed. The final chapter, Chapter 14, reviews the historical and contemporary organisation of a port's labour and workforce and assesses its impact on port productivity. In addition, the chapter outlines modern HR management approaches and their applications in port operations and management, and highlights the need for global standards of port education and training.

CHAPTER 2

PORT ORGANISATION AND DEVELOPMENT

Ports are very dissimilar in their assets, roles, functions and institutional organisation, and even within a single port the activities or services that are, or could be, performed are broad in scope and nature. Furthermore, the scope, nature and stages of port development vary greatly across the world's ports and terminals. The literature on port organisation and development is quite extensive since it cuts across various subjects and disciplines. Nevertheless, neither an established framework, nor proper terminologies have yet been established to allow a comprehensive analysis.

1 PORT ROLES AND FUNCTIONS

Ports are very complex and dynamic entities where various activities are carried out by and on account of different actors and operators; they are often dissimilar to one another. The literature on port attributes provides a variety of terms such as waterfront, estuary and maritime bases, ship/shore and multimodal/inter-modal interfaces, distribution and logistics centres, corridors and gateways, maritime industrial development areas (MIDAs) and trade and distribution maritime centres (TDMCs), industrial clusters and distriparks, free zones, trading hubs and networks.

Port functions are so diverse in scope and nature that it would be almost impossible to provide an exhaustive list of them. Much of the literature on port function has been developed by governmental and international agencies such as the United Nations Conference on Trade and Development (UNCTAD), the International Association of Ports and Harbours (IAPH), the World Bank, the US Maritime Administration (MARAD) and so on, with little original work emerging from academia over the past three decades.

On the one hand, ports have been defined through a macro-analytical approach as being geographical, physical and corporate assets. Here the word port often refers to waterway connections, relating to sea, lake, river, inland waterways and/or canal locations. Additionally other generic terms, not necessarily water-related, are also used, including dry ports with no waterway access and multimodal and inter-modal ports, combining the sea/waterways interface with road, rail and/or air transport, a concept widely used in North America and elsewhere. Port roles and functions are identified through political, geographical (urban and spatial), economic and social perspectives. For instance, ports in the USA constitute one of the five components of the marine transportation system (MTS) along with waterways, inter-modal connections, vessels and vehicles, and system users. In Singapore, the port's role lies in the provision and development of the distripark and trading hub concept, while in Japan ports are being recognised as distribution centres, industrial zones and energy supply bases, mercantile trading centres, urbanisation and city development centres, life activity bases and maritime leisure bases.

From a public policy perspective, ports are seen as critical trade and transport infrastructure facilities and as economic and development catalysts for the nations or regions they serve. Other port related topics of interest to the policy maker include urban planning and expansion, land use, safety, security and environmental sustainability, with two major approaches being identified at this level. The first approach relates port development to urban planning and management with particular importance being given to the port–city interface. Often port functions are separated from urban land uses by an "interface zone" of dereliction, usually when traditional port functions have moved to deeper waters or larger sites away from the city centre. In such cases, the original location of the port is an abandoned doorstep to the port city. However, in the past few decades there has been a return to the development of the seaside in many port cities throughout the world, where former areas of traditional port functions are now used for non-shipping activities leading to development in many different ways. The second approach perceives ports in terms of environmental factors where port planning and management should allow sustainable development and waterfront regeneration. With the widespread implementation of Environmental Impact Assessment (EIA) and Integrated Coastal Zone Management (ICZM) policies and the increasing importance of the climate change agenda, such an approach is increasingly gaining support at the international, national and even local level. Nowadays, there is as much emphasis being placed on the environmental sustainability of port development as on its economic, social and financial benefits.

Such a variety of approaches is typically illustrated in the study of port aggregate impacts, which has proven to be a controversial subject not only with many conflicting standpoints (of economists, city-planners, politicians, environmentalists, etc), but also with different methods of assessment and analysis (eg cost–benefit analysis, input–output models, general equilibrium and gravity models, mass-calculations and so on). Port impact analysis focuses on the assessment of overall effects of the port activities including aspects such as the port's contribution to growth, employment, international trade, industrial development, spatial distribution, competition, productivity, safety and the environment. An illustration of the socio-economic dimension of ports is through the study of port impacts on the economy using output models. This approach assumes that regional economies with more infrastructure will have more output and those with less infrastructure will constraint the economic output. In this approach, ports are classified according to their nature or scope of influence, and can be generally identified as being trade-related (traffic type, origin versus destination), space-related (local versus national, hinterland versus foreland), network and logistics related (hub versus feeder, direct-call versus transhipment), and sector-related (direct versus indirect). Output models in ports typically rely on input–output tables and multiplier effects to assess the economic and social impacts (direct, indirect and induced) of ports on their respective hinterlands or forelands. On the one hand, the economic and social impacts of a port are depicted in terms of its ability to generate maximum output and economic wealth such as GDP contribution, job creation and supply of hard currency. On the other hand, the assessment of direct, indirect and induced impacts depends on the extent of the added value by geographical distribution and economic sector.

Along with their economic and social impacts, ports play a major role in a country's logistical and trade efficiency. Because they are controllable aspects of global supply chains, ports deserve particular attention. Excessive costs and inefficiencies hinder trade and economic development. The relative costs imposed at ports are influenced by a number of factors such as low cargo volumes, trade imbalances, long distances, poor inland transport links, fragmented logistics and supply chains, and other economic and geographical realities. Ports can account for 8–12% of transport costs between a product's origin and its destination. The impact of port inefficiency on trade and welfare has been studied by Clark *et al.* (2002) who, on a worldwide comparison, found that improving the efficiency of a port from the 25th percentile to the 75th percentile reduces shipping costs by 12%. In other words, bad ports impose a penalty equivalent to being 60% farther away from markets. Other studies have shown that a doubling of shipping costs can reduce annual economic growth rates by about a half a percentage point. UNCTAD's *Review of Maritime Transport 2007* found that in 2001 total freight costs constituted 12.65% of the import value of goods in Africa compared with an average of 8.7% for developing countries elsewhere. The trade logistics impacts of a port assess its efficiency in relation to transport, trade and logistics costs. This part of the literature is rapidly establishing itself as a separate branch mainly due to the recent emphasis on the role of ports in *trade facilitation*. The extent to which ports reduce total logistics costs and integrate global supply chain networks is rapidly becoming a topic of national and public policy interest.

On the other hand, ports have been analysed from a micro-perspective approach in terms of sets of activities and operations shaping a port's roles and functional dimensions. A simple, yet broad definition of ports considers them as facilities where vessel maintenance and cargo/passenger transfer is ensured, but other definitions extend the port role beyond ship/cargo handling, storage and inter-modal tasks to include wide activities not necessarily linked to maritime transport and ship operations. However, there are few global reference guides on standard port operations and management. Among these, it is worth mentioning UNCTAD's *Monographs on Port Management* and the World Bank's *Port Reform Toolkit*. Other references have focused on specific port facilities or operations and are usually undertaken at national or port levels (eg the US Corps Army of Engineers *Ports' Manuals* and the port of Melbourne *Operations Handbook*).

As with many roles and functions, various activities and services can be performed by and within ports. UNCTAD distinguishes between a port's internal and external functions with the latter being divided into services to ships and services to cargo. It outlines essential facilities or activities that should be provided by ports (Figure 2.1). Services to ships include such activities as pilotage, mooring and unmooring, bunkering, supply, repair and maintenance. Services to cargo are usually cargo-handling services such as loading, discharging, storage and stacking. The World Bank identifies three types of port assets: basic infrastructure, operational infrastructure and superstructure (Table 2.1). However, these are not the only facilities and services a port can provide and there are many examples of other services offered, or that can potentially be offered, by ports. Sometimes, port activities can serve both ship and cargo interests such as those performed by the customs and health authorities, whereas other activities do not necessarily require to be carried out in the port area, for example, logistical operations performed at inland logistics centres, dry ports or inland container depots.

A third approach perceives ports as general business ventures regardless of their specific role or functional status. Here, ports are analysed in terms of business and operational units such as operations, human resources, sales and marketing. Much of recent professional and academic literature falls under this category. Other approaches integrate ports within the wider logistics and production system, and new generic terms have been used to illustrate port inter-modal and logistical dimensions. These include industrial ports, network ports, trade ports and teleports.

Port functions may be limited to simple berthing facilities, ship/shore or intermodal interfaces; or extended to trade, logistics and production centres. Operational and management features also vary with the type of cargo or ship operated and the extent of services offered. In a typical port setting, there is an extensive portfolio of operations extending across production, trade and service industries, which renders particularly difficult any attempt to consolidate port roles and functions under the same operational, business or market category. The port of New York/New Jersey is a typical example in this respect. In addition to providing multimodal services such as airports, seaports, rail and bus terminals, bridges and tunnels, the port also owns several industrial parks, the former World Trade Centre and a regional bank for urban and city development.

Nautical infrastructure (marine services)	Quay and berth infrastructure (terminal services)	Port superstructure (logistics and value-added services)
• Conservancy and protection	• Pilotage and towage	• Cargo storage and stacking
• Access and navigation	• Berthing	• Equipment services
• Shipping services	• Bunkering and supply	• Distribution and related services
• Vessel traffic management	• Ancillary services	• Information processing
• Dredging and maintenance	• Stevedoring and cargo handling	• Real estate and rental services
• Repair and maintenance	• Quay transfer operations	• Logistics and value-added services

Table 2.1: Breakdown of port functions by type of assets and facilities

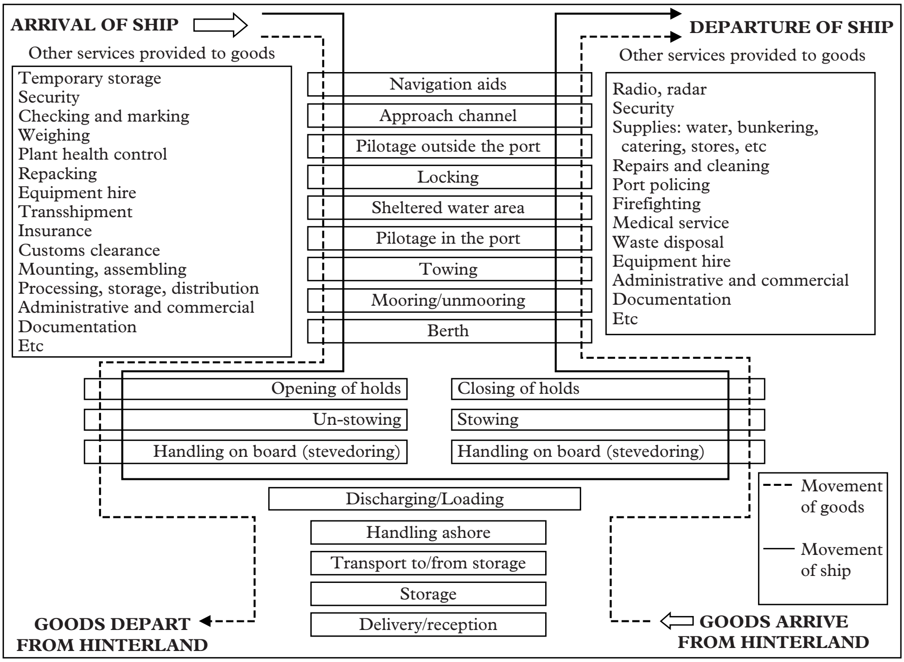

Fig. 2.1: Main operational and administrative functions of a port
Source: UNCTAD.

Nonetheless, despite the major impacts of ports on the efficiency of international transport and trade systems, there is a lack of research concerning port operations, in particular from the viewpoint of port managers and service providers (Murphy *et al.*, 1988). Among the very few existing frameworks tracing port activities, the UNCTAD's 'Improving Port Performance' (IPP) framework remains the most quoted in the academic literature. Although more tailored to the general cargo/break bulk operations, the IPP1 reference (IPP1: port operations and management) provides a reference guide for operational and administrative functions of ports. Further references were developed for other port-type operations and facilities: IPP2 for container terminals, IPP3 for equipment and maintenance, and IPP4 for strategic port pricing. On the other hand, individual efforts have focused on specific port facilities (mainly container terminals) where operational and logistics management techniques (ERP, JIT, etc) were applied in order to integrate and optimise various operations within a pre-defined framework of port functional roles (Choi *et al.*, 2003).

2 PORT INSTITUTIONAL AND ORGANISATIONAL STRUCTURE

Institutional dissimilarity also hinders a comprehensive approach to ports, as there are several organisational and ownership models applicable to world ports, even between those performing similar roles and functions. Traditionally, ports have been owned, operated and regulated by state-controlled public organisations. However, the introduction of private sector participation in ports and the emergence of new forms of port governance have led to the adoption of new models of port ownership and institutional structuring.

Current models for classifying port organisational and institutional structure use one or a combination of the following criteria: mode of administrative governance (central or local), the institutional framework (private or public), regulatory and policy system (protection, liberalisation, market regulation, etc), and labour affiliation and organisation.

A first approach looks at the degree of devolution of public decision making in port operations, management and policy. Here a variety of public port models exist—from centrally controlled ports to ports controlled by local administrations and municipal authorities. Other models include autonomous and corporate ports. An autonomous port, a model widely applied in France, French-speaking Africa and parts of Latin America, is a public enterprise which enjoys a high degree of autonomy and independence from the central government. A *port corporation* is a public company that can be either government-owned or statutory-owned depending on the legislation and regulatory regime that govern its operations and management. The trust of corporatisation is that it converts the traditional port organisation into a public company operating under the same legal rules as a private company. Over the past decade or so, several countries such as Australia and Canada have embarked on port corporatisation programmes with several forms of corporatisation models being currently under implementation or review.

A second approach refers to the public–private status of port operations and management. Here, ports are classified as being either public or private. However, because of the complexity of private sector involvement in port operations and management, some authors distinguish between four major models of port ownership and administration: the public port, the public/private port with the public sector being dominant, the private/public port with the private sector being dominant, and the private port. The *trust port*, a model mainly applied in the UK and former British colonies, is a unique model since it may be described as neither a public nor a private port. A trust port is an independent statutory corporation governed by its own legislation and controlled by an independent board of trustees. Although operating in a commercial way, trust ports do not necessarily seek profit maximisation and they have no requirement to distribute dividends to their stakeholders. Indeed, the latter have no control or power of sanction over the trust port boards, and this may create a potential deficit in accountability and efficiency.

A more elaborate approach analyses port ownership through combining the aspects of port facilities and services with the status (ie private, public or joint/mixed) of the entity owning and/or providing for them. Here the port literature provides generic terms where ports are classified into *landlord*, *service* or *tool* organisations, or variations and combinations of some or all of these. The main difference between the above three models refers back to the aspects of public or private ownership/operations of port facilities (infrastructure and/or superstructure) and of the affiliation of port workforce and labour. In the service model, the port authority owns, maintains and develops both infrastructures and superstructures, operates all handling equipment and performs all other commercial port functions on its own. Both the landlord and tool organisations own and develop port infrastructure and generally lease it to the private sector. However, while the superstructure is owned and operated by private operators in the landlord model, the tool institution still owns the superstructure but may lease it out for operational purposes to private companies. This distinction is however not always obvious. For example, in relation to the definition of superstructure assets, some ports may restrict this to cargo-handling equipment, while others may extend it to include storage, warehousing and logistics facilities. Similarly, the issue of manpower employment may be blurred across the different models. For example, many tool ports require private companies to rely on port-employed dockworkers and other labour. There exist several variations on the above terminology including functional ports, comprehensive ports, hybrid ports, fully private ports, and private service ports. Port function and ownership models are usually categorised in relation to port infrastructure, superstructure, labour and regulation.

The *port authority* or *agency* is a common institution found across various ownership models and may assume several roles ranging from being the landowner of port infrastructure, to an operator of port superstructure and/or a

	Infrastructure	**Superstructure**	**Workforce**	**Regulation**
Landlord	Public	Private	Private	Public
Tool	Public	Public (private)	Private (public)	Public
Service (public)	Public	Public	Public	Public
Service (private)	Private	Private	Private	Private

Table 2.2: Generic institutional port models

developer of both. The World Bank limits the role of the port authority to the following functions: a landlord for private entities, a regulator of economic activity and operations, a planner for future operations and investments, an operator of nautical services and facilities, a marketer and promoter, a cargo handler and storer, and a provider of ancillary activities. However, there are conflicting viewpoints about the nature and extent of the port authority's roles and functions.

Even when embracing the World Bank taxonomy, there are usually different players involved within and across port assets and facilities, for example, the harbour approach and nautical facility providers, cargo handlers on board or stevedores, cargo handlers on shore, freight forwarders, port and ship agents, bunkers, multimodal transport operators, customs, health authorities and others. Figure 2.2 summarises the variations in institutional and organisational management models across major port assets, facilities and services. The divisions between private and public ownership in Figure 2.2 are hypothetical but typical. In practice, there are various and complex institutional models of port ownership ranging from central or state models (South Africa, Thailand), decentralised models (Germany and the Benelux countries), a combination between national and local port systems (France, Italy, North America), to partially or fully private models (Japan, UK). In fact, most port institutional models lie somewhere between central/local and public/private variations. The nature and extent of public involvement in port ownership has always provoked intense debate involving issues of port operational performance, privatisation, corporatisation, devolution, regulation and policy. Yet, there is no definitive boundary between what should be controlled by the public entity and what should be managed by the private sector in ports. There is no best practice in this regard, although there is some practical evidence that the participation of the private sector has raised operational efficiency and yielded significant productivity improvements. Despite this, there is no irrefutable link between the extent of private sector participation and the level of productive efficiency.

Ports are complex and multipart organisations where institutions and functions often intersect at various levels, which makes it more difficult to

Table 2.3: Description, strengths and weaknesses of port institutional models

	Description	Strengths	Weaknesses
Public service port	• Owns, develops and maintains, both infrastructure and superstructure • Owns and operates handling equipment • Operates and performs on its own all services • Labour for all port services provided by public sector	• Huge investment required • No redundancy (in theory) • Unity of command and management	• Handling operations not• compatible with administrative duties of public entity • Private sector out of the port business • Strong power from labour unions
Landlord port	• Owns, develops and maintains the infrastructure, but leases/rents it to the private sector • Handling services performed by private sector. Labour for handling services provided by private sector • Marine and nautical services may be performed by either the public sector, the private sector, or a combination of both	• No investment required in equipment and superstructure facilities • Private sector efficiency and accountability • Investment by the private sector ensures strong market leadership, long-term relationship • Competitive market dynamics • Better management of port labour	• Possible conflict between private sector objectives and general public interest • Risk of footloose

(Continued)

Table 2.3: Description, strengths and weaknesses of port institutional models *(Continued)*

	Description	**Strengths**	**Weaknesses**
Tool port	• Owns, develops and maintains the infrastructure • Owns superstructure which is operated by the private sector • Labour for handling services provided by public sector • Marine and nautical services may be performed by either the public sector, the private sector, or a combination of both	• Huge investment required • No redundancy (in theory)	• Double entity (public and private) undertaking handling operations and management • Possibility of conflict regarding equipment assignment and operational efficiency • No control over gang and labour efficiency from the part of the private sector
Private service port	• Private sector owns, develops, and operates infrastructure, superstructure, and all other port services • Private sector provides labour for all port services • Regulatory and statutory functions may be performed by the public authority	• Port operations and management performance not influenced by political decisions • Higher efficiency in asset and human resources management (in theory)	• Risk of market failure, eg monopolistic behaviour • Difficulty in planning and implementing public port policy • Possible deviation from core port business (eg handling) to more profitable activities (eg real estate development)

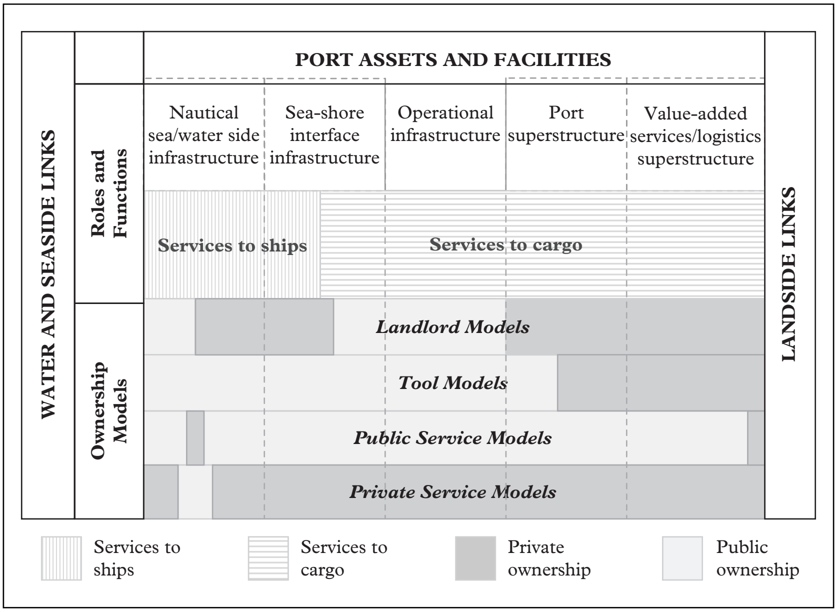

Fig. 2.2: Variations of functional roles and institutional models across different port services and facilities

identify who does what, and why in ports. Within a typical port setting, a myriad of institutions each with different, sometimes conflicting, missions and objectives, perform one or more port functions through owning, sharing, leasing or just using some or all of port assets and facilities. The appropriate organisation for ports has been one of the most debatable issues in port operations, management and policy. Over the last decade or two, there have been several attempts to delimitate public/private boundaries in the provision and management of port services, especially with the rise in popularity of Public Private Partnership (PPP) schemes and arrangements (see Chapter 4). Despite this, there is no standard model for port ownership and institutional structuring, and one can find many styles of organisational structure throughout the ports of the world.

3 PORT DEVELOPMENT

Ports have developed in different ways with a combination of trade, economic, spatial, political, social, and even cultural and military influences, and no clear pattern of port development exists. Ports have also transformed from labour-intensive merchant ports into capital and technology-intensive enterprises. Since the industrial revolution, ports have progressed into become manufacturing sites moving vast quantities of goods and commodities and using larger and expensive equipment. Following the process of containerisation and the growing specialisation of ships and terminals, ports became even more capital and technology intensive with sophisticated handling equipment and technological systems being deployed across modern ports and terminals. Ports have also developed as spatial and regional entities. Through the years, the relationship between port-cities and their hinterlands has been influenced by many factors such as economic development, industry specialisation, trading relations, military expansion, social migration, family networks, and cultural exchange. More recently, the importance of ports and their corresponding hinterlands has been influenced by new factors such as containerisation, inter-modal integration, shipping networks, logistics patterns, information technology, environmental sustainability, land use and policy.

Bird's (1980) 'any-port model' is one of the first structured attempts to explain port development. The model suggests a three-stage process of port development: setting, expansion, and specialisation. Although Bird's model may be still valid for a number of conventional ports, it neither explains the recent rise of transhipment and network type of ports and terminals, nor integrates the inland and spatial dimension of port development. Following this trend, Taaffe *et al.* (1963) suggest an increasing level of port concentration as certain hinterland routes develop to a greater extent than others in association with the increased importance of particular urban centres. The geographical system would evolve from an initial pattern of scattered, poorly connected ports along the coastline to a main network consisting of corridors between gateway ports and major hinterland centres. The models of Barke (1986) and Hayuth (1981) are quite similar, though they have introduced a process of port system de-concentration. Waters (1974) considers that port activities could be developed in three ways in relation to cargo-space dimensions: the attraction to water transportation of cargo otherwise moved by non-water transport modes (dominant hinterland), the attraction of cargo moved through other ports (competitive hinterland), and the development of its own cargo from industrial expansion in its dominant hinterland (uncompetitive hinterland). Some authors have introduced modifications to the above models in order to reflect the uniqueness of some port regions (Wang, 1998; Notteboom, 2003).

UNCTAD's 'port generations model' is another widely quoted reference describing the evolution of world ports and terminals. The main benefit of the UNCTAD model is that it explains port development from a functional and institutional perspective rather than a geographical or spatial one. Not only port roles and functions, but also institutional structuring, operational and management practices vary significantly from generation to generation. First and second generation ports, relating to ship/shore and industrial interfaces, respectively, operate bulk and break bulk cargo in a traditional manner, with the second generation ports relying more on capital than labour. Third generation ports

Fig. 2.3: The ports of Antwerp and Marseille in the years 1650 and 1575, respectively

are the product of the unitisation of sea-trade and multimodal cargo packaging (mainly in the form of containers) which has led to the development of ports as logistics and inter-modal centres offering value-added services, with technology and know-how being the major determining factors. Fourth-generation ports are mainly the result of recent vertical and horizontal integration strategies and are identified as being separated geographically but with common operators or administration (UNCTAD, 1999).

Despite its merits, the UNCTAD's generation-type port model has many shortcomings. First, it identifies port generations through sea/shore interface developments with little interest in port potential for shore/land-side expansion, as in the case of dry ports and distriparks. Second, it applies a rigid categorisation far from reflecting the composite reality of ports. Many ports in the world still perform first or second generation-type functions, and even within a single port, there may be a variety of operational and management systems intersecting across different generation categories. Third, it hypothetically equates all cargo/ship type operations and functions under the same generation. In practice though, many fourth generation ports still carry out activities of first or second generation ports, for instance, by handling first generation-type cargo and ships.

Last, but not least, the World Bank's *Port Reform Toolkit* is a recent attempt to provide a structured framework for port reform and development, focusing in particular on the interplay between public and private interests in shaping

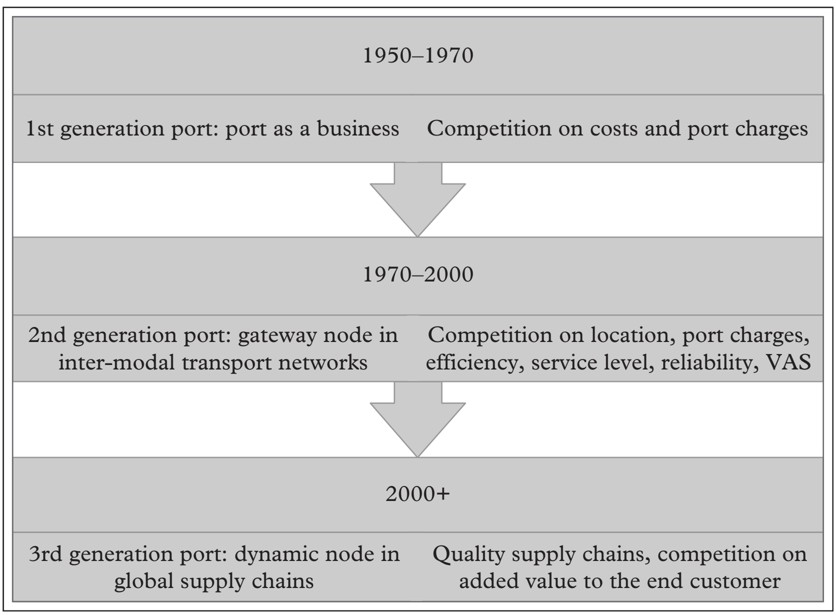

Fig. 2.4: UNCTAD's port generations model

port organisation, ownership structure, contracts and regulation, reform and development.

Despite the variety of approaches, no authoritative definition of ports' functional or organisational management exists. At one end of the scale, port functions are identified by spatial dimensions, that is, from ship/shore interface to logistics or production centres. At the other end of the scale, the functions of a port are defined by the extent of its economic and social missions and impacts. Similarly, port ownership and organisational models tend to be a combination of three variants: the extent of public/private involvement, the mode of governance (from centralised to decentralised systems), and the scope of port facilities, assets and services. Port organisation also changes with time, and what was previously thought to be an ideal-typical model of port ownership can later prove to be outdated and inefficient.

3.1 Issues in Developing a Unified Port Model

From the above categorisation, it seems that the interactions between port missions, institutions and functions have resulted in a variety of approaches to port operations and management. Probably, the major obstacle against adopting a unified model for port development and strategy refers back to the complexity and diversity of the port business at more than one level, including:

- *Organisational differences*: issues of ownership (public versus private), institutional status (landlord/tool versus service), social arrangements (labour and manpower), etc.
- *Operational differences*: types of cargo handled, ships serviced, terminals operated, etc.
- *Physical and spatial differences*: location, access, connectivity, available capacity, etc.
- *Legal and regulatory differences*: trade and transport policy, administrative procedures, safety and security regulations, environment, etc.

Bichou and Gray (2005) highlight the decisive factors that drive port development (see Table 2.4). If the institutional framework is the defining attribute, each institution will apply a distinct viewpoint to its activity within the institutional framework, to the activity of other actors, and to its role in the aggregate port management. Similarly, if missions are perceived as the defining attribute, then port assets, functions, and institutions will all be redefined accordingly. The experience of the USA provides a typical example where port missions and objectives as defined by the policy maker largely shape other attributes of port management. For instance, the early recognition of ports as inter-modal platforms has led over the years to the active involvement of multimodal operators in port operations and management, for example, rail transport operators such as CSX became port institutions through terminal ownership and management (CSX World Terminals, now part of DP World). In a similar vein, the

	Missions	Assets/ facilities	Functions	Institutions
Macro-economic approaches				
Economic catalyst	Major			
Job generator	Major			
Trade facilitator	Major			
Institutional models				
Private/public	Minor			Major
Landlord/tool/service		Major		Minor
Geographic and spatial approaches				
Port-city	Major			
Waterfront estate	Minor	Major		
Sea/shore interface	Minor		Major	
Multimodal port	Minor		Major	
Clusters				Major
MIDAs and TMDCs	Major		Minor	
Free zones and trading hubs	Minor		Major	
Hybrid approaches				
UNCTAD generations	Major		Major	Minor
World Bank model	Major			Major
Alternative new approaches				
Combinative strategies (cargo–sea–land, supply-demand led)	Major		Major	
Logistics/production systems (trade port, logistics port, teleport, etc)	Major		Major	
Business units (production, marketing, pricing, etc)	Minor		Major	

Table 2.4: The role of decisive factors in determining port approaches
UNCTAD, United Nations Conference on Trade and Development; MIDA, maritime industrial development area; TDMC, trade and distribution maritime centre.

adoption of the 1998 Ocean Shipping Reform Act (OSRA) has also redefined the role and functions of many traditional market players such as NVOCCs. In both Singapore and Dubai, the shift from local to international operations has been prompted by a major review of port roles and missions, and followed by the creation of relevant institutional structures (PSA International and DP World, respectively). There are many other examples around the world where the prior definition of port missions and objectives has led to different models of institutional, functional and operational port systems. The same logic applies to other attributes when the functions or assets/facilities criteria are considered as decisive factors. Table 2.4 categorises major literature approaches to port definition by analysing decisive factors. Major or minor influences of the decisive factors are postulated.

3.2 Current and Future Trends in Port Operations and Logistics

Seaport development strategies, operations and planning schemes have traditionally focused on sea access components such as the nautical approach, the seashore infrastructure, ship and cargo-handling equipment, and other related services and facilities. As a result, much of port operations concepts were centred on the seashore interface including such topics as port planning, operations, performance and efficiency. Similarly, the segmentation of the port market has traditionally been oriented towards the sea-leg component of the transport chain, with port development, marketing and competitive strategies being typically formulated to meet the requirements of sea transport and related cargo-handling services with little emphasis being placed on logistics and supply chain services.

Nevertheless, this one-dimensional approach neither reflects the complex structure of the port's system nor explains the dynamics of both its internal and external environments. On the one hand, the maritime conceptualisation of ports limits their functional and spatial attributes, whereas in a typical port setting an extensive portfolio of multi-institutional and cross-industry operations are, or could be, undertaken at different spatial and sectoral port levels. On the other hand, the narrow maritime transportation and trade paradigm has a limited capacity to explain the mechanisms and evolution of port management and operation systems, especially in view of recent developments in global distribution, logistics and supply chain systems. In this context, port management is experiencing change along four dimensions: the extension of the port role; strategies of vertical and horizontal integration; redefinition of the port hinterland and foreland; and reassessment of the port customer.

3.2.1 Extension of the port role

Today, the role of ports exceeds the simple function of services to ships and their cargo. The cross-functional dimension of ports implies that their roles can range from a simple berthing facility to a large distribution and logistics hub. Such diverse portfolio may require a redefinition of port's functional attributes in that the port system not only serves as an integral component of the transport system, but also is a major sub-system of the broader production and logistics system. Logistics integration and network orientation in the port and maritime industry have redefined the functional role of ports in value chains and have generated new patterns of freight distribution and new approaches to port hierarchy. Furthermore, many ports in the world are shifting to more profitable non-maritime business interests outside their traditional core businesses, for instance in areas such as real estate management, property development and recreational activities. The definition of the port role and the degree to which the port activity should be limited to or associated with ship-shore, goods transfer and/or cargo-flows management pose a dilemma as to where the demarcation line lies between port and non-port functions.

3.2.2 Strategies of vertical and horizontal integration

With many international shipping and logistics market players undertaking vertical and horizontal integration strategies, including those involving ports, the conventional taxonomy of port institutional players should be fundamentally reviewed. Strategies of vertical integration include ocean carriers and other multimodal providers (eg railroad firms) engaging in terminal leasing and ownership, but also ports (or port operators) offering a wider range of logistics and multimodal services. Shippers are also sometimes perceived as port owners, such as through dedicated oil or car terminals. Horizontal integration strategies were less common in the past but are gaining more support in recent years, through port co-operation and mergers and, more particularly, with the expansion of certain ports beyond their initial spatial bases. The impacts of such changes on the port industry are dramatically significant in the sense that today's ports can be owned and managed by many types of institutions (both within and outside international shipping and logistics markets), and that the long-established perception of ports as non-moveable assets may no longer hold so much validity.

3.2.3 Redefinition of the port hinterland and foreland

Traditional concepts of port hinterlands and forelands along with the derived port-marketing terminology (captive, dominant, competitive, etc) have become less relevant. Strategic expansion and networking of ports and port operators, along with the scope of landside extensions, currently undermine the significance and application of spatially homogenous port ranges and hinterlands. Not only are ports no longer immoveable (if not as fixed assets, at least as institutions), but also the impacts of globalisation, deregulation and privatisation have shifted port competition to the cross-border, cross-industry levels.

The instigation of new logistics patterns of maritime and inter-modal transportation, such as in terms of hub, transhipment and network models, means that modern ports, wherever they are or could be located, can now compete for far-reaching cargoes with far-distant counterparts. Similarly, the increasing channel control and bargaining power of ocean carriers in international shipping and logistics, including as port owners and operators, means that modern ports will bear a higher risk of footloose relocations, and hence recurrent changes in spatial and functional features.

3.2.4 Reassessment of the Port Customer

Whilst ports have always been perceived as an integral part of the shipping and maritime business, the extensive portfolio of port operations traversing production, trade and service industries renders particularly difficult any attempt to approach world ports homogeneously under the same market category. This, compounded with the substantial restructuring of international shipping and logistics markets, actually blurs the demarcation lines between previously separate markets for logistics services. For instance, today's mega-ocean carrier functions are not restricted to the sea-leg transport, but are widely extended across logistics and supply channels, including as port operators and multimodal transport providers. Similarly, many non-maritime businesses, such as warehousing, inter-modal and distribution activities and also trading and financial services, are increasingly operating within or around port locations. This means that the current portfolio of port users no longer solely consists of sea transport operators and their intermediaries, but is extended to a wide range of customers along the supply chain, including shippers, 3PL providers and inland transport operators.

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CHAPTER 3

PORT PLANNING

Port planning is an area where several topics related to port investment, capacity, design, operations, strategy, and policy are dealt with simultaneously. It offers the opportunity to apply methods and techniques from intersecting disciplines such as engineering, economics, business management, geography and environmental studies. It also links port activity with both maritime and inland transport systems as well as with the wider logistics and supply chain system.

The core objective of port planning is to seek a balance between shortages in capacity and over-capacity at adequate cost, price and service levels. This involves decisions related to operational productivity and optimisation, network and demand modelling, design and layout configuration, market research and development, project appraisal and economic valuation, investment financing and analysis, competition and pricing, and public policy and development. Port planning is also about finding the right balance between, on the one hand, the business and economic drivers of port capacity, and on the other, the constraints imposed by spatial planning, land use, environmental sustainability, and various policy and societal factors.

Capacity is an important characteristic of transport infrastructure. It indicates the capability of the infrastructure system to accommodate transport modes and vehicles and to provide associated services at specific cost and service time levels. However, capacity may be defined in different ways. From an engineering perspective, port capacity is defined as the maximum technically possible utilisation rate that can be achieved in the short-run with the existing port facilities and resources: infrastructure, equipment, labour, technology, etc. This definition denotes the *theoretical* or *designed* capacity as opposed to the *practical* or *effective* capacity. The latter indicates the maximum capacity which can be achieved at a quality of service acceptable to most customers, for instance by incorporating a general tolerable level of congestion. However, when the port operator seeks to provide a higher or a particular level of service quality to his customers, such as in terms of a ship's faster turnaround time, the maximum capacity that can be achieved under these arrangements may be described as the *commercial* capacity. On the other hand, the *economic* capacity is defined as the capacity beyond which the average operating costs for port

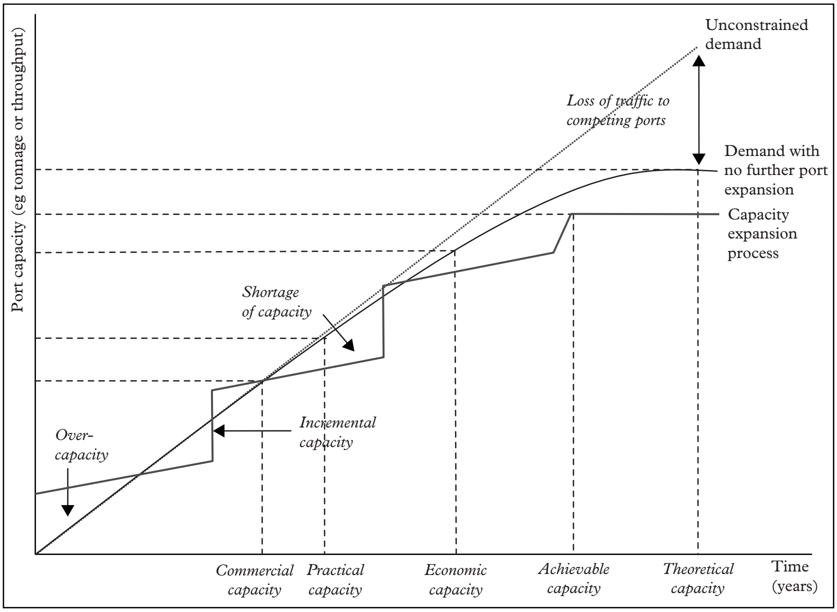

Fig. 3.1: Illustration of different definitions of port capacity

activities and services begin to rise. Finally, the *incremental* capacity describes situations where incremental port capacity is added at regular time intervals.

The study of port capacity involves both capacity planning and capacity management. Capacity planning is the techno-economic process of predicting the required additional capacity that matches the future demand for port services, including the study of engineering and financial options of implementation. Capacity management, on the other hand, refers to the process of optimising port operations for a given capacity, while ensuring a balance between cost-effectiveness and service quality. Capacity planning and capacity management are often linked to structural and non-structural measures of port capacity. Structural measures focus on facility expansion such as dredging works, land reclamation and the acquisition of new port equipment. Non-structural measures, on the other hand, focus on improving utilisation of existing facilities. Examples of non-structural measures include reducing demand (congestion pricing, traffic diversion, slot auctioning, etc) and/or improving operational and procedural efficiency (eg lesser ship and cargo dwell time (DwT), faster data exchange and inspection, etc).

Another distinction must be made between various horizons of port planning or port plans: operational planning, strategic planning and long-term planning. Operational planning deals with short-term (eg daily) planning including allocation of port facilities and resources, and may be implemented in terms of several detailed planning modules such as berth planning, yard

	Port plans	**Time range**	**Scale**	**Level of details**
Capacity planning	Master/ development plans	≥10 years	Large	Low
	Strategic/ business plans	3–5 years	Medium	Medium
Capacity management	Operational plans	Daily/ weekly	Small	High

Table 3.1: Different types of port planning

planning and gate operations. Strategic planning is generally undertaken between three and five years and emphasises the use of existing port capacity and resources, as well as those to be acquired in the medium-term, with a particular focus on market planning and corporate strategy. Long-term planning involves the production of a master plan for the development of facilities and acquisition of heavy equipment in order to meet the long-term demand for port services. In any case, planning is needed across all areas of port systems including infrastructure, equipment, vehicles and labour.

1 CAPACITY PLANNING

Planning for port infrastructure essentially involves establishing the optimal capacity whereby port facilities and services are provided at the appropriate service time and cost levels. It is a complex process which comprises at least three components: design, evaluation and financing, and involves a wide range of port actors and stakeholders. Since the evaluation and financing of port projects are discussed in detail in Chapter 4, this chapter will restrict the discussion to the subject of capacity design.

The design of port capacity involves the analysis of the expected demand and the required supply of port capacity, and the development of alternative strategies to affect the demand/supply scenarios and mechanisms. An important aspect of the design of port capacity is determination of the level of long-term demand for port facilities and services. Several factors impact port demand including the general economic condition, shifts in logistics and supply chain systems, trade flows and transport demand projections, development of ship's size and technology, traffic routing and distribution patterns, port markets and competition, and user's choice and selection. These factors include both endogenous and exogenous aspects. The former refer to factors that fall within the control of the port operator or authority, for instance port performance and operational efficiency, terminal tariffs and charges, and the

Demand	Supply
• Trade growth and economic output • Trade and economic policy • Shifts in production and logistics networks • Traffic forecast and freight flow categories • Routing patterns and return logistics • Shipping fleet, size and technology • Inland transport and logistics requirements • Transport and logistics costs • Port choice and selection	• Existing port capacity • Landside infrastructure and capacity • Planned capacity expansion • Port congestion and productivity • Port costs and prices • Competition from inland transportation

Table 3.2: Determinants of the demand and supply of port capacity

range and quality of port services. The latter refer to external factors that are beyond the control of the port operator, for instance the growth of the world economy, the increase in ship size and a change in trade or tax policy.

1.1 Demand for Port Capacity

During the past four decades or so, several techniques have been developed for modelling freight transport systems as they reflect the need for a detailed analysis and for integrating different layers (eg trade, geography, logistics and the wider economy) of the broader transport system. For an extensive review of the transport and freight modelling literature, the reader may refer to the Freight Model Improvement Program website of the US Department of Transportation (www.freight.dot.gov).

For the purpose of this book, we categorise these approaches into two main groups which can be used to simulate port demand: transport demand modelling and port choice modelling. The former approach focuses on mode and route selection while the latter focuses on port selection.

1.1.1 Transport demand modelling

Given the origin and destination (O–D) flows and a transportation network, two main approaches can be used for modelling port and freight transport demand. The first approach consists of simulating macro-economic relationships to predict port demand based on a fixed market share, while the second approach seeks to simulate traffic assignment based on static transportation network and port expansion assumptions. A combination of both approaches can be used to simulate the effect of competition and to incorporate autonomous demand growth. As shown in Figure 3.2, the procedure of port traffic forecasting follows the classical transport forecasting four-step process namely

Decision problem	**Typical modelling challenges**	**Typical techniques employed**
Production and consumption	Trip generation and facility location Freight/economy linkage Consumption patterns	Trip generation models (1970s), I/O models (1970s), LUTI models (1970s), SCGE models (1990s)
Trade	International trade Value to volume conversion	LUTI models (1970s), gravity models (1970s), SCGE models (1990s), agent-based simulation models (1970s)
Logistics services	Inventory location Supply chain management considerations	Multimodal networks (1980s), agent-based simulation models (1970s), logistics choice models (1990s)
Transportation services	Choice of mode Inter-modal transport light goods vehicles	Simple trip conversion factors (1970s), multimodal networks (1980s), discrete choice models (1990s)
Network and routing	Routing and congestion Tour planning City access	Multimodal networks (1980s), network assignment models (1980s), simulation models (1990s)

Table 3.3: Summary of freight modelling approaches and techniques

trip generation, trip distribution, mode choice and route assignment. The main elements of port traffic forecasting are:

- analysis of the macro-economic development,
- analysis of the economic developments in the region,
- trade/traffic generation model,
- trade/traffic distribution model,
- modal split analysis, and
- spatial/geographical split analysis.

Other relevant factors include:

- survey/perception of customers,
- survey/perception of users (not direct customers),
- technological innovation (eg, ship's size and speed, cargo handling productivity),
- pricing arrangements (eg, strategic and congestion charging),
- policy and tax policy (eg, subsidising short sea shipping to reduce road congestion).

Traffic forecasting

The starting point for freight demand modelling is the estimation of future trade flows by O–D, trade lanes, type of commodity, and type of cargo packaging (eg containers, break bulk (BB), etc) in case of general cargo goods. Methods of trade forecasting usually rely on complex econometric models and data available from national governments (eg customs data, foreign trade statistics), research and consulting organisations (Data Monitor, GTI services, Global Trade Tracker, etc), and international agencies (eg the World Bank World Integrated Trade Solution (WITS), the United Nations Commodity Trade statistical database COMTRADE), the EUROSTAT, OECD, UNSD, UNCTAD/WTO joint Common Dataset (CDS) for merchandise trade statistics). Sometimes, detailed O/D matrices may not available in some countries and adequate estimations may be used instead. Several factors influence the estimation of trade flows including socio-economic growth (GDP, population, consumption, price inflation, etc), economic and trade policy (protection versus liberalisation, currency exchange policy, emergence of trading blocks, etc), structure of economic output (competition and factor substitution, shifts in economic structure, etc), and changes in logistics and supply chain systems (changing nature of markets, intra-firm trade, configuration of supply chain processes, trends in international procurement, production, distribution, etc). With the increasing trend of globalisation, global factors have become more predominant for explaining international trade flows than country-specific traditional factors.

Traditionally, freight demand forecasting relied on times-series and cyclical projections to estimate trade forecast and the amount of transport demand derived from it. However, these models overlook the international and changing nature of trading and logistics markets and do not account for transport or logistics costs and for policies to reduce them. Modern methods of freight transport demand modelling use a variety of approaches ranging from gravity to network modelling.

Gravity models are mathematical models based on Newton's formulation of gravity which considers the distance and the physical size between two objects. It is used to formulate geographical and spatial interactions such as traffic flows. In the basic formulation of gravity models, the freight flow F_{ij} between two origin–destination regions i and j can be estimated as follows:

$$F_{ij} = \frac{kP_iP_j}{d_{ij}^{\alpha}}$$

where:

P_i and P_j are the masses (economic size) for the locations of origin and destination, respectively, d_{ij} is the distance between the two locations, k is a constant determined when adjusting the model, and α is a constant representing the intensity of friction or transport system's efficiency between the two locations.

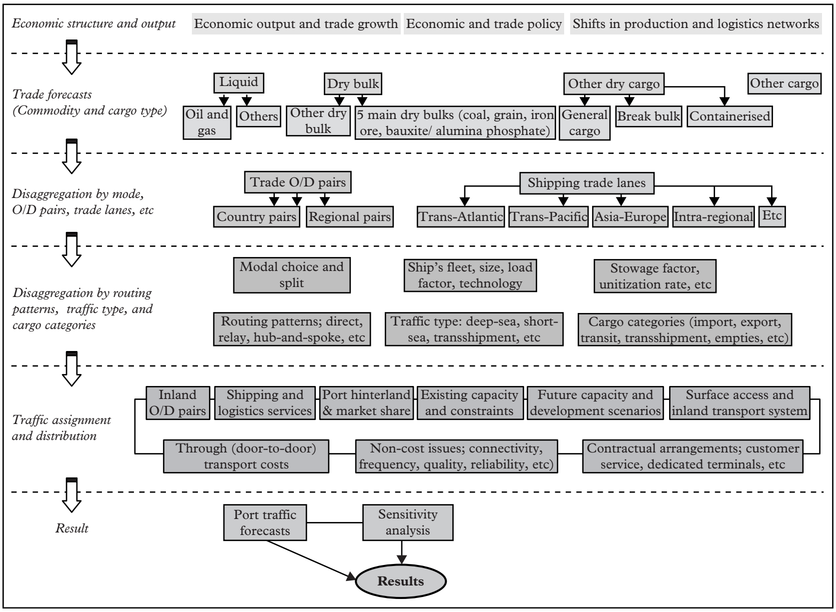

Fig. 3.2: The process of a general framework for port demand and traffic forecasting.

In order to make the gravity model operational, the simple formulation above has been extended to include operational constraints as well as additional parameters such as transport and transit costs. A major impulsion to gravity models was given by the use of input/output (I/O) and spatial computable general equilibrium (SCGE) models. Spatial price equilibrium models are used to determine traffic flows simultaneously between origin and destination, and are based on the equilibrium condition between a commodity's demand price and its supply price plus the transportation costs. The main drawback of these models is that they are complex and difficult to calibrate vis-à-vis all parameters, especially where an agent's behaviour is included. Spatial economic models have been developed to integrate trade and transport systems but fall short in integrating distribution logistics and supply chain network systems.

In network modelling, a network equilibrium model is developed so that the users of the network are assumed to be multi-criteria decision-makers. Here, the determination of port demand requires an analysis of freight transport demand in a shipping and port network characterised by competing routes and fluctuations of freight flows. Network equilibrium models are commonly used for the prediction of traffic patterns in transportation networks that are subject to congestion. These models are based on the equilibrium condition that generalised transportation costs are minimal and equal for homogeneous routes. The main advantage of these models is that they are able to describe actors in detail and incorporate their behaviour through game theory. A major development in this regard is the emergence of freight logistics models that analyse the trade-off between transport and inventory holding. Here O/D trade flows for production and consumption locations are linked to O/D tables for warehouse locations and distribution centres. In recent years, supply chain network equilibrium models have been developed to optimise the behaviour of the various agents in the supply chain and derive the related equilibrium conditions. However, we are not aware of any supply chain network model being developed or applied in the context of port planning and operations.

Traffic assignment

At the centre of network modelling is one or several traffic assignment models that simulate route and mode choice. Traffic assignment involves route (or path) and mode choice between origins and destinations, usually by minimising generalised cost. Various trade-offs have to be made for a route selection decision. The generalised cost-concept usually involves a weighted sum of different cost components, the most common of which are transport cost and transit time. Further degrees of refinement include the incorporation of stochastic and congestion effects.

Traffic assignment models can be either static or dynamic, with the latter providing insight on time variability and dependencies. Techniques for analysing traffic assignment models can range from mathematical modelling to computer simulation. For ports, much of traffic assignment models aim at minimising total transport cost and the constraints related to port capacity. Factors related to total transport costs include distance, maritime costs, inland costs and port charges. Factors related to port capacity include the port's area, throughput and productivity, all of which decide the level of marginal social cost. Other relevant factors in the modelling of the supply of port capacity are travel and transit time and the user's value or opportunity cost of time (see Chapter 4). Finally, decisions on freight flows are not defined by cost and price considerations alone, and other aspects such as connectivity, frequency, reliability, and quality of service are also important factors in the traffic assignment process (see Chapter 9).

1.1.2 Port choice modelling

The general objective of port choice models is to study competition patterns in ports and analyse their positioning, marketability, contestability and attractiveness. Sometimes, port choice models are used to forecast/analyse traffic distribution patterns, undertake feasibility studies for port development, and/or explain users' behaviour mainly that of carriers and shippers. In the literature on the determinants of port choice, three main factors can be identified: route factors,

cost factors and service factors. Route factors include location, accessibility, connectivity, hinterland network, frequency and transit time. Cost factors include freight rates, tariff and charges and capacity. Service factors refer to aspects such as efficiency, congestion, reliability, flexibility, safety and security. Table 3.4 lists the main decision factors in recent studies on port choice modelling.
Different approaches to model the port selection process. D'Este and Meyrick (1992) categorises port choice models into three main groups: input-oriented models, outcome-oriented models and process-oriented models:

- Input-oriented models relate to the scope and relative importance of the various factors that influence carrier choice. Examples of input-oriented modelling include factor analysis and calculating importance means. A general criticism directed at these models is that they do not really give an insight into the actual decision-making process.
- Outcome-oriented models are concerned with predicting the outcome of a particular decision situation by using advanced mathematical techniques. In the context of port competition, the decision outcome can either be the selection of the port itself or the routing/logistics decision that induces the selection of the port. Given the difficulty to model the aggregate behaviour of economic players in the selection of ports, researchers have mostly applied disaggregate demand models using such techniques as discrete choice analysis and the analytical hierarchy process (AHP). The power of these techniques results from their ability to translate psychological behaviour into mathematical terms. For example the fundamental principle of discrete choice analysis is the one of utility maximisation borrowed from microeconomic theory, but the impracticality of specifying and estimating a model that can always predict individual choice has led analysts to use the psychological concept of random utility. As for the AHP, the technique allows the combination of objective and subjective perceptions into an integrated decision process based on ratio scales from simple pair comparisons. A general shortcoming of these techniques is that they tend to be mechanistic in nature with their success being judged by their predictive power rather than their explanatory ability.
- Process-oriented models use qualitative techniques believed to better explain how different decision-making factors interact taking into account the nature of the port environment within which the interaction occurs. A good example of such models is the process-oriented model developed by D'Este (1992b) to represent ferry choice in the roll-on roll-off (Ro-Ro) freight market between Australia and Tasmania. Mangan *et al.* (2002) employed process-oriented modelling in addition to an input-oriented model to study the decision making process in the Ireland/UK Ro-Ro freight transportation market. Critics of these models point out their qualitative nature and focus on niche markets, which limit the scope of applications.

Another distinction in port choice modelling is made between behavioural models and inventory models. Behavioural models largely focus on transport

Reference	Location	Price	Efficiency	Frequency	Reliability	Infra-structure	Range of services
Tongzon and Sawant (2007)	3	2	1			4	5
Gonzalez (2000)		2			3	1	
Tuna and Silan (2002)			2		1		
Yeo *et al.* (2006)			2			1	3
Ugboma and Ogwude (2006)			1	2		3	
Malchow and Kanafani (2003)	1						
Nir *et al.* (2003)		1	2				

Table 3.4: Output of the studies: main decision factors for port selection

mode decision variables, for instance by seeking to minimise shipping or door-to-door transport costs when modelling port choice. These models have been criticised because they mechanically allocate traffic flows to the least-cost option, and as a result a new line of research relying on inventory models has emerged. Unlike behavioural models, inventory models integrate both transport and logistics decision variables, with the latter including factors such as inventory cost, production system, shipment size and frequency (see Chapter 4). Therefore, decisions on port modelling are not defined by cost and price considerations alone; and factors such as connectivity, reliability, and quality must also be considered in port and mode choice. Other relevant factors include supply chain strategies (network configuration and segmentation, production and demand planning processes, etc) and marketing considerations (brand image, fidelity, discounts straight re-buy, etc). While the notions of captive and contestable hinterlands are central to port choice and competition, there is increasing focus on port logistics and global supply chains which are of importance because of the fast changing patterns of international logistics and global supply chain systems. These aspects and others are discussed in Chapter 10.

As for the analytical models of port choice, the literature may be categorised into three types of models: qualitative analysis, economic modelling, and discrete choice analysis:

- Qualitative analysis uses surveys and interviews of industry stakeholders to investigate two major issues—who selects the port for each shipment and what factors influence the selection of port. Neither question has generated consistent results, but most authors have suggested that the port for each shipment is chosen primarily by the carrier.
- Economic models may be developed into three directions: linear programming models that assign fleets in simplified situations, economic models that represent costs of carriers or ports, and economic models that represent carriers' decisions.
- Discrete choice modelling focuses on a measure that does not require the formulation of profits or costs nor requires the conversion of each selection factor into a monetary value. If we only focus on disaggregate choice models, a key distinction is made between revealed preferences (RP) techniques and stated preference (SP) techniques. Revealed choice data provides information about past choice decisions individuals made on the subject of interest. The SP approach uses choice models derived from stated choice experiment data and is very useful for situations where the subject of study is behaviour in the presence of new situations. A key assumption is that decision makers behave rationally (although admittedly bounded) and will always choose those alternatives that yield maximum utility or satisfaction.

No technique is systematically superior to others in modelling port selection and authors advocate the mixed use of different methods. Therefore, it is

Reference	Method	Country
Tongzon and Sawant (2007)	Importance means	Malaysia, Singapore, Thailand
Gonzalez (2000)	Factor analysis	Brazil
Tuna and Silan (2002)	Factor analysis	Port of Izmir (Turkey)
Yeo *et al.* (2006)	Hierarchical fuzzy process	Korea
Guy and Urli (2006)	Multi-criteria analysis	Ports' range Montreal—New York
Chien-Chang Chou (2006)	Stackerlberg optimisation	Chinese ports
Lirn *et al.* (2004)	AHP	Transhipment services worldwide
Ugboma and Ogwude (2006)	AHP	Nigeria
Aversa *et al.* (2005)	Mixed integer programming	South America East Coast (11 ports)
Meifeng-Luo and Grigalunas (2005)	Simulation	US coastal container ports
Garcia-Menendez *et al.* (2004)	Multinomial logit model	Port of Valencia (Spain)
Veldman and Buckmann (2003)	Multinomial logit model	Western Europe (3 ports)
Malchow and Kanafani (2001, 2004)	Multinomial logit model	United States (8 ports)
Nir *et al.* (2003)	Multinomial logit model	Taïwan (3 ports)

Table 3.5: Characteristics of previous port choice studies

particularly important to understand the context of each port and the specific objectives of the choice modelling exercise before choosing an adequate model formulation. Table 3.5 outlines the methods and data sets of recent literature on port choice modelling.

1.1.3 A model for port choice from the perspective of the shipper

The work presented in this section is a summary of the methodology and procedure used in a recent consultancy assignment undertaken by the author and another expert for the study of route choice modelling of containerised imports and exports in three main ports in a North African country. Because of contractual and confidentiality constraints, references to these ports and data about them have been removed.

The study reported here adopts the shipper's (exporter/importer) perspective on port selection, considering port choice as one component of an integrated routing choice process. The overall modelling methodology considers port choice as a specific output of a five-step decision process as outlined in Table 3.6. Much of the discussion that follows deals with step 1; namely the description of the models used to compute the route choice probabilities.

Routing choice definition

Exports or imports of unitised cargo through a given port can be perceived as the outcome of a sequence of choices that include the following three steps:

- *Production:* decision to buy or sell a quantity of a selected cargo,
- *Distribution:* selection of suppliers or prospection of customers, and
- *Routing:* choice of a transport and a logistics alternative.

Step	Objective	Desired outcome	Method
1	Estimate demand function	Routing choice probabilities	Discrete choice modelling
2	Estimate future trade flows by product in tons	Aggregated trade volumes	Linear regression and average means
3	Distribute aggregated trade volumes to origin destination pairs	Future trade flows by product and by O/D pair	Linear projections, industrial production/population data used to distribute traffics by province
4	Derive national/ regional unitised traffic volumes by product and O/D pair	Containerised and Ro-Ro traffic estimates	Interviews and data collection (for unitisation rates). Statistical series for containerisation rates
5	Allocate traffic volumes to routing alternatives	Traffic estimates by route Throughput estimates by port	Aggregation of choice probabilities (step 1) over total traffic volumes by product and O/D pair (step 4)

Table 3.6: Overall model structure
Ro-Ro, roll-on roll-off.

All the above steps are affected when additional infrastructure capacity is provided, for instance through the opening of a new port or a road infrastructure:

- *Induced production* is often perceived as a positive externality of a port investment. It includes aspects such as industrial activities in the port's vicinity and in the region and the induced consumption of the workers and their families. The availability of transport also opens new opportunities to all export and import companies and the net growth in sales may be counted as an induced trade attributable to the port project. Other factors such as trade agreements and partnerships and development of transport services (in addition to transport infrastructure) may also be considered.
- *Traffic distribution* is also largely affected by a port project. Here we consider switches from one supplier to another or from one customer to another, which do not account for a net growth of traffic but rather traffic redistribution. It is especially true in the case of supply where transport cost plays an important role in the selection of suppliers.
- *Traffic routing* is also affected by transport infrastructure provision. A new transport infrastructure is meant to capture a share of existing traffic between O/D pairs and this impact on routing decision should be modelled as well.

Discrete choice model formulation

The output-oriented model used for the calculation of probability P_{ia} corresponds to a multinomial logit model formulated as below. The model was calibrated based on SP data due to the absence of historical data and extensive freight statistics. Generally speaking, stated choice models are based on information integration theory in psychology, random utility theory in economics, and econometric specifications of discrete choice models. The presumption is that shippers arrive at a choice by cognitively integrating the utilities attached to the attributes that characterise the choice object, according to a simple algebraic rule and by implementing a utility-maximising rule to convert their preferences into a choice. The model outputs are calculated for a given shipment of a decision-maker (i) and the choice probability (P_{ia}) associated to the choice of any possible alternative a.

$$P_{ia} = \frac{e^{-\alpha_a - \sum_{j=1..m} \beta_{ij} x_{ija} + \sum_{k=1..l} \beta_{ik} s_{ik}}}{\sum_{b \neq a} e^{-\alpha_b - \sum_{j=1..m} \beta_{ij} x_{ijb} + \sum_{k=1..l} \beta_{ik} s_{ik}}}$$

where:

α_a is an alternative specific constant (ASC),

x_{ija} is the *j*th attribute of alternative a for decision maker i (time, cost, etc),

S_{ik} is the *k*th attribute of decision-maker *i* or his cargo (product type, lead time, etc), and
β_{ij} and β_{ik} are alternative-specific and decision-maker specific model parameters, respectively.

The model formulated above encompasses a deterministic utility component V_{ia} which is assumed to be linear in its parameters and is defined as:

$$V_{ia} = \alpha_a + \sum_{j=1..m} \beta_{ij} x_{ija} + \sum_{k=1..l} \beta_{ik} s_{ik}$$

After having formulated the model, one must specify its components namely:

- *The decision makers (i):* The decision makers are local shippers (importers and exporters but not foreign traders), who use the services of at least one of the general cargo ports under study to export or import production inputs or finished goods from/to the region. These shippers are either directly or indirectly (through suppliers, clients or intermediaries) involved in the actual choice process and are in general assumed to play the key role in the decision chain.
- *Alternatives (a):* In order to estimate the assumed utility function and to test the underlying choice model, shippers in the sample were presented with six alternatives, which were believed to capture most of the container traffic volumes in the context of the port range under study:
  - container shipping at port A with road haulage to/from the port,
  - Ro-Ro shipping at port A with road haulage to/from the port,
  - container shipping at port B with road haulage to/from the port,
  - container shipping at port B with train haulage to/from the port,
  - Ro-Ro shipping at port B with road haulage to/from the port, and
  - container shipping at port C with road haulage to/from the port.

Alternative *a* is chosen by decision maker *i* if: $U(x_{ia}, s_i, \beta_i) > U(x_{ib}, s_i, \beta_i)$. For any other logistics pathway alternative *b*, where $[U(x_{ia}, s_i, \beta) = V(x_{ia}, s_i, \beta_i) + \varepsilon_{ia}]$ is the disutility associated to the choice of alternative *a* by decision maker *i*. ε_{ia} is a stochastic component that accounts for unobserved decision variables which affect the choice process (fidelity to one alternative, concentration of transporters, etc). The error terms (ε_{ia}) are assumed to be independently and identically Gumbel EV1 distributed.

- *Alternative attributes (x_{ija}):* These can be obtained through industry surveys and in-depth interviews. The attributes used in this study to characterise the alternatives were:
  - end-to-end transport cost (shipping + inland transport + terminal handling + port charges),
  - end-to-end transit time (shipping + inland transport in both export and import destinations + port DwT in both destinations),

– frequency of maritime services, and
– inland transport mode (truck or train).

- *Attribute levels* which are calculated on the basis of actual values and realistic variation around these values. Extensive interviews and market analyses are required.
- *Decision maker characteristics* (s_{jk})*:* The ones identified for this study were:
  – value-to-weight ratio,
  – production system (make-to-order, make-to-stock, just-in-time, etc),
  – product type or category,
  – conditioning of shipments (FCL/FTL or LCL/LTL), and
  – International Commercial Term (INCOTERM) used.

1.2 Supply of Port Capacity

In the simple case with two agents (port and ocean carriers), the basic supply–demand model for port capacity relies on finding the trade-off between ship costs in the port and the port cost for providing additional capacity. Holding all else constant, the feasible solution is a compromise between on the one hand ships' berthing (service and non-service) and waiting costs and, on the other, port operating (traffic related) and investment (capacity-related) costs.

When several agents are involved, finding the optimal port capacity consists of determining the supply–demand equilibrium between aggregated port

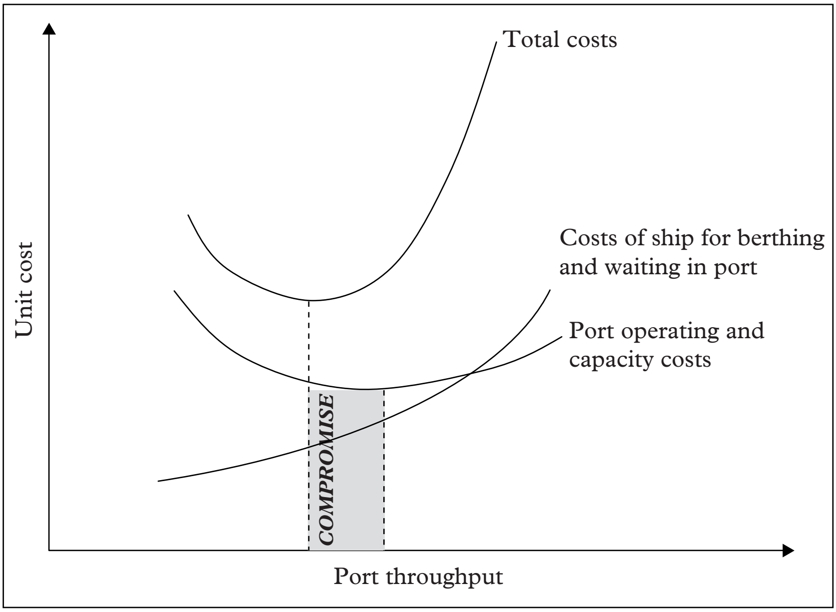

Fig. 3.3: Illustration of the trade-off between ship and port costs

- Duration of the contract
- Dues and handling charges
- Time windows
- Performance and efficiency
- Hours of working
- Dedicated services
- Inland services

Fig. 3.4: Elements of a contractual review between ports and shipping lines

demand and port costs. The latter normally integrate both commercial and public interests and can be calculated using the marginal costing approach, the strategic pricing approach, and at times both approaches, and/or other relevant pricing methods (see Chapter 5).

2 CAPACITY MANAGEMENT

Traditional textbooks limit capacity management to the day-to-day planning for ship and cargo handling operations at berth, yard and gate systems. However capacity management also includes strategic planning which focuses on medium-term planning of business plans and strategy.

2.1 Strategic Port Planning

Strategic planning involves the preparation of a formal document, which identifies the organisation's long-term mission, formulates its medium-term objectives and strategies, and guides the implementation of such strategies through detailed business plans, and conducts a regular annual review.

Strategic planning is closely related to both long-term planning and annual planning, but differs from them by its medium-term time horizon, strategic focus, and level of decision making. Strategic plans are normally prepared every 3–5 years but are reviewed on an annual basis. They may include a limited amount of capital investment, but the primary focus is on the use of existing resources (physical, human, financial, etc). Examples of medium-term objectives include the reduction of ship waiting time, the increase of container throughput, and the introduction of new arrangements for resource relocation (eg a 24-hour working pattern). A typical strategic or business plan would include the following:

- a reminder of main objectives and strategies,
- a series of sequenced and clear actions to be undertaken,
- detailed job assignments,
- inventory of resources and their allocation,

- detailed budgets and financial projections,
- specific programme targets,
- management structure, and
- performance and evaluation procedures.

A key aspect of strategic planning is the preparation and review of contractual and service arrangements with port users and customers taking into consideration any relevant changes both within and outside the port environment.

The process of strategic planning starts with the formulation of a set of medium-term objectives and the likely changes that impact both the internal and external port environment. This may be done through a SWOT analysis using approaches such as market research and trend analysis. Here, port management must identify and select the proper strategies that will achieve previously stated objectives. Sometimes, it may be necessary to change or adjust the initial objectives. Figure 3.5 depicts a typical framework for strategic port planning. The objectives are of three kinds: long-term objectives corresponding to the mission statement at the corporate level, medium-term objectives corresponding to strategic objectives at the departmental level and short-term objectives corresponding to targets at unit and operational levels.

Four components are involved in the strategic planning process: market and traffic forecasting (see above), issues of port competition and marketing (see Chapter 9), the strategic implementation process and a system of performance

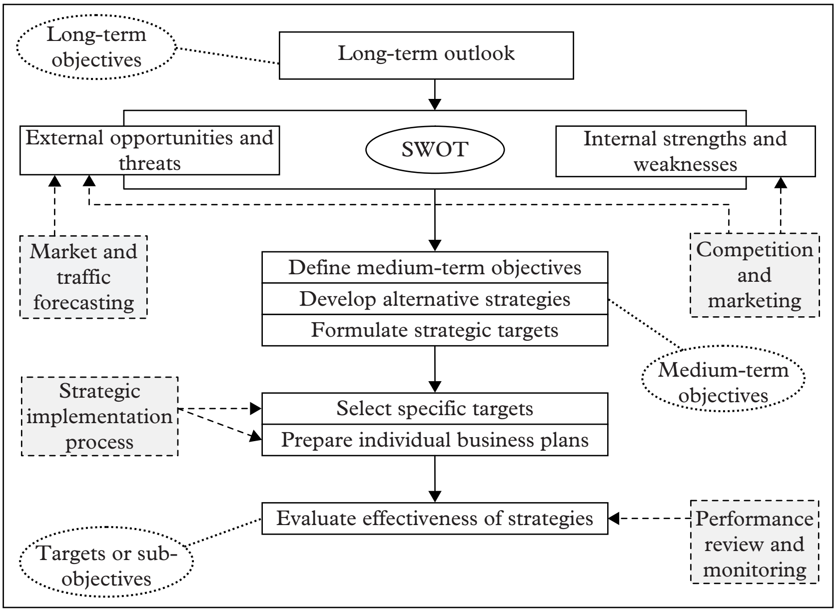

Fig. 3.5: Process and elements of strategic port planning

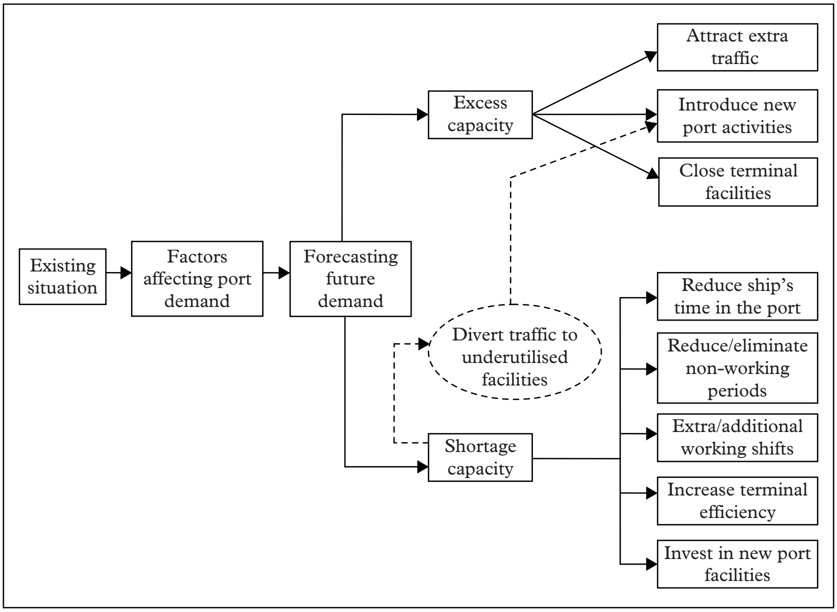

Fig. 3.6: A simplified approach for port planning and development

review. Alternative strategies for implementing a port's strategic plan should be identified and selected during the process of objective and strategy formulation. The implementation programme follows the identification of alternative strategies through the adoption of a business plan with detailed assignments at different levels of port operations and management. Finally, the system of performance monitoring and evaluation is a continuous process which involves corrective actions and is undertaken annually through financial reporting and budget planning. Where needed, corrective actions will be taken either to modify strategic objectives or to adapt the action plan to new conditions. The system of performance monitoring also entails a series of key performance indicators (KPIs) and a structured comparative analysis of planned objectives with achieved results with specific indicators. Figure 3.6 shows a simplified framework for integrating both long-term and strategic port planning with the objective of achieving optimal capacity utilisation and allocation of port resources.

2.2 Operational Port Planning

Broadly speaking, operational planning can be divided into two main components: information management and resource allocation. Information management refers to the collection and analysis of data and information regarding ships, inland vehicles and their cargo. Resource allocation follows information management through a planning process for berth allocation (generally on a first-come first-served basis), working resources (equipment and labour) and any other supporting resources. The planning of gate and inter-modal operations (including receipt and delivery) follows the same procedure, although this may involve other sets of problems such as land-based congestion and transit delays.

Operational planning modules include the activities of berth planning (quay transfer), yard planning (transfer, stacking and warehousing) and gate and inter-modal planning (cargo receipt and delivery).

2.2.1 Berth planning

Berth planning covers vessel and cargo data, berth configuration and resource allocation. Vessel and cargo data includes both general and specific information about the ship's technical features (name, registration and insurance, class and ISPS certificates, capacity and dimensions, structure and displacement tonnage, stress and stability, crew and cases of illnesses, etc), layout and bay configuration (hatch covers, cargo access and stack weights, lashing facilities, bay plans, slot addresses and container positions—bay-row-tier, etc), service routes (inbound and outbound voyage, estimated times of arrival (ETA) and

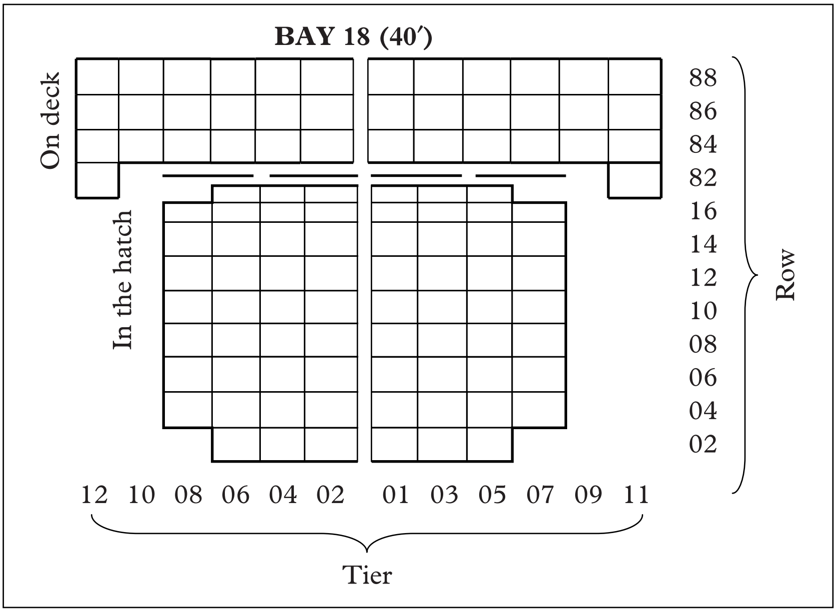

Fig. 3.7: Container identification in the ship

departure (ETD), vessel services, etc), and her cargo (number, type, size, class, dangerous goods, loading and stowage, slot allocation, etc).

These plans are the output of the vessel planner (not to be confused with the line planner) whose task is to reduce the ship's port duration and optimise her stowage capacity and terminal efficiency given a number of constraints such as the sequence of ports of call, scheduling and time table, cargo type and distribution, packaging weights and dimensions, and segregation rules and handling procedures. Technical and structural elements such as sea and port limits, load line rules, ship's stability and hull stresses, floatation and moments, lashing factors and wind stacks, etc should also be taken into consideration. These tasks are usually carried out by the captain or the officer on board.

Information received from ocean carriers and shipping lines can be used for both traffic planning and berth planning. For the former, data on mooring requests (ETAs/ETDs) and vessel's descriptions are used for nautical and traffic management purposes including the reservation of pilots, tugs and mooring gangs. The planning for these activities is usually within the remit of the VTS centre and the Harbourmaster's office. For the latter, data on cargo type and attributes, vessel configuration and bay layout are used to make reservations of terminal berths and for loading and discharging facilities including cranes, equipment, human resources and any other relevant inputs. The planning of these activities is carried out by the port's berth (or ship) planner whose objective is to optimise port capacity at minimum cost and congestion levels. Vessel information data can also be used for the planning of bunkering, repair, supply of provisions, target inspection, and regulatory control and compliance (eg, flag and port state controls).

Pro-forma vessel schedules and move counts declared by shipping lines form the basis for berth planning. Vessel pro-forma berth windows are based on advance schedules and initial vessel call information sent several days/weeks prior to ETA. Berth windows are negotiated between the lines and terminal operators and are estimated from the number of container lifts and the required time and date of operation. Special arrangements may be undertaken for incidental vessel calls or for vessels arriving out of pro-forma windows.

Within few days of the ship's arrival, detail vessel profile information is provided to the terminal operator including the approximate ETA, the required ETD, and the expected move count split, for instance the number of total and specific discharge and load moves of standard, out of gage cargo (OGG), BB, dangerous (IMDG class), empty, and reefer containers. The input from the line is used to prepare berth and resource allocation resulting in a draft berth plan transmitted to the line for confirmation. In the case of container cargo, the factors considered in the preparation of the berth plan include discharge and load projections, container attributes (type, size, weight, point of discharge (POD)), gang allocation, crane split and sequencing, and expected KPIs for crane, labour and berth productivities. The final berth and stowage plan is based on an agreement between the line and the terminal operator and takes into

Fig. 3.8: The VTS operation room of the port of Dover

consideration both the terminal's deadlines for receipt of outbound cargo (cut-off times) and the late changes and modifications made by the shipping line.

The capacity requirements for the berth can be deducted from waiting line or queue analysis, which is a function of the following elements:

- The arrival rate which is the frequency at which ships arrive at a waiting line according to a probability distribution. It is generally accepted that the arrival rate most frequently follows a Poisson distribution.
- The service time which is the time required to serve a ship. The distributions most commonly assumed for service times are either the negative exponential service time distribution or the constant service time.
- The queue discipline which is the order in which ships are served. The most common service rule is *first come, first served*, but other queue disciplines are possible for instance when some shipping lines have priority berthing. Often, ships are scheduled for service according to a predetermined appointment (berthing window). Furthermore, queues can be of infinite or finite length.
- The queue structure which consists of servers (the number of parallel berths for servicing ships) and stages (the number of servers in a sequence a ship must go through). Often, the waiting line structure for ships in ports is made of either a single-server/single-stage system, such as in the case of

a single or a dedicated berth, or a multiple-server (several berths)/single-stage (handling operation) system. Sometimes, multi-stage processes can take place, for instance when a ship has to wait first through a lock opening before being serviced in the berth.

For general cargo ships, it is generally accepted that vessel arrivals and service time conform to an exponential service time distribution while some bulk carriers such as tankers usually follow a constant or near constant service time distribution. Here, the Erlang distribution is expressed as:

$$E(t) = e^{-\frac{Kt}{T}} \sum_{n=0}^{nk-1} \frac{\left(\frac{Kt}{T}\right)^n}{n!}$$

where:

E is the Erlang distribution,
T is the average inter-arrival time, which follows a Poisson distribution,
n is the number of arrivals by time t, and
K is the exponential service time.

For general cargo berths, Table 3.7 shows the variations in the congestion factor (waiting time as a percentage of service time) by number of berths and berth occupancy ratio (% of time berths are occupied by ships being serviced), given a random arrival pattern and a negative exponential distribution with a first come, first served queue discipline ($M/E_2/n$), where M denotes the Poisson distribution of random arrivals, Erlang2 (E_2) is the exponential service time distribution, and n is the number of berths. For container terminals, Table 3.8 shows the berth occupancy and service time under the assumption of regular ship's schedule and an E_2 exponential service time distribution ($E_2/E_2/2$).

2.2.2 Yard planning

Yard planning tasks cover the planning for cargo transfer, staking, and storage in the yard, the allocation of yard space and the assignment of pools (equipment and labour) to points of work including such activities as housekeeping (overhead moves) and dispatching of vehicles (internal and external) along defined routes and pathways (path finding). In the case of container terminals, yard plans are prepared based on existing yard inventory, layout and staking capability of yard handling equipment (eg chassis, RTG, RMG, straddle carriers), the types and attributes of containers, the service and port rotation (in case of transhipment containers), policies for cargo dwell-time and free storage period, the location of the container freight station (CFS) within or outside the yard, and strategies for cargo split and area allocation.

Within the yard, containers are arranged on the floor forming rows and columns, and then stacked one above the other. Here, container locations, called slots, are identified using the bay, row and tier coordinates as showed

Berth occupancy	Number of berths							
	1	2	3	4	5	6	7	8
0.1	0.08	0.01	0	0	0	0	0	0
0.15	0.13	0.02	0	0	0	0	0	0
0.2	0.19	0.03	0.01	0	0	0	0	0
0.25	0.25	0.05	0.02	0	0	0	0	0
0.3	0.32	0.08	0.03	0.01	0	0	0	0
0.35	0.4	0.11	0.04	0.02	0.01	0	0	0
0.4	0.5	0.15	0.06	0.03	0.02	0.01	0.01	0
0.45	0.6	0.5	0.08	0.05	0.03	0.02	0.01	0
0.5	0.75	0.26	0.12	0.07	0.04	0.03	0.02	0.01
0.55	0.91	0.33	0.16	0.1	0.06	0.04	0.03	0.02
0.6	1.13	0.43	0.23	0.14	0.09	0.06	0.05	0.03
0.65	1.38	0.55	0.3	0.19	0.12	0.09	0.07	0.05
0.7	1.75	0.73	0.42	0.27	0.19	0.14	0.11	0.09
0.75	2.22	0.96	0.59	0.39	0.28	0.21	0.17	0.14
0.8	3	1.34	0.82	0.57	0.4	0.33	0.27	0.22
0.85	4.5	2	1.34	0.9	0.7	0.54	0.46	0.39
0.9	6.75	3.14	2.01	1.45	1.12	0.91	0.76	0.65

Table 3.7: Congestion factor in $M/E_2/n$ queue
Source: UNCTAD.

in Figure 3.10. For the planning of bloc yard and container stacking, two main strategies may be used: segregation or scattering. In the segregation strategy, some areas of the yard storage are formerly reserved to classes of containers identified by their attributes (eg import, export, hazardous, refrigerated, etc). For instance, using the destination rule for export containers, the latter are stacked either one above the other, in decreasing order from bottom to top, according to the ship's ETD, or simply if they have the same destination. In the scattering strategy, also called the random rule, space is not allocated in advance but the decision is made in real time. In this case the choice of a container location and the sequence in which containers will be stacked or withdrawn are completely random. This strategy takes into account the intrinsic randomness associated with the process of container handling, stacking and distribution.

Often, ports provide covered transit sheds for break bulk cargo, CFSs for LCL containers, tanks for liquid bulk, yards for open storage, warehouses for

Berth occupancy	Number of berths							
	1	2	3	4	5	6	7	8
0.01	0.02	0	0	0	0	0	0	0
0.15	0.03	0.01	0	0	0	0	0	0
0.2	0.06	0.01	0	0	0	0	0	0
0.25	0.09	0.02	0.01	0	0	0	0	0
0.3	0.13	0.02	0.01	0	0	0	0	0
0.35	0.17	0.03	0.02	0.01	0	0	0	0
0.4	0.24	0.06	0.02	0.01	0	0	0	0
0.45	0.3	0.09	0.04	0.02	0.01	0.01	0	0
0.5	0.39	0.12	0.05	0.03	0.01	0.01	0.01	0
0.55	0.49	0.16	0.07	0.04	0.02	0.02	0.01	0.01
0.6	0.63	0.22	0.11	0.06	0.04	0.03	0.02	0.01
0.65	0.8	0.3	0.16	0.09	0.06	0.05	0.03	0.02
0.7	1.04	0.41	0.23	0.14	0.1	0.07	0.05	0.04
0.75	1.38	0.58	0.32	0.21	0.14	0.11	0.08	0.07
0.8	1.87	0.83	0.46	0.33	0.23	0.19	0.14	0.12
0.85	2.8	1.3	0.75	0.55	0.39	0.34	0.26	0.22
0.9	4.36	2	1.2	0.92	0.65	0.57	0.44	0.4

Table 3.8: Congestion factor in $E_2/E_2/2$ queue

long-term storage, etc. Here, the storage capacity would depend on two main factors: the DwT which denotes the occupancy time of the yard and the sheds, and the requirements of each type of cargo in terms of the surface/storage capacity needed. The stowage factor is the surface occupied by one tonne of goods. According to the aggregate stowage factor for the different cargo, the surface needed for storing one tonne varies on average between 0.5 and 5 per m^2.

An illustration of the interactions between demand and supply of port capacity can be found in the calculation of container yard (CY) capacity. From a demand approach, the CY area is estimated based on demand factors such as the number of containers categories, the DwT, the mode of operation system, the height of the containers stacked, and the peak factor (see Figure 3.10). From a supply approach, the emphasis is on the number of containers the CY area can accommodate given the type of containers, the utilisation factor, the stacking height, and other factors.

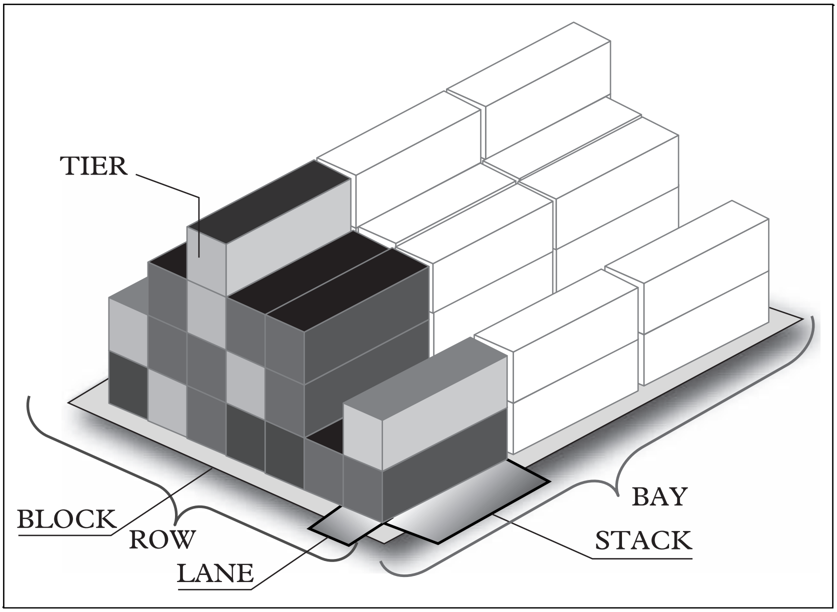

Fig. 3.9: Container identification in the yard.

Cargo	Stowage factor (m^3/ton)
Bagged cement	1
Bagged sand	0.5
Bagged flour	1.3
Bagged animal feed	1.5
Bagged tea or coffee	1.8
Frozen fish	2.1
Paper rolls	2.5
Circuits fruits	2.5
Cotton bales	2.7
Grapes	3.5

Table 3.9: Typical cargo stowage factors

1. Traffic forecast and terminal throughput estimates
When developing a new terminal or expanding an existing one, port managers should first determine the container traffic that will pass through the port. There are robust economic tools for traffic and trade forecasting, although we believe that a purely economic approach may fall short in understanding the mechanisms and dynamics of international logistics distribution and networking systems.

2. Estimates of the proportion of various container categories
This relates to the desegregation of container throughput by status (import, export, transit or transshipped), type (FCL, LCL, empty, special), dimension (TEU, FEU and non-standard) and any other relevant factor. Some types of cargo, eg dangerous goods, must be treated differently for stowage arrangements and stowage factor calculation.

3. Estimates of the average Dwell Time
The average Dwell Time a container is expected to remain in the container yard is a function of the distribution of container categories and the time spent for container inspection, document processing and any other relevant requirement.

4. Estimates of the required CY area

- The first step in estimating the required CY area is the calculation of the number of "ground TEU slots" nee ded in the CY by multiplying the estimated throughput with the average Dwell Time.

- The second step is to calculate the ratio between the stacking capacity and the stacking height, the latter depending on the equipment used (SC, RTG, RMG, etc) and the proportion of container categories (empties > exports > imports > specials).

- The third step is to include the allowance for aisle ways/pathways for stacking operations and equipment access depending on the chosen CY configuration. Allowances for CFS (if located within the CY), safety spaces, non-stacking and any other additional areas, must also be considered.

5. Estimates of the required terminal area
Once the CY area is estimated, one needs to include the space for aprons, interchange points (at both quay and gate interface), gates, offices and any additional operational or administrative areas. To these, it is recommended to include allowances for "peak-factor" and seasonal variations as well as for reserve space for future expansion. It is usual to allow for an additional 20–30% variation at each step of calculation.

Fig. 3.10: A demand approach for estimating CY and terminal requirements

Demand approach

$$CY = (C_p * A * DwT) * \frac{1 + F}{360} \qquad \text{(UNCTAD, 1985)}$$

$$CY = \frac{C_p * A * (DwT + 2)}{365 * Z * 10^4 * (H + 2h) * U} \qquad \text{(Frankel, 1987)}$$

Supply approach

$$C_C = GS_A * (0.6 * S) * (K / DwT) \qquad \text{(Dharmalingam, 1987)}$$

$$C_C = \frac{GS_T * H * W * K}{DwT * F} \qquad \text{(Dally, 1983)}$$

where:
CY: required CY; C_p: projected container volume (TEU); *A*: area per container TEU; *DwT*: average DwT in the CY; *F*: peaking factor; *Z*: storage utilisation factor; *H*: average expected stack height by the average number of containers in used stacks; *h*: standard deviation of stack height; *U*: total area utilisation; C_c: container capacity (per year); GS_T: total ground slot; GS_A: available ground slot; *S*: ground slot utilisation factor; *K*: number of days per year.

2.2.3 Gate planning

Gate planning works in a similar way to berth planning but in the opposite terminal interface; hence focusing on inland vehicle bookings and on landside receipt and delivery. It includes the planning of rail/truck entry and exit (gate-in/gate-out), yard and warehouse dispatch, and sometimes platform and freight configuration. Much of the planning problems at this level relate to the policies for cut-off times and late arrivals, the choice between direct routing and indirect routing, the latter requiring a transfer/transit system due to for instance lack of proper documentation or administrative clearance from the part of the shipper. Gate planning and control is becoming a key issue in port planning and operations due to increased queues and congestion on port roads, the emphasis on the port-city interface, and the recent agenda of port security and inspection.

CHAPTER 4

PORT INVESTMENT AND FINANCE

1 FINANCIAL STATEMENTS AND RATIO MEASURES

1.1 Financial Accounting and Financial Statements

Financial accounting is involved in the preparation, auditing and presentation of financial statements. Financial statements are used to record the historical financial position of firms and organisations. There are three major financial statements: the balance sheet, the income statement and the statement of cash flows. Normally, the law of a country provides standard rules and guidelines for preparing financial statements—see for instance the US generally accepted accounting principles (GAAP). In the absence of a country-specific accounting framework or in the case of international operations, frameworks such as the international financial reporting standards (IFRS) or the International Standards Accounting Report (ISAR) may be used. Financial accounting is also referred to as public accounting to indicate that financial statements are publically reported to external users such as shareholders, creditors and investors.

The income statement, also called the profit and loss account, provides information about the operating costs and profits of an organisation over a specific period of time, usually a year. It summarises all the sales and revenues, and any other sources of income, expenses and overheads which arise or are due during that period.

The balance sheet is a snapshot statement of a company's financial position at a specific moment in time. It depicts the company's assets and liabilities, and can be presented either in a horizontal or a vertical format. Assets can be either fixed assets (land, buildings, equipment, vehicles, etc) or current assets (cash money, bank deposits and any items that can easily be encashed). In a similar vein, liabilities are divided into current liabilities, long-term debt and equity; the last refers to the shareholders' or company owners' money. Thus in a balance sheet, assets must always equal liabilities plus equity. The balance sheet must not be confused with the *balance of trade* or with the *balance of payment*; the first records the difference in monetary values between the exports and imports of a country vis-à-vis the outside world while the second is a record of debit and credit transactions of a country with foreign countries and international institutions.

The statement of cash flows measures the changes in cash over a given period of time, and indicates whether or not a company has enough cash to pay its creditors. It is similar to the balance sheet, but it registers only cash assets in the left (or upper) side, with all the remaining assets, eg depreciation, being registered with the liabilities as deductions.

Asset depreciation is an important concept in accounting and financial management and refers to the amortisation of fixed assets over time. It represents the cost of using owned (not leased) equipment but is not linked to the fluctuations in the market price of an asset due to the changes in supply and demand. For the purpose of tax laws, asset depreciation is recorded in financial statements as a cost or an expense which reflects the diminishing value of physical assets and equipment. There are different methods for calculating depreciation, the most commonly used are:

- *Straight-line depreciation (linear)*. Equal amounts every year with a constant percentage of the original investment. Hence the operating efficiency and repairs remain constant throughout the period:

$$\textit{Annual depreciation charge} = \frac{\textit{Original value} - \textit{Scrap value}}{\textit{Life of Asset}}$$

- *Declining balance depreciation*. Highest in the first year and declining year by year with a constant percentage of the remaining book (residual) value. Thus the operating efficiency is declining while repairs are increasing. It is often used for vehicles, fixtures and fittings.

$$\begin{array}{r}\textit{Reduced balanced annual}\\ \textit{depreciation charge}\end{array} = \textit{(Remaining) book value} * \textit{Year (\%)}$$

- *Annuity*. Lowest in the first year and increasing year by year. This is the reverse of the declining balance method and includes the time value of money into the calculation of depreciation.
- *Accelerated depreciation*. Highest in the first year and decreasing year by year (also called sum-of-years' digits). Here, annual depreciation is calculated by multiplying the depreciable cost by a schedule of fractions.
- *Activity depreciation*. Assumes that depreciation is a function of the level of activity or the output, not of time. The life of the asset is estimated according to the level of activity which may vary according to the forecasts of production and output. Activity depreciation is usually used for ships, terminal equipment and other types of port assets.

In addition to the accounting depreciation described above, there are two other forms of depreciation: financial depreciation and economic depreciation:

- *Financial depreciation* corresponds to the reimbursement of a loan and allows for the calculation of cash charges of production. However, because financial depreciation has a duration which is usually less than that of the average life of the asset, a net profit will be generated between the two periods. The formula below shows the total annuity ($\sum_{t=1}^{n}[(A_t)]$)

of reimbursement which covers both the principal ($V_{\downarrow 0}$) and the interest ($\sum_{t=1}^{n}[(V_{t-1})]$).

$$\sum_{t=1}^{n} A_t = V_0 + i\sum_{t=1}^{n} V_{t-1}$$

- *Economic depreciation* extends the concept of financial depreciation to take into account the economic value of the asset. This is done by calculating the change in the market price of the capital at the beginning and at the end of the life of the asset. The formula for calculating economic depreciation is similar to that for financial depreciation with the difference that an economic interest rate (*e*), rather than a financial rate, is applied.

$$\sum_{t=1}^{n} A_t = V_0 + e\sum_{t=1}^{n} V_{t-1}$$

Needless to say that because public ports (as opposed to private ports) are usually exonerated from paying tax on profits, the tax dimension of depreciation disappears and amortisations show as simple internal transfers between the port's operating budget and its investment budget. Despite this, depreciation remains an important tool for the calculation of port tariffs and charges especially in the case of self–financing ports.

1.2 Managerial Accounting and Ratio Measures

In contrast to financial accounting which deals with historical reports destined for external users, management accounting focuses on costing, budget preparation, investment appraisal and modelling, all of which are forward looking and are usually prepared for internal use. Financial ratios are useful in monitoring financial results and for strategy formulation. However, they should be interpreted carefully and in line with the port's missions and objectives.

1.2.1 Activity ratios

Activity ratios measure the efficient use of the company's assets and resources. The three ratios frequently used are:

$$\textit{Receivable turnovers} = \frac{\textit{Annual credit sales}}{\textit{Accounts receivable}}$$

$$\textit{Inventroy turnover} = \frac{\textit{Cost of sale (cost of goods sale)}}{\textit{average inventory}}$$

$$\textit{Operating ratio} = \frac{\textit{Operating expenses}}{\textit{Operating revenues}}$$

1.2.2 Profitability ratios

Profitability measures the ability of a firm to generate profits. The ratios most used are:

$$Gross\ margin = \frac{Gross\ profit}{Net\ sales}$$

$$Return\ on\ assets\ (ROA) = \frac{Net\ income}{Total\ value\ of\ assets}$$

$$Return\ on\ equity\ (ROE) = \frac{Net\ profit}{Shareholder's\ equity}$$

$$Return\ on\ investment\ (ROI) = \frac{Net\ profit}{Owner's\ equity}$$

1.2.3 Liquidity ratios

Liquidity measures the ability of a firm to acquire cash to meet its short-term (immediate) financial obligations. Liquidity is usually expressed through the following ratios:

$$Net\ Working\ Capital = Current\ Assets - Current\ Liabilities$$

$$Current\ Ratio = \frac{Current\ Assets}{Current\ Liabilities}$$

$$Quick\ Ratio = \frac{Current\ Assets - Inventory}{Current\ Liabilities}$$

1.2.4 Capital structure (debt or financial leverage) ratios

The purpose of these ratios is to measure the long-term solvency of a firm, ie the ability of a company to pay its debts. The main measurement ratios for leverage are:

$$Gearing\ ratio = \frac{Interest\ debt}{Equity + Interest\ debt}$$

$$Debt\ ratio = \frac{Total\ debt}{Total\ assets}$$

$$Debt\ to\ equity\ ratio = \frac{Total\ debt}{Total\ equity}$$

$$Interest\ coverage = \frac{EBIT\ (Earnings\ before\ interests\ and\ taxes)}{Interest\ charges}$$

$$Solidity = \frac{(Equity + reserves)}{Total\ balance\ sheet}$$

In ports, financial ratios should be read together with physical and customer performance indicators in order to assess the overall port efficiency and performance. Superior financial performance may be driven by monopolistic pricing, cost inflation, currency depreciation, subsidies and tax exemption, tariff and non-tariff barriers, and other external conditions, which may not reflect the true or overall port performance. Further discussion on the inadequacy of financial indicators for calculating port performance and benchmarking is provided in Chapter 7.

2 PORT COSTS AND COSTING

2.1 Types of Port Costs

The rationale behind port costing is that it enables port management to control costs and operations and allocate resources efficiently. Cost structures in transport and port operations are generally perceived in terms of generic categorisations such as direct versus indirect costs, internal versus external costs, capital versus operating costs, fixed versus variable costs, average versus marginal costs, etc.

Direct costs are the costs directly allocated to a specific cost objective such as a product, an activity or a customer. Indirect costs are the costs that cannot be allocated to a particular cost objective and are often classified as overheads or general costs. In ports, direct costs correspond to the capital required for building and maintaining port infrastructures and terminal superstructure, as well as for equipment and vehicles acquisition and repair.

Internal costs are the costs intrinsic to an activity of a port or a terminal while external costs are the costs associated with port externalities such as congestion and deterioration of the environment. Costs can also be categorised by functions or operations. In ports, costs are usually broken down into four elements: land costs, capital and infrastructure costs, equipment and superstructure costs, and labour and running costs.

Capital costs are the upfront costs of providing a capital asset while operating costs are those associated with its daily operation and maintenance. Port capital costs include the costs of design and construction, equipment and vehicle acquisition, and related tax and professional work. Operating costs include labour costs, maintenance costs, and expense costs (energy, administration, insurance and security, etc).

Fixed costs are costs that are independent of the quantity of production while variable costs are those that vary with the throughput or volume of the activity. Fixed costs of ports include the costs of infrastructure and buildings, equipment and vehicles dredging and maintenance, interest and depreciation, insurance and security and salaries of permanent staff. Variable costs of ports include costs related to the salaries for temporary staff, energy and utility expenses, taxes and administration, overheads and related costs. The cost structure of ports is marked by a large fixed cost and a relatively low variable cost.

The marginal cost is the increase in total costs that arises at each level of production when the quantity produced changes by one extra unit. In other words, it is the additional cost of producing an additional unit. The relationships between marginal cost, fixed cost, variable cost, average cost, and total cost are shown in Figure 4.1.

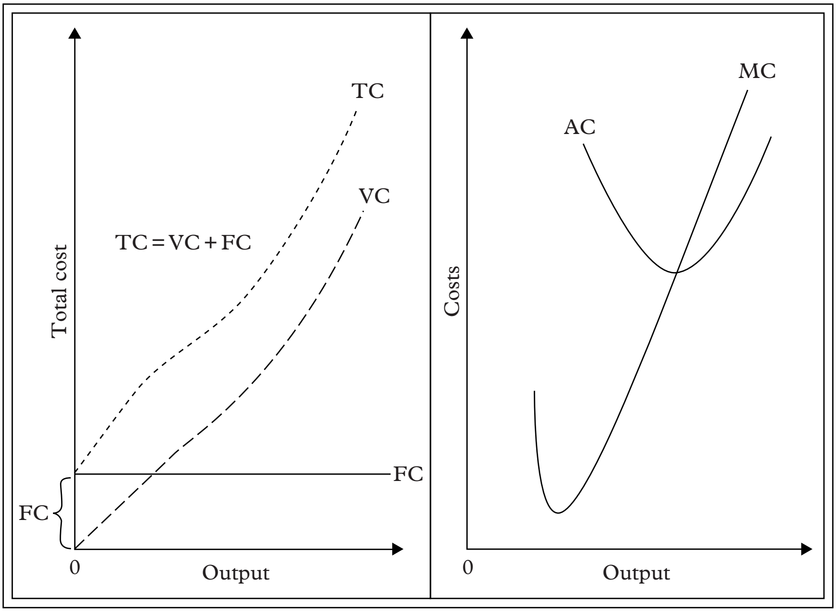

Fig. 4.1: Illustration of fixed, variable, average, marginal and total costs

$$AC = \frac{TC}{Q} = \frac{FC + VC}{Q}$$

$$MC = \frac{\Delta(TC)}{\Delta(Q)} = \frac{\Delta(VC)}{\Delta(Q)}$$

where:
TC: total cost; FC: fixed cost; VC: variable cost; AC: average cost; MC: marginal cost; Q: quantity produced or output.

2.2 Logistics Costing

From a logistics approach, the calculation of total costs is an important aspect in cost analysis. Under the traditional approach to costing, every department will be considered as a cost centre (eg purchasing, production, marketing, distribution, etc) but it is difficult under this approach to integrate total costs.

Furthermore, it has been shown that all major cost elements in a logistics system are interrelated and that any change made in one business area is likely to impact other areas as well as the total cost of the firm. For instance, the production manager may seek a longer production run to achieve economies

Table 4.1: Disaggregation of container-terminal capital and operating costs

Cost elements			**Capital costs**	**Operating costs**
Land and terminal	Design and mobilisation		√	
	Dredging		√	
	Quay structure		√	
	Container and open storage yards		√	
	Sheds and buildings		√	
	Reception facilities and special zones		√	
	Other civil works		√	
	Lease		√	
	Tax and professional fees		√	
Equipment	Container handling	Quay cranes	(new) √	(old) √
		Spreaders	(new) √	(old) √
		Yard cranes: RTG, RMG, straddle carriers, etc	(new) √	(old) √
		Forklift truck, reach-stacker, etc	(new) √	(old) √
		Tractors/trailers	(new) √	(old) √
		Radio and communication	(new) √	(old) √
		Work vehicles	(new) √	(old) √
		Engineering service vehicles	(new) √	(old) √
		Computers (hardware and software)	(new) √	(old) √
	ICT equipment and programmes		(new) √	(old) √
	Fuel supply and utilities equipment		(new) √	(old) √
	Perimeter zone/security equipment		(new) √	(old) √

(*Continued*)

Table 4.1: Disaggregation of container-terminal capital and operating costs (*Continued*)

Cost elements			**Capital costs**	**Operating costs**
Labour	Management	General: admin, sales, accounting, etc		√
		Engineering and maintenance		√
		Operations and control		√
		IT and research		√
	Operations	Quay, yard, and gate supervisors		√
		Crane operators and supervisors		√
		Tractors and yard vehicle drivers		√
		Depot and storage clerks		√
		Ship, yard, and gate clerks		√
		Computer, personnel, and control clerks		√
	Maintenance	Technicians, mechanics, and electricians		√
Other operating expenses	Fuel supply/ utilities	Fuel, energy, electricity, water, etc		√
	Insurance, auditing, royalties and legal fees			√
	Security, safety and environmental care			√
	Other overheads	Marketing and communications		√
		Training and professional development		√
		Travel, events and entertainment		√

of scale, the transport manager a cheaper freight rate to reduce transport costs, and the marketing manager a faster delivery time to satisfy customers. These objectives may be conflicting and integration through total cost analysis (TCA) should be sought. TCA is a structured approach for understanding the total cost associated with logistics services. The costing method proposes a trade-off analysis among different internal functions to minimise the total cost, while at the same time maintaining customer satisfaction.

Another problem in traditional accounting and costing systems is the allocation of overheads and general expenses. The allocation of expenses that are not direct expenses is often arbitrary and can be controversial. Activity-based costing (ABC) and direct product profitability (DPP) are two logistics techniques that can deal efficiently with the allocation of overheads. ABC proposes an evaluation of the costs of a firm's activities based on the actual resources and time consumed to perform them. It does so by identifying and assigning the costs specifically generated by activities, as opposed to products or services. ABC seeks to identify the activities which are responsible for different costs and associate them with their respective portion of overhead costs. Overheads may be allocated based on volume, time, revenue, etc. As shown in Figure 4.2, the technique involves a two-stage procedure for assigning cost-to-cost objects. The first stage focuses on determining the costs of activities within the system, while the second stage allocates activity costs to port cost centres consuming the work performed. DPP works in the same way as ABC and is used widely in the retail

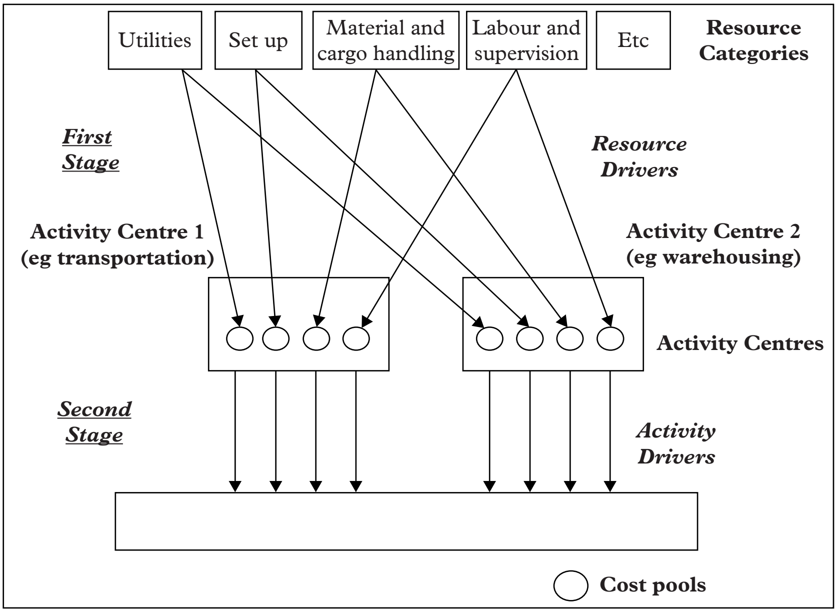

Fig. 4.2: Example of an ABC application

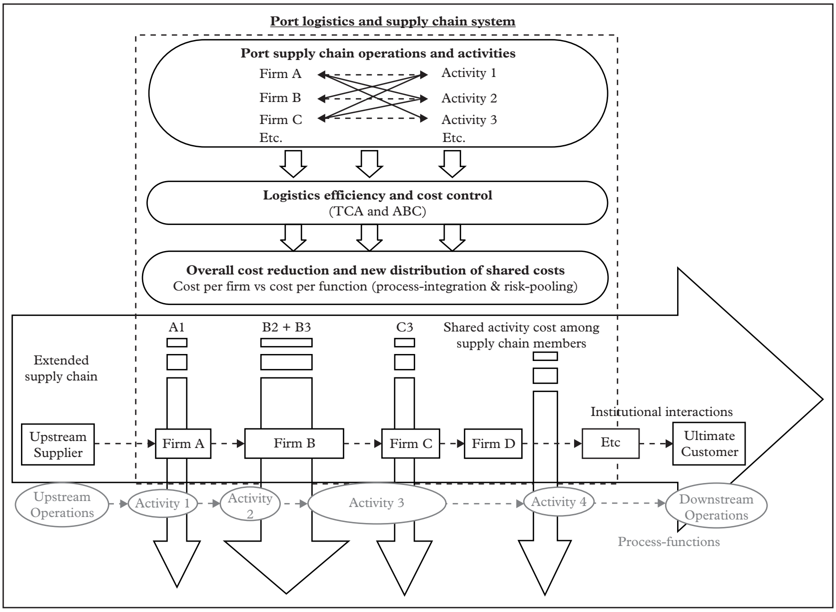

Fig. 4.3: A model for cost control and distribution across port supply chain components

sector. It consists of identifying and measuring the costs directly attributed to individual products or customers so as to reduce the customer's costs of ownership, for instance by adopting a more efficient storage and distribution system.

From a supply chain perspective, costs should be shared between supply chain members. Figure 4.3 provides a basic framework of supply chain costing and is relevant to activities shared by a number of stakeholders and users of the port community. The proposed framework is structured around a three-stage approach. First, various functions and activities undertaken by port community and supply chain members are identified and listed by institutional and functional port components. In each case where port operations involve more than one facility or entity, activities are pooled and cost-assessed on the basis of ABC and TCA to eliminate waste expenses across the port's supply chain and ensure optimal cost reduction. Finally, a new configuration of cost assessment and distribution will emerge by allocating a share of the reduced costs to each port supply chain participant. In Figure 4.3, A1 corresponds to the cost borne by firm A in performing function 1, while (B2+B3) refers to the cost share of entity B in undertaking activities 1 and 2.

2.3 Analysis of Port Costs from the Perspective of Users

Although ports are a key node in international shipping and logistics chains, port costs are only an element of transport and logistics costs. While it may be assumed that ocean carriers select the route (and port) that minimises the time and transportation costs in the transportation process from origin to destination, shippers will try to reduce the total logistics and supply chain costs. Furthermore, global 3PLs and other integrated service providers nowadays offer packages that reflect total logistics cost and include full coverage of risk for the cargo from origin to destination. Therefore, they not only seek to extract costs and efficiency advantages from the transport chain but also seek to deliver added value to the end customer while extracting value and competitive advantage for themselves.

In this section, we attempt to breakdown maritime transport and logistics costs and highlight the role of port direct and indirect costs. From the perspective of the shipper or cargo owner, the total cost of distribution is the sum of purchasing, transportation and storage costs in the movement of finished products through the post-production channel. Therefore, logistics costs may be broken down into two major cost elements:

- Costs of motion, which includes *transport cost* (while in ship or in vehicle) and *handling cost* (loading/unloading, packaging, etc).
- Costs of holding, which includes *rent cost* (space, machinery, maintenance) and *waiting cost* or the opportunity cost tied up in the stock.

Port costs may be defined as the sum of handling costs and rent costs. Handling costs in ports include the costs relative to the ship's mooring/unmooring, towing and pilotage, stowing and un-stowing, cargo loading and discharging, consolidation and break bulk, cross-docking, packaging, and other related activities. Rent costs in ports include port dues on ships, maintenance and dry-docking costs, cargo storage costs, and other relevant costs.

2.3.1 Transport costs

Transport costs are a major element in logistics and may constitute up to 70% of total logistics cost. Different transportation modes have different cost functions depending on transport, product and shipper's attributes.

Transport attributes include aspects of mode price, transit time, reliability, availability and other relevant criteria. Product's attributes are also an important factor in transport and mode choice. Major product attributes are value-related (product's selling price, value-to-density ratio), weight volume-related (density, stowage factor, ease of handling), risk-related (hazardousness, perishability, pilferability), and market-related (time sensitivity, life cycle, availability in markets). Finally, shipper's attributes may be divided into consignment attributes, such as order frequency, order size and product mix and ownership features such as the terms of sale (INCOTERM) and supply chain relationships.

Based on mode price, distance and shipment size, Figure 4.4 illustrates the modal shift and combination possibilities across different modes of transport. This approach is widely used in modal split and traffic assignment decisions,

	Inland transport			Water transportation		Inter-modal
	Air	**Road**	**Rail**	**Sea**	**Inland waterways**	
Speed/transit time	5	4	4	2	1	3
Cost (freight cost)	5	4	3	1	1	3
Safety	5	4	5	4	4	4
Reliability	5	5	4	3	2	4
Flexibility	3	5	3	3	2	4
Availability	4	5	3	Various	Various	2
Environment friendly	1	2	4	5	5	3
Infrastructure cost	4	5	5	4	Various	3
Maintenance costs	4	4	5	2	Various	Various
Door-to-door	2	5	3	2	1	4
Cargo value	5	4	4	3	2	4
Cargo volume	1	2	4	5	4	4

Table 4.2: Comparison between different freight transportation systems
Scoring guide: (1) poor/very low; (2) low; (3) modest; (4) high/good; (5) very high.

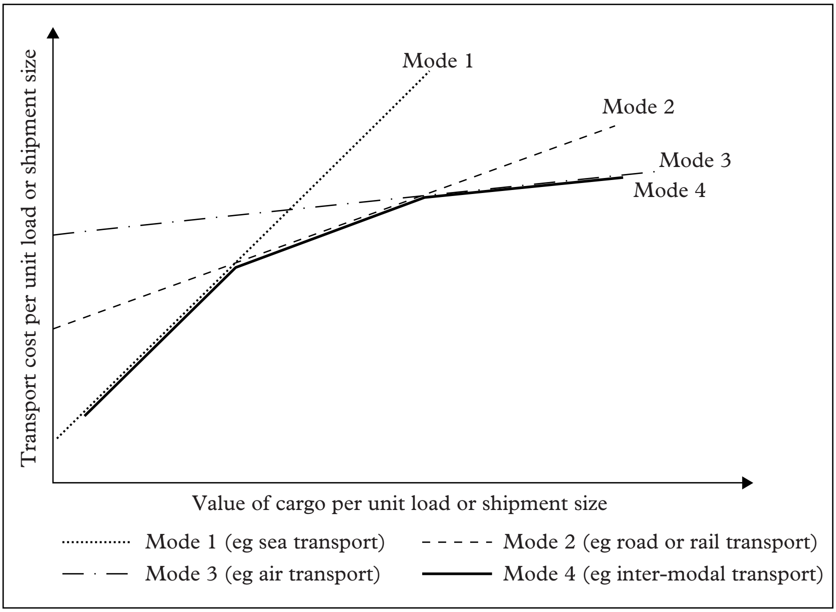

Fig. 4.4: Transport cost, shipment size and mode choice.

usually by assigning different cost functions to different transportation modes. For instance, the cost of maritime transport in TEU km or TEU nm (nautical miles) is calculated based on the average speed, speed restrictions, handling and buffer times at terminals and scheduled maintenance and repair as well as the capacity and occupancy rate. The unit transport cost (*TC*) can be formulated as follows:

$$TC = a + (b * d)$$

where:
a is fixed cost, b is variable cost, and d is distance.

MDS trans-modal has used a similar approach to calculate land transport costs in their recent UK port demand forecasts and transhipment studies. As illustrated in Figure 4.5, the MDS methodology calculates container land transport costs from each county to each potential port as follows:

$$TC_{rail} = 201 + (0.2624 * d)$$
$$TC_{road} = 80 + (0.7500 * d)$$

where:
d is the distance from the country to the port in km).

The fixed cost for rail is higher than for road because it includes local collection and delivery costs to/from the rail depot (£89 per TEU) and the extra lift-on

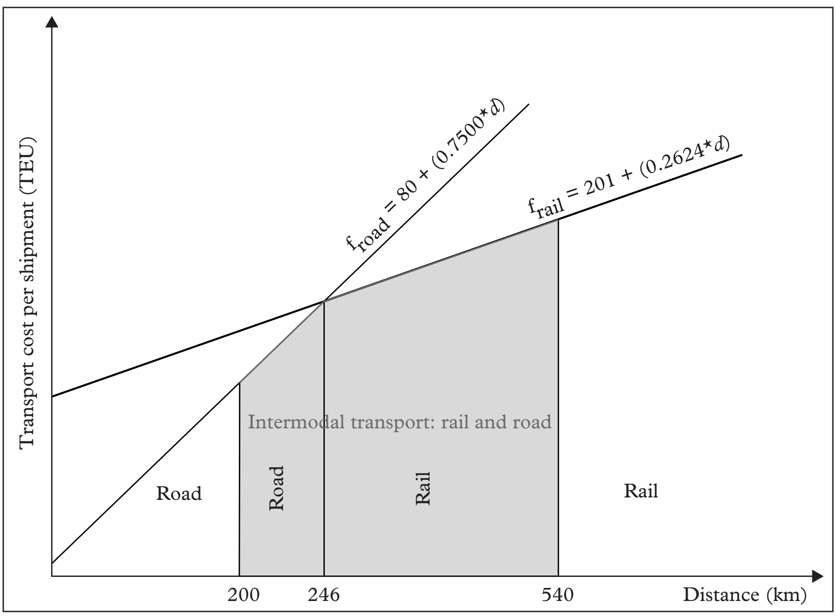

Fig. 4.5: Modal shift assumptions in the MDS container demand study.

lift-off costs at the inland rail depot (£62 per TEU). The two formulae give a similar cost for a port–country distance of approximately 246 km. Above this distance, where the average cost of road transport is more than rail, the rail cost is used. For distances below it, the road cost is adopted as the inland transport cost.

For ocean carriers, port costs are a big element of ship operating costs. Port costs to shipping lines may be broken down into three major cost elements: the costs of port dues on ships (pilotage, pilotage and towage, supply and waste disposal, etc), the costs of cargo handling and storage charges (loading/unloading, processing and storage, transfer and distribution) and the costs of the time in port, ie the costs arising from port congestion and inefficient operations.

2.3.2 Handling Costs

Despite the TEU container being the unit shipment size across modes, the approach depicted in Figure 4.6 does not take into consideration mode capacity limitations, economies of scale, and marginal cost per shipment. This is because costs and charges differ depending on rail, road, railroad, and ship-barge loads (see Chapter 10 for more information on these load categories). For instance, the World Bank's survey[2] on the relationship between shipment

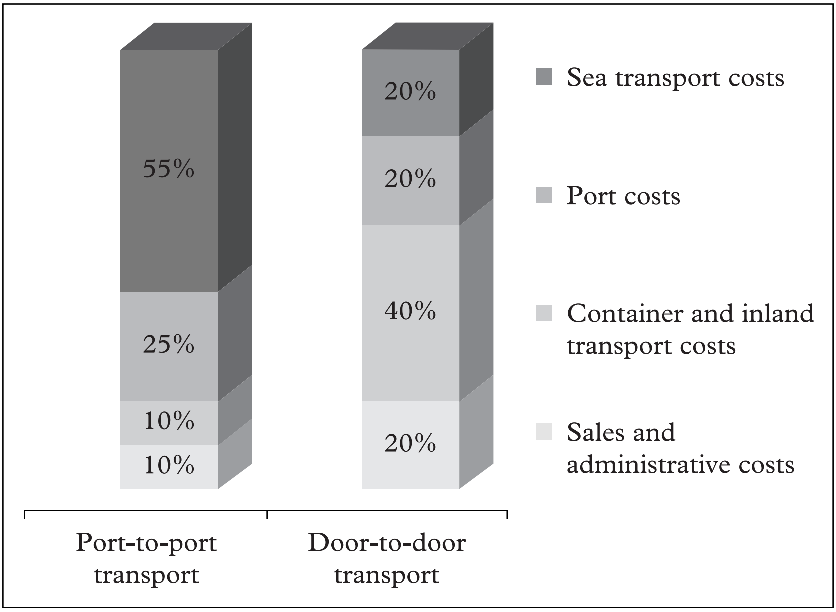

Fig. 4.6: Typical cost structure of container shipping

1. See www.rutner.com/LOGT4232/slides/LOGT%204232%20Ch06%20-%20Liners.pdf
2. See www.worldbank.org/html/fpd/transport/ports/trf_docs/bulk_tr.pdf

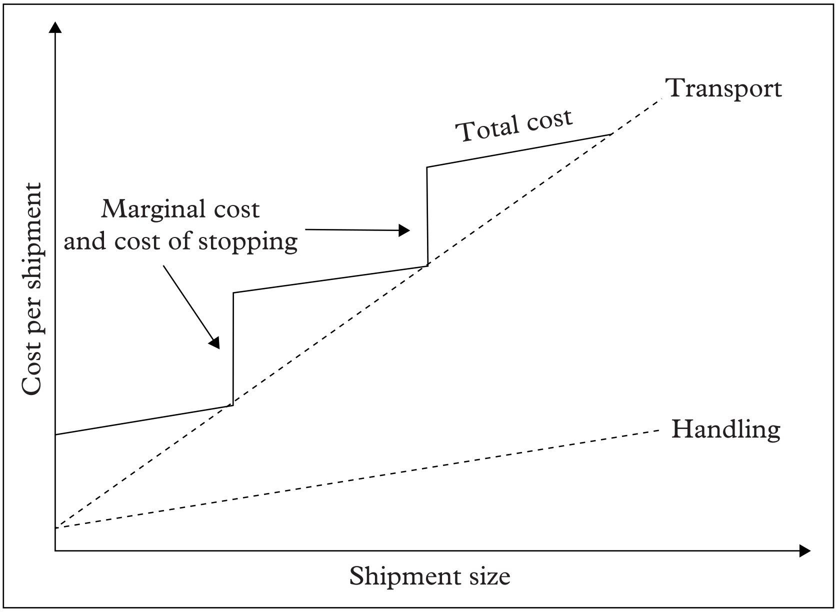

Fig. 4.7: Inclusion of handling and friction costs

size and transport charges found that costs tend to be inversely proportional to shipment size. Furthermore, Figure 4.6 does not take into account handling, stopping, and friction costs. Figure 4.7 shows that transport cost increases linearly with distance and shipment size, leading to four cost components: cost of distance, cost of stopping, cost of handling and marginal cost per shipment.

From the above discussion, a simplified formula for operating a ship (ie excluding capital and maintenance costs) may be derived as follows:

Ship Operating Costs = Costs at sea (transport costs) + Costs in ports (stopping and handing costs)

$$\text{Ship}_{\text{OC}} = [D(A + gS)] + [(B + hS) * S(\alpha + \beta S)^{-1}]$$

where:

D: distance travelled by sea; S: size of ship; $(A + gS)$: cost of a sea voyage, where A is the fixed cost and g is the variable cost; $(B + hS)$: ship handling costs in port, where B is the fixed cost and h is the variable cost; $\alpha + \beta S$: daily tonnes moved by a ship of size S, where α and β are constants; $S(\alpha + \beta S)^{-1}$: time in port (in days).

2.3.3 Holding costs

From a shipper's (cargo owners) perspective, holding costs are the sum of rent costs and waiting costs. Figure 4.9 shows the breakdown of different elements

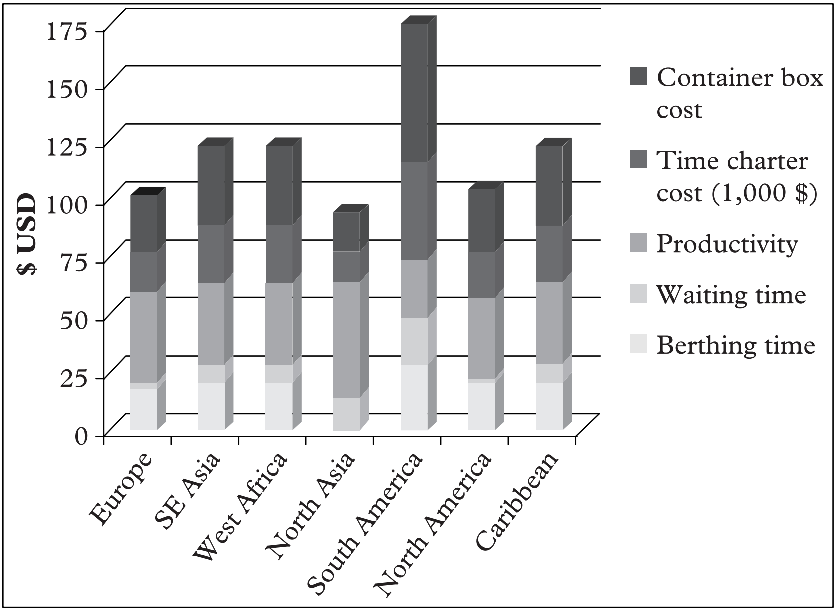

Fig. 4.8: Operating cost of an 8000 TEU container-ship
(*Source:* Maersk/APM Terminals, 2006).

for the calculation of the cost of waiting, also called the inventory carrying cost. Inventory carrying costs can be categorised into capital costs (opportunity cost or interest), inventory service costs (taxes and insurance paid as a result of holding inventory) and inventory risk costs (risks and charges for depreciation, obsolescence, damages and relocation). Usually, they are expressed as the aggregate penalties for holding cumulative items through the waiting time period. Obviously, the level of the penalty depends on the value of the item as a proportion of either the production price or the selling price.

2.3.4 Logistics costs

Shippers seek to minimise total logistics costs (*TLC*) per shipment by minimizing transport costs (*TC*) and inventory carrying costs (*IC*) associated with mode and port choice. A simplified model to calculate *TLC* can be expressed as follows:

$$TLC = TC + (PV * VTT * IC)$$

where:
TLC: total logistics cost per shipment
$TC = f(\alpha * d)(w, v)$: Transport Cost per shipment, which is a function of the freight rate (α), the distance (d), and the shipment size (expressed as the

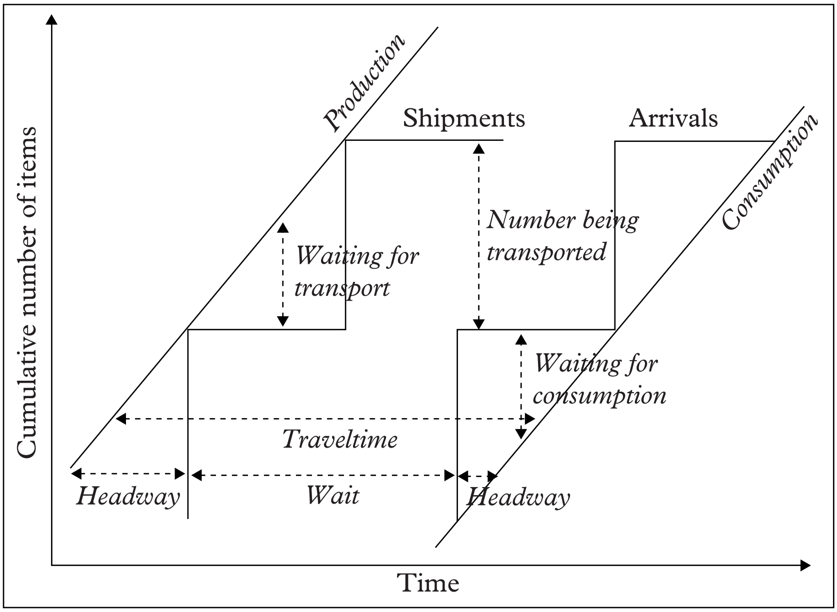

Fig. 4.9: Illustration of waiting time (Adapted from Bell, 2007)

product of weight *w* and volume *v* or as the standard load unit such as TEU)

PV: Value of product per load or shipment size

VTT: Value of transit time, which can be expressed either as the expected transit time per shipment or as a saving ratio of freight rates.

$IC = f(PV * \beta)$: Inventory carrying cost per shipment, which is a function of *PV* and the inventory carrying charge β (opportunity cost or interest typically expressed as a percentage of the total value of the product).

The transit time denotes the total expected elapsed time from origin to destination. The shipper incurs the inventory cost for both the stock in the pipeline as well as the inventory cost for the safety stock carried to protect against uncertainties in shipment arrival. Both costs can be expressed as a value of transit time (*VTT*). To capture both pipeline and safety stock, several researchers use the 98% "fill rate rule" which denotes the percentage of the time that demand is met from in-stock inventory. The 98th percentile includes all inventory required to be held to account for both long duration (stock in the pipeline) and arrival time variability (safety stock). Other researchers have used relative saving values expressed in percentage of freight rates to calculate *VTT*.

A unique *IC* or *VTT* figure should not be applied to all products given the different values and time sensitivities of different products. Several authors

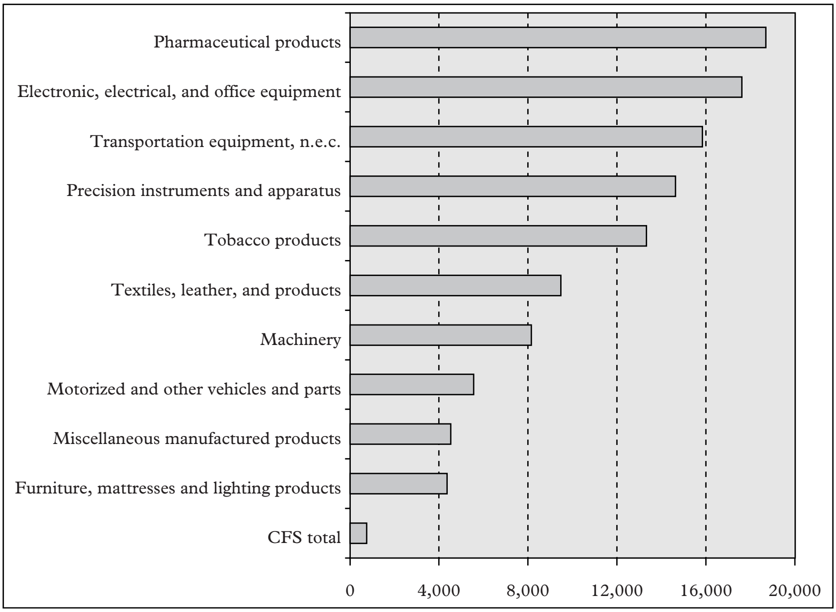

Fig. 4.10: Top 10 commodity groups ranked by value per ton (*Source:* US DoT).[4]

have estimated *VTT* and *IC* relative to product value (*PV*) with average costs typically estimated in the range of 20–30% of commodity value per year.[3] The PV for commodity shipments may be sourced from data provided by national and international customs and trade agencies such as in the example shown in Figure 4.10. The calculation of total logistics costs described above should not be conclusive because shippers may have different logistics strategies or may use the same product or shipment at different stages of the supply chain process. Indeed, the trade-off between transport cost minimisation and inventory cost (lead time) reduction has implications that go beyond operational decisions to include aspects of strategic network configurations. For instance, while sea transport is almost solely based on the principle of cost minimisation, the advantages of using ports through a combination of combined sea and land transport can only be achieved if specific production and inventory policies and adequate design of logistics facilities are implemented.

3. See, for instance, Delaney (2000), *11th Annual State of Logistics Report*, Cass/ProLogis; and Euro-case (2001), *Freight Logistics and Transport Systems in Europe*, Euro-case.
4. US Department of Transportation, Bureau of Transportation Statistics, 2002, *Commodity Flow Survey* (www.bts.gov/programs/commodity_flow_survey).

3 ECONOMIC VERSUS COMMERCIAL APPRAISAL OF PORT INVESTMENTS

Assessing the overall viability of port investments requires a commercial and an economic evaluation. The investment cost and the service price, which determines the financial revenues, are the inputs to the commercial evaluation. In addition to the investment cost, the direct, indirect and external effects are the main inputs to the economic evaluation.

From a public sector perspective, ports are seen as public goods and a growth provider. Here, one would seek to optimise socio-economic utility by providing sufficient port infrastructure. From the private sector perspective, ports are private goods and business opportunities. In this case, one would try to achieve cost efficiency, marketability and commercial profitability. Thus, public investment would normally occur if external utility is greater than external costs of externalities and non-marketable goods. On the other hand, private investment would normally occur if the profit expected is greater than a specific rate of return, usually above the market interest rate. In the first case, cost benefit analysis (CBA) and other methods based on the assessment of macro-economic utility and social desirability would prevail. In the second case, methods of commercial appraisal based on the assessment of market profitability and investment recovery would apply. Sometimes, hybrid solutions are considered, for instance when both private and public capital is involved, eg through private and public partnerships (PPPs) or when public subsidy is provided to cover the difference between current and expected returns.

3.1 Economic Appraisal

Starting from the notion that ports are public goods, the costs and benefits must be identified and quantified in ways that are different from that of financial costing. For instance, some financial costs such as sunk costs are excluded while external costs such as costs of externalities and depletion must be included in the economic analysis. The economic evaluation of port projects involves the identification, quantification and comparison of the costs and benefits usually through CBA. Cost efficiency analysis (CEA) is an alternative method to CBA and is applied when the output is fixed and the economic benefits cannot be expressed in monetary terms. However, standard CBA and CEA methods do not take into consideration how costs and benefits are shared or distributed and alternative methods such as stakeholder analysis (SHA) are used instead.

Once the costs and benefits of a project have been identified and quantified, they should be valued according to common criteria. For instance, monetary valuation of externalities may be based on the willingness to pay (WTP) approach or on shadow prices. On the other hand, the economic rate of return (ERR) should take into account relevant factors such as price controls, subsidies and tax breaks. For a review of the economic analysis of projects, the

	Incremental	Non-incremental
Outputs	Adjusted demand price or WTP	Adjusted supply price or opportunity cost
Inputs	Adjusted supply price or opportunity cost	Adjusted demand price or WTP

Table 4.3: Basis of economic valuation of project outputs and inputs
WTP: willingness to pay.

reader may refer to the guidelines issued by the World Bank and the Asian Development Bank.

Models that are widely used to study the indirect effects of ports include production function models (see Chapter 7), regional-economic models and input–output models. The latter may be grouped under the general heading of port impact studies which are widely used to assess the socio-economic net present value (NPV) of all direct and external (positive and negative) port impacts. Port impact studies have emerged as an area of applied research that can bridge port and trade activities with the wider economic, social, environmental, and spatial impacts. The literature on the subject may be divided into two major lines of research: port economic impact and port trade efficiency.

3.1.1 Port economic impact

Port economic impact may be considered as a branch of economic geography, extended to the fields of social development, spatial planning and environmental economics due to the increasing importance of the port–city interface. Port impacts on the economy are measured to assess the macro-economic and social impacts of ports on their respective hinterlands or forelands. In this approach, ports are seen as economic catalysts for the regions they serve where the aggregation of port services and activities generates socio-economic benefits (Bichou and Gray, 2005). 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 related academic literature (eg Verbeke and Debisschop, 1996; Rodrigues *et al.*, 1997):

- *Direct impact* is associated with firms and providers of port services located within or directly linked to the port activity. This includes services to ships (pilotage, tugging, mooring/unmooring, supply and bunkering, maintenance and repair, ship and port agency, etc), services to cargo (stevedoring and cargo handling, storage and warehousing, inland transport and delivery, value added logistics, freight forwarding, customs clearance, banking and insurance, etc), port management (HR, civil works, building and maintenance, safety, security, environmental protection, etc), and any other related activity such as government installations and port educational institutions. Many organisations linked to direct impact are part of what is commonly referred to as the port community. Direct impact also includes taxes and fees from spending in the local area by visitors who arrive by sea and spending in the local area on goods and services by terminal and port tenants.

- *Indirect impact* is the aggregate impact on the economic and business activity of firms which are located within or around the port area and for which the port is a determinant factor in their locational decisions. Examples include manufacturing and industrial businesses, logistics and distribution centres, trade and service firms, etc, for which the port closure would result in a relocation of their activities outside the port area.
- *Induced impact*, often referred to as the multiplier port effect, is the combined effect of both the direct and indirect port activities on other sectors of the economy. The multiplier effect depends on a range of factors such as the nature of port traffic, type of cargo handled, geographical and spatial distribution, etc.

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 form a core part of national accounts and are usually produced by national statistical agencies. I–O models are formulated as sets of linear equations that depict the inter-industry relations of an economy through a matrix showing the inputs and outputs of different branches of the economy. Nonetheless, it was not until the 1950s that the spatial economy and transportation implications of I–O models were fully considered due in particular to the concept of interregional input–output developed by Walter (1956). Basic equations for a standard I–O model, as extracted from Kwak *et al.* (2005), are illustrated below:

$$X_i = \sum_{i=1}^{N} X_{ij} + F_i = \sum_{i=1}^{N} a_{ij} X_j + F_i$$

(Tables viewed horizontally: supply-driven model)

$$X_j = \sum_{i=1}^{N} X_{ij} + V_j = \sum_{i=1}^{N} r_j X_i + V_j$$

(Tables viewed horizontally: demand-driven model)

where:
X_i: total gross output in sector i;
V_j: Total gross output in sector j;
X_{ij}: inter-industry purchases of producing sector i from supply sector j;
F_i: final demand for products in sector i;
V_i: final value added by sector j;
a_{ij} and r_{ij} are direct input (output) coefficients, respectively.

Most available I–O models in the literature 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. The direct impacts are usually measured using industry and employers' surveys, 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 port 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 ranges between 4 and 5 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 spill-overs to other countries when inter-country I–O tables exist (Van der Linden, 1998; EEIG 1997).

The US MARAD "Port-Kit" Model 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 the 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. Among recent studies using the MARAD's Port Kit Model to assess port economic impacts, it is worth mentioning the work of Kite-Powell (2005) who used the MARAD model to estimate the economic implications of port call dislocation in the port of Boston.

I–O models are quite simple but require high quality and detailed data. Their main analytical drawback is the assumption of equilibrium and the inability to handle changes in relative prices. Furthermore, the use of multiplier effects is not always consistent with economic theory because of the way multipliers are selected and calculated, especially where negative externalities (congestion, pollution, etc) are not usually accounted for where assessing the wider economic impact of ports. I–O models are also static by nature and a typical I–O model for ports usually fails to capture changes in freight systems, cargo volumes, geographic shifts and other dynamic effects.

Where detailed data is not available, or it is too expensive or it takes too long to undertake a direct flow survey, the computation of economic impact is based on mass calculations. The method consists of calculating the overall value added by the firms geographically located in the port or its hinterland,

Table 4.4: Mass calculation methods to assess port impacts on the economy

<table>
<tr><td colspan="2">A. Impacts on the economic wealth: value-added measurements
When statistical data is available, economic impacts are assessed using the input/output matrix:</td></tr>
<tr><td>Impact on employment
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)</td><td>Impact on the National wealth
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)</td></tr>
<tr><td colspan="2">When detailed data is not available or is not reliable, two techniques may be used:</td></tr>
<tr><td>Direct flow calculations
Aggregated added value by port operator:
$$T_{ip} = \sum salaries + \sum profits + \sum taxes$$
Overall aggregated added value:
$$Port\ contribution = \frac{Tip}{regional\ or\ national\ GDP}$$
The overall contribution is estimated through the multiplier factor (K_{ip}). The more the distribution of output is diversified, the higher the multiplier factor</td><td>Mass calculations
When it is too expensive or takes too long to undertake a direct flow 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</td></tr>
</table>

(*Continued*)

Table 4.4: Mass calculation methods to assess port impact on the economy (*Continued*)

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, and - impact on the balance of payments: port as a source of foreign currency and employment.

Source: Compiled and adapted from various sources including UNCTAD and World Bank sources.

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.

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. CGE models, by their nature, assume equilibrium and are also based on input–output relationships, but allow for more interaction between constituent markets in order to achieve equilibrium for all sectors. Because of the use of a long-run utility function (the possibility of assuming that consumers display preferences over differentiated goods which are produced by imperfectly competitive firms), CGE models have gained more popularity in the transport research including for cross-sectoral applications used for quantifying the impacts of port efficiency on trade facilitation (APEC, 1999). In a rare application to ports, Dio *et al.* (2001) use a CGE model to analyse the impacts of port efficiency improvements on the Japanese economy. The results of various illustrative price shocks show that Japan's port productivity has a substantial impact on the shipping industry, but only a minor contribution to the country's GDP.

Despite their usefulness in highlighting the benefits of the port activity and its wider benefits, their "black box" nature, assumptions about equilibrium, requirement for large data inputs, and inability to capture the dynamic effects in terms of adaptations to changes in transport conditions that take place in the microscopic/micro-economic level (eg firms and households) limit their usefulness and ease of application. Economic impact studies are also context dependent and their results may be misleading if used for the purpose of port benchmarking. Indeed, the approach was criticised because it portrays ports as competing regions rather than competing firms or business organisations. In Chapter 1, we 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.

3.1.2 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 in its infancy as both the definition of the subject and the approach to it have not yet stabilised.

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 in 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 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, for instance between single-port efficiency versus country-port efficiency, operational efficiency versus cross-border efficiency, throughput versus traffic figures.

3.2 Commercial Appraisal of Port Investments

The main commercial interest associated with port projects is the recovery of the cost of investment. A financial evaluation is therefore required to determine the financial viability of a port investment and estimate the recovery period. Financial appraisal of investment decisions relies on a number of methods the most common of which are: the return on investment (ROI), the pay-back method and the discounted cash-flow (DCF).

3.2.1 Return on investment

The ROI, also expressed as the accounting rate of return (ARR), is the ratio of the money generated or lost relative to the cost of the investment.

3.2.2 Pay-back method

The pay-back period measures the length of time taken to repay the initial capital cost. The method operates on a cash flow basis rather than a profit basis, hence taking into account depreciation, tax, grants and subsidies.

$$Pay\text{-}back\ in\ years = \frac{I}{R - C}$$

where:
I = total investment; R = average annual operating income; C = average annual operating costs.

3.2.3 Discounted cash flow

The DCF technique evaluates future expenses and revenues at different times in order to account not only for the time value of money (pay-back method) but also for the effects of interest rates, risks, and inflation. The calculation of DCF is based on the NPV and the internal rate of return (IRR). Under the NPV method, an investment is acceptable when the NPV ratio is greater than zero (>0), otherwise it should be rejected. The IRR is defined as the discount rate which returns a NPV of zero ($NPV = 0$).

$$Present\ Value\ (PV) = \frac{C}{(1+r)^t}$$

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$

where:
PV = present value; C = expected cash flow (future sum receivable); r = discount rate; t = time in years.

Conventional methods for estimating discounted rates are based on the financial or the opportunity cost of capital. However, a suitable discount rate is often difficult to estimate because of factors such as inflation, purchasing power, taxes, premium risks, and other uncertainties. A widely used discount rate method in securities investment is the capital asset pricing model (CAPM) shown below.

$$r = r_f + \left(\beta * \left[(r)\right]_{\mathrm{m}} - r_f\right)$$

where:
r is discount rate; r_f is riskfree rate; r_m is the expected return on the market; β is the estimate of the beta of the cash flows being evaluated.

The estimates of beta of shares of most listed companies are available from financial sources such as Bloomberg.

3.3 Project Risks and Risk Analysis

Risk is inherent in all projects and investments, and can be defined as the chance or the probability of an unexpected event occurring, or an expected outcome not taking place. Investors' willingness to accept risk is a function of the degree of accuracy of information they receive and on their perception of the risks on which they base their investment decisions. The risks commonly identified in port projects include the following: construction risks, financial risks, economic risks, traffic and revenue risks, regulatory risks, political risks and environmental risks. All risks associated with a given project or investment should be identified, quantified, priced and allocated accordingly. The general framework for risk assessment and management is outlined in Chapter 12.

3.3.1 Construction and operating risks

Construction and operating risks relate to project delays caused by design changes, cost overruns due to underestimation of operating costs, and/or the difficulty of acquiring administrative and environmental clearance.

3.3.2 Financial risks

Financial risks are the risks emanating from financial constraints such as insufficient cash flows, lack of long-term debt capital, and unsuitable financing structures and mechanisms. Monetary policies can also be the cause of a financial risk, for instance a high variability of interest and exchange rate and restriction on currency convertibility. Where the analysis of financial risk indicates public financial support is necessary, the latter can be achieved through different instruments ranging from equity guarantees, debt guarantees, exchange rate guarantees, to direct grants and subsidies subordinated.

3.3.3 Economic risks

Economic risks result from changes in economic policy which can affect the normal progression and implementation of investment and management decisions. Sources of economic risk include trade policies that increase protection and restrict market access and fiscal policies that over-tax port services and reduce the value to port investors.

3.3.4 Commercial (traffic and revenue) risks

Traffic and revenue risks stem from the uncertainty of port demand, and are sometimes referred to as commercial risk. They may be a major problem throughout the process of port development, from project inception until completion.

3.3.5 Regulatory risks

Regulatory risks emanate from the scope and degree of authority by which the regulator exercises regulatory responsibilities over prices and competition rules, safety, security and environmental regulations, and any relevant contractual arrangement or public obligations vis-à-vis port stakeholders and customers. Examples of regulatory risks include regulations that prevent port access and investment opportunities, and actions that terminate port contracts and concessions.

3.3.6 Political risk

Political risks are non-commercial risks such as wars, terrorism, political conflicts, bureaucracy, corruption, and other illegal irregularities that arise from unstable government systems, incoherent institutional frameworks, and unfavourable government policy.

3.3.7 Environmental risks

Environmental risks emanate from activities such as dredging, bunkering, pollution and contamination, disposals and cargo spillage, CO_2 emissions from ships and port vehicles and equipment, noise, and any other factors that impact the quality and sustainability of a port's environment and eco-system.

4 PORT FINANCING AND PRIVATE SECTOR PARTICIPATION

In the past, public funding was the main source of port finance. Port operators require a certain level of return from their investment in port facilities and in a number of cases the return is unlikely to be sufficient for them to justify the investment. In many cases, while the benefits to the ports themselves may be small, the benefits to the wider economy can be substantial. Developing facilities at ports can also stimulate economic growth in the port's hinterland through the creation of jobs and can often lead to improvements in the transport infrastructure. In these circumstances, it may be appropriate for the public sector to intervene and provide the funds to facilitate port development. A variety of instruments can be used for public funding of port projects including grants and subsidies, bonds and equity shares, low interest-rate loan schemes, to guarantees and preferential access to capital markets. Debt financing from multilateral development agencies (eg World Bank, European Investment Bank, Asian Development Bank, African Development Bank) and backed by the Government was also a popular instrument of port finance, especially in developing countries. On the other hand, neither retained earnings nor debt financing from commercial lenders was widely used, and both instruments accounted for only a small proportion of global port finance.

Over the last three decades or so, the general tendency has been towards joint-venture and user financing with a greater role of private sector participation in ports. This trend has set in as a result of the rising cost of large-scale port investment, the growing restrictions on public funding of port infrastructure, and the widespread process of port reform and deregulation.

Port infrastructure and associated activities can be categorised into maritime access infrastructure, port infrastructure and superstructure, and landside access infrastructure. Maritime and land access entails long-lived, largely sunk assets with costs that cannot be easily assigned to specific port users. Thus these assets are not likely to be attractive to private investors and are typically owned by governments or possibly a consortium of port operators. Although a lot of non-access port infrastructure and superstructure are also long-lived assets, their costs can be more easily assigned to port users. Accordingly, there is much greater scope for private participation and investment in these assets.

Between 1990 and 1998, 112 common user port projects with private participation reached financial closure in 28 developing countries, with investment commitments totalling more than US$9 billion (World Bank, 2001). There have been around 200 port or terminal privatisations and PPP projects in the last 20 years, and it has also been estimated that the share of the proportion of

The cost of purchasing terminals (price/earnings ratio)	
Sold for	**2007 share price**
P/E ratio × 14—In 2005 DP World purchased CSX terminals *P/E ratio × 15—In 2006 Admiral Acquisitions bought ABP* *P/E ratio × 19—In 2006 DP World's purchase of P&O ports* *P/E ratio × 16—In 2007 Deutsche Bank bought a share in Peel ports*	*P/E ratio × 20—Forth ports* *P/E ratio × 25—ICTSI* *P/E ratio × 36—CMHI* *P/E ratio × 58—SIPG*
Recent examples of financial institutions investing in ports and terminals • *2005: Babcock and Brown (Australia), a private equity firm, buys PD ports (UK)* • *2005/6: Peel Holdings (UK) buys MDHC (UK) (now 49% owned by Deutsche bank)* • *2006: Admiral Acquisitions, a private equity firm buys ABP (UK)* • *2006: Ontario Teachers' Pension Plan Board (OTPPB buys Orient Overseas Container Line (Hong Kong) entire terminal operations (excluding Long Beach and Kaohsiung)* • *2006/2007: Macquarie Bank buy 40% stake in Hanjin (S. Korea) terminals* • *2006: KGL (a private equity firm) awarded a 40-year BOT concession to develop the new container terminal in Damietta, Egypt, adding to its existing operations in Kuwait and the UAE* • *2007 DP World Assets in America sold to AIG, an international insurance company*	

Table 4.5: Price-to-equity ratio and investment trends in ports and terminals (Compiled from various sources including Lloyd's List, Drewry, BMT and others.)

container throughput handled by public-run container terminals has declined from around 45% in 1991 to less than 21% in 2004 (Drewry Shipping Consultants, 2006). More recent trends show a growing interest of financial firms and private equity funds in port finance and investment.

4.1 Economic Benefits of Private Sector Participation

There is plentiful evidence of the economic benefits of restructuring, deregulation and privatisation. Relative to private owners and operators, experience shows that public owners and operators are less able (and have fewer incentives) to control costs, are slower to adopt new technologies and management practices, and are less responsive to the needs of port users. The following summarises four experiences with private sector involvement:

- *Kelang Port Authority:* In 1986, Kelang Port Authority (Malaysia's main port) divested its container operations. Crane handling improved from 19.4 moves per hour in 1985 to 27.3 in 1987, bringing Kelang's performance close to that of Singapore. The return on fixed assets grew at an average annual compound rate of just 1.9% in 1981–1986 prior to divesture, but thereafter jumped to 11.6% in 1986–1990, due to improvements in productivity and throughput rather than higher prices. By 1990 port workers were paid 60% more an hour in real terms, worked on average 6% more hours each, and produced 76% more than before privatisation.
- *Colombia:* In 1993, Colombia concessioned its four main ports to separate regional port authorities, which then contracted with operators that use the facilities. New laws abolished most restrictive labour practices and allowed stevedoring services to compete freely at each port. Average waiting time per vessel dropped from 10 days before 1993 to nothing afterwards, container moves per vessel per hour increased from 16 to 25, bulk cargo shifted per vessel per day increased from 500 tonnes to at least 2,500 tonnes, working hours per day increased from 14 to 24, and working days per year increased from 280 to 365. Although the initial concessions involved little investment, the main reason for their success seems to have been the removal of restrictive practices and the development of effective competition both within and between ports.
- *Argentina:* Between 1990 and 1993, the Argentine government abolished most of the restrictive working practices at ports and on vessels. Argentine shipowners were allowed to temporarily register their ships under foreign flags and so benefit from lower requirements on crew's size. Contracting arrangements with stevedore companies were freed up, pilotage and towage services were deregulated, and operators were allowed to set their own tariffs. An important reform authorised the private sector to build and operate ports for public use, undermining the market power of existing ports. The port of Buenos Aires was split into three areas with separate functions and administrations, one of which was further split into six terminals that were concessioned to compete with each other. Although this was subsequently regarded as too much fragmentation, deregulation and privatisation increased port investment and performance significantly. In the port of Buenos Aires between 1991 and 1997 annual container traffic jumped from 300k TEUs to more than 1m TEUs, the number of cranes increased from 3 to 13, labour productivity almost quadrupled, and the average stay for a full container dropped from 2.5 to 1.3 days. As a result the port of Buenos Aires was able to successfully compete with Santos in Brazil, South America's largest port, surpassing it from 1997 onwards in terms of cargo handling (Hoffman, 1999). Some port services in Argentina were supplied by the

private sector before the reforms of 1990, for example the private sector managed stevedoring at the port of Buenos Aires. But because of excessive regulation, inadequate competition, strong labour unions, and low investment by the port authority, no significant improvements in performance were achieved in the early years of private participation.

- *Mexico:* In the mid-1990s Mexico began a decentralisation program that led to the concessioning of the country's major ports to private operators. In addition to lower tariffs and improvements in efficiency, privatisation enabled the port system to cover its costs, which it was not doing beforehand. Indeed, the system now generates substantial tax revenue for the government whereas before it depended on public support. This improvement in the finances allowed the port authorities and concessionaires to undertake substantial investment in expansion and modernisation.

4.2 Public–Private Partnership

Broadly defined, a PPP is a contractual arrangement between a public sector body and a private sector party resulting in the private sector delivering and operating public infrastructure facilities and/or providing port services over an agreed price[5] and period of time. While PPP arrangements temporarily transfer all or part of the rights and duties relative to a public port service, they do not imply full privatisation. Effective PPPs should be seen as a tool available to the public sector to enhance the delivery of port infrastructure and services. However, PPP ventures are not without criticism mainly because of the complexity and risks that arise during the PPP planning and implementation process and due to the shift from public sector provision to private sector provision.

Key to any successful PPP project are the principles of risk sharing, value of money, consistency, transparency, accountability and competitive process. The risk-sharing principle denotes the cooperative venture between the public and

Advantages	**Disadvantages**
Competitive process Increased transparency Accountability Financial and commercial considerations Private sector efficiencies Private sector innovation Risk sharing and transfer	Complexity Loss of control High transaction costs Higher borrowing costs Skills deficit for public sector Structuring risks Public perception and political reactions

Table 4.6: Pros and cons of PPPs

5. Typically, the price for terminal PPPs includes one or the combination of three components: initial lump-sum money, an annual rent, and a royalty per ton or TEU.

private sectors based on a balanced allocation of risks and rewards. The value of money principle ensures that PPP projects have a better value of money than public sector projects. Consistency ensures that the PPP design, transaction and implementation process is consistent with government policies and objectives as well as with PPP standards and principles. Transparency and accountability ensure that there is both a transparent PPP transaction process as well as a clear definition of the roles and responsibilities of the public sector and the private sector parties.

4.2.1 Types of PPPs

The PPP spectrum covers a variety of contractual options that can be classified in terms of the scope of operations and level of control they provide to the public or the private sector. On the other hand, the range PPP options may change from one country to another or from one sector to another. Below are the main PPP options for ports, but these are neither inclusive nor exhaustive:

Procurement

Procurement or outsourcing is basically a service contract in which the public port entity contracts out an operation or a service to a third party through a process of open or restricted competitive bidding. The practice of outsourcing has been and is still used for non-core nautical activities such as maintenance dredging, bunkering, pilotage, mooring and unmooring, towage, and so on.

Licensing

The port grants, against an agreed licence fee, permission to the private operator to use the port's infrastructure and/or superstructure. The latter remain under the ownership and control of the public port entity. Licensing is different from concessions (see below) because there is no exclusivity or concession life span; in that other operators may be brought in to operate and manage the port infrastructure.

Management contracts

Under a management contract, a port or terminal facility is run and managed by a specialised port management company who provides management services, brings operational skills and know-how, agrees (usually) to employ the existing port staff, but the public sector retains control over all the assets. Furthermore, the financial arrangement differs from that of service contracts in that port fees and charges are paid by the user to the public agency in charge of port management (eg the port authority) which, in return, pays a fee to the contractor based on his input and performance results. Sometimes, a management contract is tried out before being converted to a more extensive concession-type contract (for example APM Terminals in the port of Aqaba in Jordan).

Concessions

The term concession in its generic meaning implies a contractual arrangement by which the public sector party transfers to the private sector party and for a pre-determined period of time the rights for the provision of port operations and public services on land and infrastructure in the public port domain. Under a concession contract, the public sector party (government, municipality, port authority, etc) grants to the private operator the rights to finance, design, build, equip, maintain, and/or operate facilities and equipment in the public port domain for a fixed period of time after which the facility or the equipment may or may not be transferred back to the public sector. In either case, the private operator must cover investment costs and assume all commercial risks and liabilities throughout the duration of the concession. There are three main forms of concession contracts: lease contracts, regular concession contracts and build-operate-transfer (BOT)-type concession contracts.

- *Lease:* A lease is basically a rental contract in which the port leases an asset (infrastructure, superstructure, or both), or the right to use it, for an agreed period of time in return for a bulk payment or a series of instalments. There are two main types of lease arrangements: lease contracts and leasehold agreements. Lease contracts, which often have a built-in renewal clause, apply when an operator enters into a long-term lease on the port land and also becomes responsible for superstructure and equipment. Leasehold agreements are simple rental agreements with only land or warehouse facilities being leased. The rate for lease or rental contracts can be calculated on the basis of a flat rate (fixed periodical compensation), a mini–max rate (variable fee with a floor and a ceiling, both related to traffic levels), or a shared revenue rate (variable fee, with a floor but no ceiling, related to traffic levels).
- *Regular-type concession contracts:* A regular concession contract typically involves the establishment by the Government or the public authority in charge of port management of a special purpose company, which can be public, private or both, and which is entrusted with providing funds and as a concessionaire of the port facility. Under a regular concession contract, the special purpose company leases land from the Government, and the lease contract then becomes an integral part of the concession agreement.
- *BOT-type concession contracts:* By heavily resorting to the private sector to fund new port development, a BOT concession type adds on extra dimensions to regular-type concession contracts. First, it significantly increases the operational role, the management control, but also the financial exposure of the private sector. Second, a BOT-type concession often involves the setting up of a consortium which, in addition to the special purpose company, includes the prime contractor (construction or engineering firm)

and the operator. Last, but not least, the BOT-type contract must include additional clauses related, *inter alia*, to the financing, design, construction and completion of the new port facility. Several contractual options exist under the broad umbrella of BOT-type of concessions. In addition to pure BOT contracts, the most widely used concession contracts in ports are BTO, WBOT, BOO, BOOT and EOT.

- Under a BOT concession, the government provides an exclusive grant to the private sector to build and operate a port facility for a specified period of time. After the expiry of this period, the grantor can lease out the facilities or, if the facilities have to be completely rehabilitated, he can grant a similar or different concessional arrangement. A BOT agreement implies that the concessionaire has rights similar to holding a title which allows him to use the port facility as a corollary to loans during the period of concession.
- BFOT (Build, Finance, Operate, Transfer), BTO (Build, Transfer, Operate), and WBOT (Wraparound BOT) are special variations of BOT concessions used where the private sector is also in charge of project financing, where legislation forbids private ownership of public infrastructure, and where the private sector is in charge of expanding a public-owned port facility, respectively. Other variations include the Design, Build, Finance, Operate (DBFO) and the Design, Build, Finance, Maintain (DBFM) models. Both models provide a high degree of private sector control with little or no demand risk.
- In the Build-Operate-Own (BOO) contract, the assumption is that there will be full and permanent privatisation of the facilities built or operated at the end of the concession period of the concession agreement. The terms of a BOO concession should explicitly grant ownership of the facilities that will be built.
- Under the Build-Operate-Own-Transfer (BOOT) agreement, the ownership title over port assets and infrastructure conveys to the concessionaire during the concession period but is transferred to the Government at the end of the concession. This arrangement facilitates the granting of loans by financial institutions to private terminal operators. However, subject to project economics, the concessionaire takes at least some demand risk in BOOT structure.
- Under the Equip-Operate-Transfer (EOT) scheme, port infrastructure already exists, but superstructure is supplied and operated by the private sector for an agreed period of time, after which it is transferred to the public sector.

4.2.2 Design and process of PPPs

As shown in Table 4.7, the structure of PPP design and transaction, which starts with pre-qualification and closes with the bid award, is only part of a wider process for PPP planning, execution and evaluation.

Table 4.7: Framework of PPP procedure and component

PPP framework and components	Sub-activities	Tasks
1. Preliminary assessment and policy formulation	Country assessment	Political, social, and economic assessment Regulatory framework and service regulation Labour and administrative issues
	Market and sector assessment	Market and industry dynamics Identify port sector private investors (domestic and international) Port organisation, regulation, and institutional structure Analysis of industry stakeholders and key interest groups
	Appropriate mechanisms for policy formulation	Anticipated benefits from private sector participation Sector reform and modernisation Appropriate mechanisms for PSP involvement
2. Project specification and PPP model selection	Project identification	Identify sector-specific problems and service provisions Identify potential projects for PPP implementation
	PPP options	Identify PPP options for port projects Evaluate PPP options suitability and attractiveness to private operators Analyse government role and capacity relative to different PPP options
3. Feasibility study: technical and economic analysis	Technical assessment	Demand and traffic forecasting Condition of infrastructure, useful life and depreciation of assets Engineering economic analysis (costing versus performance targets) Manning, safety, security and environmental requirements
	Economic valuation	Definition and measurement of public utility Assessment of externalities Cost benefit analysis (economic and social)

	Nature and levels of competition	Competition in the market/Competition for the market Yardstick competition Capital market competition
	Tariff setting and payment mechanism	Tariff definition and structure Payment and cost recovery mechanisms
4. Financial appraisal, risk assessment and financing structure	Financial appraisal	Project cash flow and financial modelling Pay-back, NPV and IRR methods
	Risk assessment	Identification of risks: political, construction, revenue, currency, environmental, etc Risk assessment, allocation and transfer
	Sensitivity analysis	Alternative costing scenarios Alternative tariff schedule and adjustment
	Financing structure	Direct grant and loans Provision of guarantees Incentive performance payment and cost sharing schemes
5. Analysis of legal and regulatory framework	Diagnostic and assessment	Diagnostic of legal environment Legislation for procurement procedures Assessment of suitability and constraints
	Amendments and restructuring	Role of public and institutional stakeholders Restructuring, legal and institutional reform Flexibility for negotiations and alternative approaches

(Continued)

Table 4.7: Framework of PPP procedure and component (*Continued*)

PPP framework and components	Sub-activities	Tasks
6. Transaction strategy and design	Components of transaction strategy	Information/memo and marketing Pre-qualification. Bidder due diligence Draft bid documents. Negotiation of draft bid documents Bidding and tendering Draft award and closure
	Transaction document package	Request for proposal/tender document Draft contract Operating licence and other regulatory documents Implementation agreement and government support
	Hiring external consultants and advisors	Objective of hire Requirement and elements of due diligence Terms of reference
	Establishing PPP management team	Tasks and challenges in PPP project management Nature and composition of the team Objective and staffing of the team

(Continued)

Table 4.7: Framework of PPP procedure and component (*Continued*)

PPP framework and components	**Sub-activities**	**Tasks**
7. Tendering and bidding process	Options for bidding arrangement	Competitive bidding Competitive negotiations Direct negotiations Other arrangements
	Bidding process	Steps for tendering process Pre-qualifiers criteria Information and marketing management Pre-bid contact with stakeholders Closing PPP contract
	PPP award and management	Bid content and evaluation Contract management Post-project review: price adjustment, renegotiations Conflict resolution

PPP: private and public partnerships.

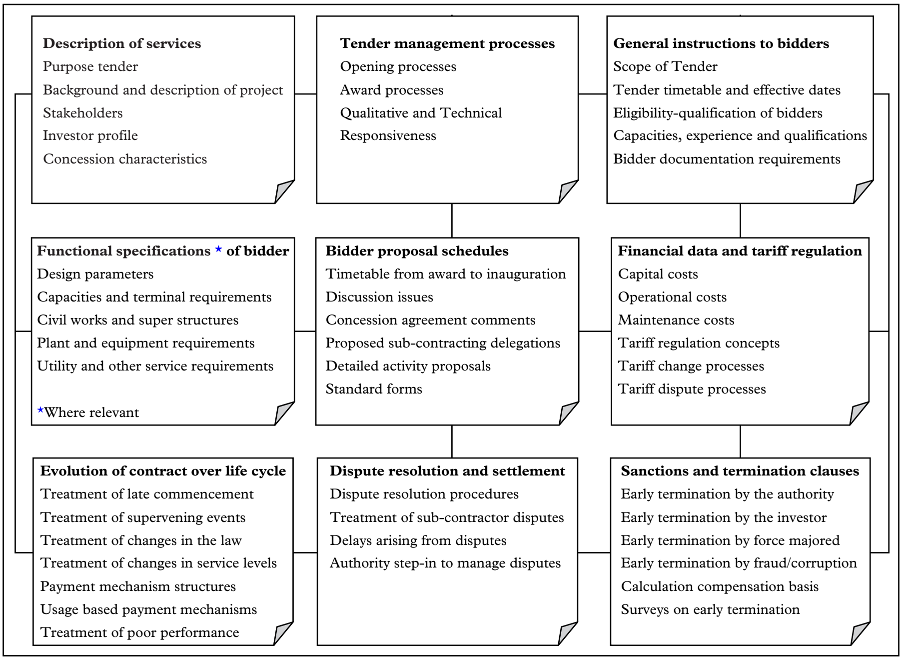

Fig. 4.11: Main components of a tender document

A key aspect of the PPP process is the preparation and design of a tender document. The main aspects that a tender document should address include the followings:

- general obligations and rights of the parties,
- description of the obligations/rights of the operator,
- insurance, liability indemnification issues,
- evolution of the contract over the life cycle,
- economic and financial clauses,
- tariff, fees and payment basis,
- mechanisms for changes and review,
- sanctions and termination clauses, and
- dispute resolution and settlement.

The clauses listed in Figure 4.12 illustrate the main elements of a generic tender document, although these may change considerably depending on the nature of the project and the type of PPP transaction.

Clause 1 Introduction
Clause 2 Duration of contract
Clause 3 Service commencement
Clause 4 Protections against late service commencement
Clause 5 Supervening events
Clause 6 Warranties
Clause 7 Price and payment mechanism
Clause 8 Availability requirements
Clause 9 Performance requirements
Clause 10 Payment mechanism, management and monitoring
Clause 11 Maintenance
Clause 12 Payments and set-off
Clause 13 Changes in service
Clause 14 Change in law
Clause 15 Price variations
Clause 16 Sub-contracting, employees and documentary changes
Clause 17 Assignment
Clause 18 Change of ownership
Clause 19 Land, equipment and other property interests
Clause 20 Treatment of assets on expiry of service period
Clause 21 Early terminations
Clause 22 Calculation and payment of early termination payments
Clause 23 Surveys on expiry and termination
Clause 24 Indemnities, guarantees and contractual claims
Clause 25 Insurance
Clause 26 Information and confidentiality
Clause 27 Intellectual property rights
Clause 28 Dispute resolution
Clause 29 Authority step-in
Clause 30 Miscellaneous provisions
Clause 31 Direct agreement and senior lenders
Clause 32 Competitive dialogue and commitment letters
Clause 33 Due diligences over sub-contracts and financing documents
Clause 34 Refinancing
Clause 35 Financial robustness: contractor distress
Clause 36 Bond and corporate finance
Clause 37 Annex

Fig. 4.12: General clauses in a typical tender document

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CHAPTER 5

PORT PRICING

Port pricing is another area where several topics related to port capacity, investment, competition, strategy, policy and regulation are dealt with simultaneously. Depending on the sources of port finance, the definition and structure of port costs, the elasticity and regulation of port demand, port objectives and other relevant factors, methods of port pricing may range from marginal cost and average cost pricing, to congestion and strategic port pricing. Furthermore, the pricing nomenclature in ports includes terms such as tariffs, dues, prices, taxes and levies, each of which may be targeted at a single user or activity or at a combination of port users and services.

1 PORT PRICING STRATEGIES

Broadly speaking, there are three main approaches to the determination of port charges: cost-based pricing, congestion pricing and strategic pricing.

1.1 Cost-Based Pricing

Given the wide range of port activities and services, the structure of port prices depends on the cost classification which refers to these activities, each with its own set of cost components such as internal versus external costs, fixed versus variable costs, and average versus marginal costs.

1.1.1 Marginal cost pricing

The objective of marginal cost pricing is to maximise social surplus and to allocate resources efficiently. This approach is used to charge the user for external costs and as a benchmark for efficient utilisation of port resources subject to perfect market conditions. A marginal port cost should then include (i) the marginal cost imposed on port infrastructure and resource, for instance the costs of port maintenance, dredging, equipment renewal, and so on (ii) the marginal cost imposed on other port users, for instance congestion and scarcity costs, and (iii) the marginal cost imposed on society, ie outside the port

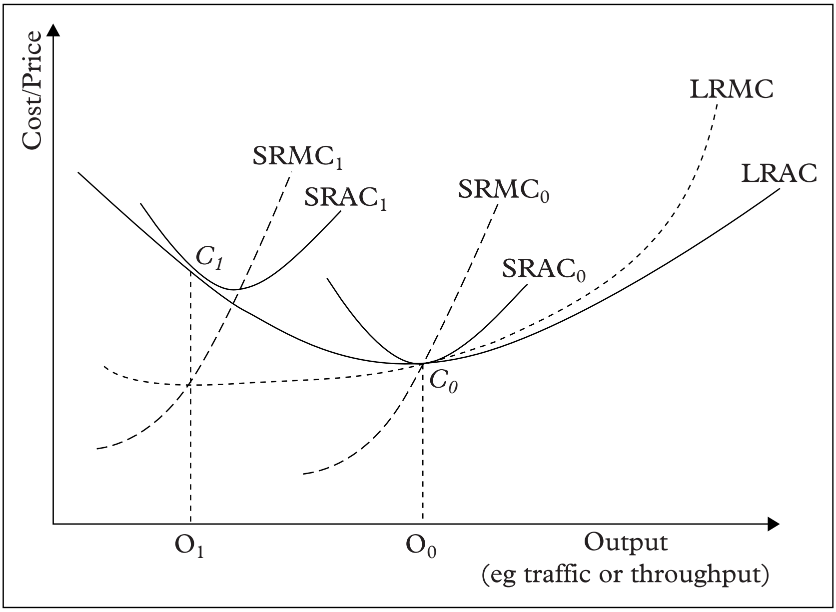

Fig. 5.1: Illustration of short-term and long-term marginal costs

system, for instance environmental, safety and security costs. However, since marginal costs are normally lower than average costs (AC), port investment cannot be recovered in full. In other words, there is no consideration of implementation costs or of the financial or budget constraints under the marginal costing approach.

Figure 5.1 illustrates the pricing mechanism under short run and long run marginal cost pricing. In short run marginal cost (SRMC) pricing, port charges are set to reflect the external costs imposed by the additional use of port infrastructure while holding port capacity constant, assuming that it costs very little to change the price. Where prices are costly to change, long run marginal cost (LRMC) pricing is used where all inputs, including port capacity, are allowed to vary. In long run average cost (LRAC) pricing, the curve indicates the minimum infrastructure cost for each level of traffic, and is positioned below, above or at the same level as the LRMC curve depending on whether economies of scale are increasing, decreasing, or constant, respectively. Note that SRMC and LRMC will be equal when there are constant returns to scale for a traffic level that matches port supply.

In the simplified example in Figure 5.2, the equilibrium between the $SRMC_0$ and the demand curve D exists at equilibrium demand Q_0 at price P_0. When demand increases while port capacity remains constant, the demand curve shifts from D to D′ which sets the new equilibrium at Q′ and P′. The port congestion price is expressed as the annual change of the marginal external

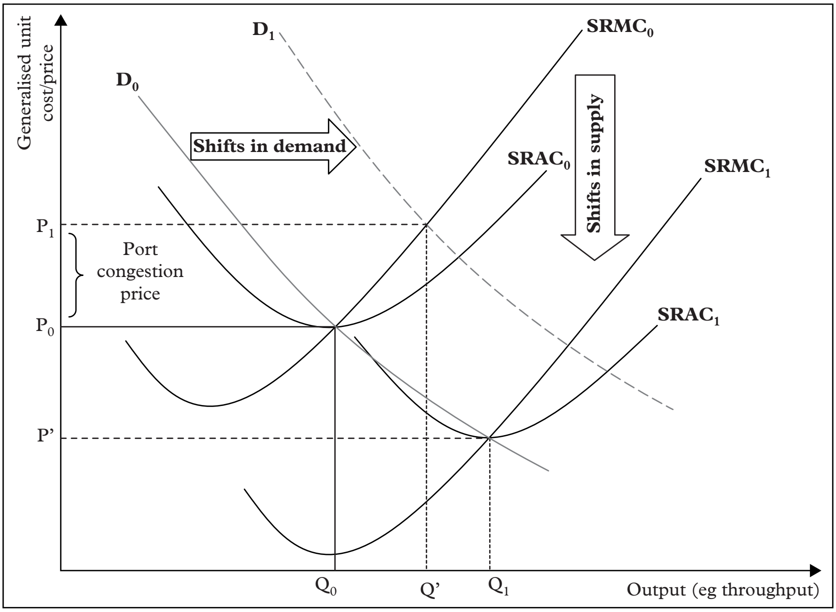

Fig. 5.2: Interplay between SRMC and variations in port demand

cost due to the autonomous growth of port demand. On the other hand, if port capacity increases while demand remains constant, the supply curve shifts from $SRMC_0$ to $SRMC_1$ which sets the new equilibrium at Q_1 and P_1.

Marginal port pricing may be useful in case of public financing of port facilities, but the approach has a number of shortcomings. Rothengatter (2003) states marginal cost pricing may not be optimal in practice because of the following reasons:

- measurement is complex,
- equity and dynamic effects, including investment and technology choice, are ignored,
- financing and institutional issues are ignored,
- price distortions elsewhere in the economy are ignored, and
- implementing marginal social cost pricing may involve substantial administrative costs, which may not always be justified by the benefits it brings.

1.1.2 Average cost pricing

When infrastructure costs must be covered, for instance in case of a private port, a charge to the user equal to the average port cost should be applied. Here, average (and total) costs and revenues are set to be equal to the sum of financial costs, and the cost recovery price is set to correspond to a break-even or a return-on asset value. In order to enable port investments to be fully recovered, the various cargo-types and shipping services are treated equally while no consideration is given to the structure of resource costs (sunk, external, marginal, etc).

1.1.3 Multi-part tariff pricing

Recognising that, in an industry marked by economies of scale, levying SRMC = LRMC would give rise to financial deficits; some researchers have suggested the use of a multi-part tariff pricing. For instance under a two-fare or *Ramsey* pricing, charges may be designed so that one part pays for the fixed cost and the other part for the variable cost, or one part combines both. In marginal cost and cost recovery approaches a standing charge may be added to the marginal cost for instance by charging frequent port users or high-value cargo. In doing so, the two-part fare not only helps in minimising the loss of benefits in relation to marginal cost pricing but can also lead to price discrimination.

1.2 Congestion Pricing

Congestion pricing consists of levying a congestion surcharge to users in order to reduce port congestion. As illustrated in Figure 5.3, congestion pricing

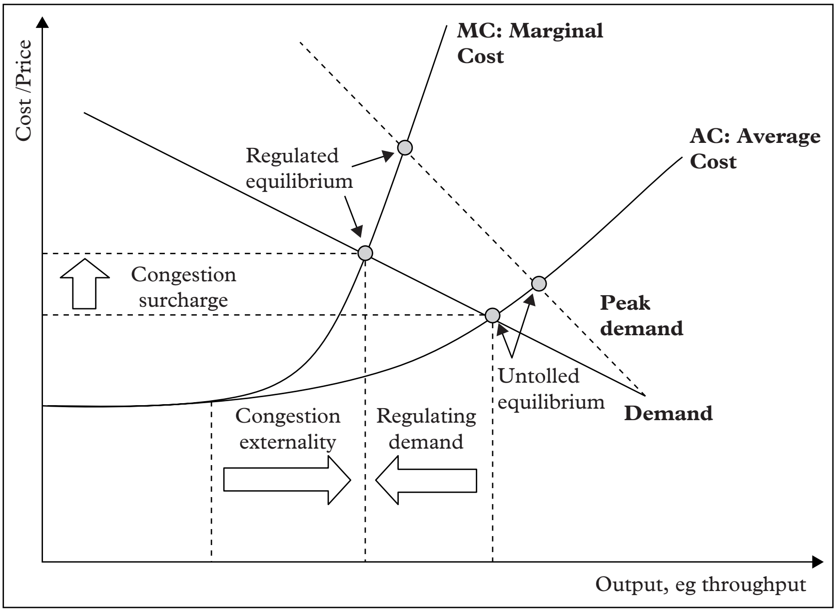

Fig. 5.3: Illustration of the congestion pricing

combines both demand-based and variable-cost strategies, hence making it possible to regulate port demand without increasing supply while at the same time requiring port users to pay for the negative externalities they create. Slot auction is a hybrid strategy which combines congestion, multi-tariff and value-based pricing. Under slot auctions, port users can bid for priority berthing or access passage at specific port or canal slots against a higher charge according to their willingness to pay.

1.3 Strategic Pricing

Traditionally, pricing practices in the port industry were based on the premise that (i) ports enjoyed a high degree of monopoly with limited scope of competition and (ii) any changes in port prices would not be reflected in freight rates and tariffs because the latter tend to be the same for ports within a certain region, particularly in the case of shipping conferences. As discussed in Chapter 9, this is no longer the case in most shipping and port markets.

Strategic pricing is based on the premise that pricing can be used as a tool to promote port competition. As for Ramsey pricing, strategic pricing involves a certain degree of price discrimination (and counter-discrimination), for instance by shipping service (origin versus destination, domestic versus foreign, feeder versus mainline), type of traffic (import, export, transit, transhipment), and value of cargo (low-value versus high-value commodities).

UNCTAD has introduced the cost, performance, value (CPV) approach and claims that this strategy allows port managers to levy tariffs in order to accomplish different sets of objectives. Cost-based pricing is used to maximise the use of port services or cover their costs; and prices are based on the incremental cost for achieving higher outputs. Performance-based pricing is used to promote the efficient use of port facilities and reduce congestion. Here prices are established according to the rate of utilisation of port facilities, for instance through a system of rebates and surcharges. Here, the concepts of price elasticity and traffic demand are used to set up the port charge. Value-based pricing may be assimilated to demand-based pricing aimed at maximising port profits and revenue, but the latter strategy is also applied in situations of limited competition where prices are set according to the user's ability to pay for port services. The CPV approach establishes both a floor (eg the incremental cost of serving the user) and a ceiling (the value received or perceived by the user) for pricing purposes, and provides flexible limits within which port prices can fluctuate.

2 PORT PRICING IN PRACTICE

In a highly competitive and commercial marketplace, port and terminal operators today are hard-pressed to negotiate port dues and tariff charges with shipping lines and other port customers and users. As ports become more aware of the structure and evolution of their cost base, modern approaches for tariff setting rely on management accounting data, eg achieving a specific rate of return, rather than on traditional pricing by historical accident such as through the UK RPI-X formula. The latter is used for updating price caps from year to year by linking historical prices to the inflation rate (the retail price index or RPI) plus or minus an X factor which may be based on the costs of service improvements and infrastructure upgrades to be passed on to port customers. The RPI-X formula denotes a generic price cap policy as adopted in the UK and elsewhere for economic and market regulation, but the formula itself may be much more complex to calculate in practice.

Because of the growing competition from neighbouring ports and other inter-modal transport systems, port tariffs are being increasingly negotiated and adapted according to service agreements with shipping lines (number of ships' call, volume of loaded/discharged cargo, range of services, etc). Here, marginal cost pricing may be applied to set the fork (floor and ceiling) of port's tariff. Ports may also use price discrimination to discriminate between captive and non-captive customers and users. However, as this may not be allowed in regulated port operations, service contracts (such as terminal concessions where tariff indexing are published prices) are widely used to ensure fairness and transparency. On the other hand, the extent to which terminal handling charges (THC), ie the charges that shipping lines pass on to shippers, reflect actual port charges is becoming a controversial issue because of confidentiality reasons and lack of reliable data.

As for the structure of port charges, these may fall broadly into two main categories: user charges and service charges. User charges are directly related to the port user or customer, eg shipping lines versus terminal operators, and to the nature and objectives of the utilisation of a port's infrastructure. Service charges refer to the charges relative to the use of different port resources, facilities and services, and may be further categorised by charging units such as marine services (eg pilotage and towage), conservancy and wharfage dues, facility charges (eg berthing and storage), cargo services (eg stevedoring, cargo handling and storage), and other service charges (eg equipment rental, bunkering and supply, cargo long-term warehousing and processing). The calculation of user and service charges depend on a number of criteria such as:

- *The ship*: eg type, origin and destination, range of operations, and volume and dimension. The latter are usually expressed in terms of taxable volume ($V = Length * Width * Draft$) or K-ratio by type of ship

$$\left(K = \frac{loaded\ tonnage}{unloaded\ tonnage} \right)$$

- *The cargo*: eg type of traffic, cargo volume, weight, or tonnage, and/or commodity classification (eg NST Code).
- *Passengers*: eg number of crews and passengers, age, nationality, vehicle type and registration.

K-ratio	Taxable ship volume
≤0.133	10%
≤0.100	30%
≤0.050	50%
≤0.0350	(95–1300*K*)%

Table 5.1: Ratio K and proportion of port dues for Ro-Ro and container vessels in the port of Marseille

Appendix 1 depicts the published tariff for container terminal operations at the port of Salalah in Oman.

APPENDIX 1: SALALAH CONTAINER TERMINAL TARIFFS

(Effective from 1st April 2008, all Charges in US$)

A1.1 Marine Charges

A1.1.1 Consolidated marine charge

The consolidated marine charge shown below is applicable for all vessels calling at a berth on the container terminal and includes pilotage, tugs, berthing and unberthing charges, port dues and daily sanitary charge. Rate includes up to 24 hours free waiting at the anchorage when available in case vessel arrives ahead of the berth availability.

Vessel LOA Category First 12 Hours Berth Time Berth Time thereafter (or part thereof) (per hour or part thereof)

Up to 150 m: 2,250 50
Over 150 m up to 175 m: 2,750 60
Over 175 m up to 200 m: 3,500 70
Over 200 m up to 250 m: 4,250 90
Over 250 m up to 300 m: 5,250 100
Over 300 m up to 350 m: 7,750 125
Over 350 m up to 400 m: 10,250 150
Over 400 m: 12,750 175

Terms and conditions

- Any delay or Pilot kept waiting through fault of vessel or agent will be counted as berth time used.
- Any delay to tugs through fault of vessel or agent will be billed at US$400 per tug per hour or part thereof.

- In case more tugs are utilised for any reason than the requirement as per Harbour Master's circular no 05/2000 (as updated from time to time), then these are chargeable at the rate of US$400 per hour or part thereof Container Terminal Tariff Effective 1 April 2008.
- Any delay to mooring gang through fault of vessel or agent will be billed at US$100 per hour or part thereof.
- For billing purposes, only complete hours starting and finishing on the hour are counted, eg vessel berthing at 6.25am and un-berthing at 7.45pm counts at 12 complete hours from 7am to 7pm so in this case no additional berth time over first 12-hour period will be billed.

A1.1.2 Other charges

Charge for additional skips requested per day 50.00 per skip
Fresh Water 5.20 per metric ton
Electricity 0.08 per kW hour
Rat Guard for mooring ropes per day 13.00 per guard

Terms and conditions

- Charge for additional skip includes cost of placing the skip at the berth.
- Fresh water supply is subject to minimum 10 tonnes per delivery.
- Vessels without Rat Guards will be required to hire from the Port.

A1.2 Charges for Containers

A1.2.1 Loading/discharging of import/export containers

Up to 20' Over 20'
Loaded containers 75,115
Empty containers 3,040

Terms and conditions

- No volume incentive applicable on import/export container rates.
- Additional charge of US$10 per container for hazardous containers including empty container with cargo residue, and additional charge of US$50 per container for IMO classes 1, 5.2, 6.1, 6.2, 7 and other hazardous cargoes requiring special handling.
- Direct delivery is not normally allowed and even if it is, no discount on these rates is applicable.
- Non-cellular vessels are not normally handled at the terminal; in case Port agrees to handle 25% additional charge is applicable.
- 10% additional charge for Public Holiday working.
- Rates include lashing and unlashing charges.
- Minimum billing of US$5,000 per vessel call for total loading/unloading of Import/Export and Transhipment containers.

A1.2.2 Loading/discharging of transhipment containers

Up to 20' Over 20'
Loaded Containers 140,200
Empty Containers 100,140

Volume Discount rates are offered on Transhipment Container rates based on total number of moves within a 12-month period as follows:

More than 10,000 moves, up to 20' Over 20'
Loaded Containers 120,170
Empty Containers 90,130

More than 25,000 moves
Loaded Containers 100,130
Empty Containers 80,115

More than 50,000 moves
Loaded Containers 90,120
Empty Containers 75,105

Terms and conditions

- Rates shown are for full cycle, ie Vessel to CY to Vessel.
- One full cycle counts as two moves.
- Half the applicable rate is billed against the inbound vessel and half the applicable rate against the outbound vessel.
- Additional charge of US$10 per container for hazardous containers including empty container with cargo residue, and additional charge of US$50 per container for IMO classes 1, 5.2, 6.1, 6.2, 7 and other hazardous cargoes requiring special handling. These charges covers full cycle, ie Vessel to CY to Vessel.
- Non-cellular vessels are not normally handled at the terminal, in case Port agrees to handle 25% additional charge is applicable.
- Volume Discount rates shown above are available upon application in advance to the Port supported by a suitable guarantee acceptable to the Port.
- Volume of moves will be reviewed after 6 months and Port will raise additional billing in case volume of moves is not in line with guaranteed volume.
- Import/Export Container and Restow moves (Restow counts as one move) can be counted in Volume of moves but Volume Discount rates are only applicable on Transhipment Containers.
- 10% additional charge for Public Holiday working.
- Rates include lashing and unlashing charges.
- Minimum billing of US$5,000 per vessel call for total loading/unloading of.
- Import/Export and Transhipment Containers.

A1.2.3 Restows

Any Restow 60 per container

Terms and conditions

- Rate also applies to pontoons, hatch covers and stacking frames.
- No volume incentive applicable on Restow rates.
- 10% additional charge for public holiday working.

A1.2.4 Use of special equipment

Each Lift 100 per container

Terms and conditions

- Not applicable to Break Bulk Cargo (see C-14).
- Applicable to each lift under C-1, C-2, C-3, C-7, and C-8.

A1.2.5 Free-time and container storage rates

Free time is applicable as follows:

Import/Export Loaded Containers (except categories below) 10 days
Empty Containers 20 days
Transhipment (except categories below) 20 days
Hazardous Cargo Containers 7 days
Over dimensional Containers 7 days

Thereafter storage charges apply as follows:

Import/Export Loaded Containers: Up to 20' Up to 40' Over 40'
Per day for first 7 days 5.00 10.00 11.25
Per day for next 7 days 7.50 15.00 17.00
Per day thereafter 10.00 20.00 22.50
Transhipment and empty Containers:
Per day for first 7 days 3.75 7.50 8.50
Per day for next 7 days 5.50 11.00 12.50
Per day thereafter 7.50 15.00 17.00

Terms and conditions

- For Import and Transhipment Containers, free time commences on the day of discharge of the vessel, and demurrage charges stop on the day container leaves the port or is loaded on a vessel. For Export Containers, free time commences on the day the container entered the Port, and demurrage charges stop on the day container is loaded on the vessel.

- Storage charges for over dimensional containers are double the above rates.
- Storage charges for Hazardous Cargo Containers are US$50 per day. This charge is also applicable to any containers leaking chemicals.

A1.2.6 Charges for refrigerated containers

Electric Supply/Monitoring of Refrigerated Containers per day 30 per container

Terms and conditions

- Charges commence from the day container is plugged into Port electricity supply.
- Charges are inclusive of plugging/unplugging.

A1.2.7 Shifting charges

Within Container Terminal 60 per container
Within Port Area 70 per container

Terms and conditions

- Rate includes one move and the associated lift on/lift off if applicable.

A1.2.8 Truck loading/unloading

For each loading or unloading 20 per container

Terms and conditions

- Truck loading/unloading charge applies to all import/export containers that are delivered and received at the CY both loaded and empty.
- 10% additional charge on public holidays.

A1.2.9 Weighing of containers

Use of weighbridge 15 per weighting

Terms and conditions

- The above rate is exclusive of any shifting that may be required which will be charged in addition.

A1.2.10 X-ray inspection of containers

Use of X-Ray Inspection Machine 30 per inspection

Terms and conditions

- The above rate is exclusive of any shifting that may be required which will be charged in addition.

A1.2.11 Delays to crane

After 30 minutes idling, per hour or part thereof 300 per crane

Terms and conditions

- Also applicable in case of cancellation of call or delay in vessel arrival without at least 24 hours advance notice.

A1.2.12 Miscellaneous services

Up to 20' Over 20'
Sweeping Containers 15.00 30.00
Fitting or removing Tarpaulins 25.00 50.00
Unstuffing/(re)stuffing of cargo in Customs Inspection area 60.00 120.00
Knocking down ends of Flatbed Containers 12.50 per unit
Bundling Flatbed Containers 50.00 per bundle
Application/removal of placards 7.50 per placard
Cost of placard if provided by Port 5.00 per placard
Seal number checking in yard or at gate 7.50 per seal
Seal number checking at vessel side 25.00 per seal
Seal fixing (customer provides seal) 7.50 per seal
Seal fixing (Port provides seal) 10.00 per seal
Measuring over dimensional containers 25.00 per container
PTI (Pre-Trip Inspection) for Reefer Containers 40.00 per container
Retrieving Data from Data Logger 20.00 per container

Terms and conditions

- The above rates are exclusive of any shifting(s) that may be required which will be charged in addition.

A1.2.13 Administrative charges

Data Amendment 15 per container
Renomination Charge 50 per container
Document or printout issued at request of customer 25 per document

Fine for undeclared, wrongly declared, poorly stowed or incorrectly packaged:

Hazardous Cargo First Offence 650
Subsequent offences 2,600
Over-dimensional Containers First Offence 260
Subsequent offences 1,300

Terms and conditions

- Data Amendment charge applies in, but is not limited to, the following cases:
  - Transhipment to local;
  - CY to CFS delivery;
  - Non-declaration of Port of Discharge after operational cut-off;
  - Change in Port of Discharge after operational cut-off;
  - Non-declaration of outbound carrier after operational cut-off;
  - Change in outbound carrier and/or outbound vessel after operational cut-off.
- Any Data Amendment that involves the box being shifted from one stack to another will also incur shifting charge.
- Renomination Charge applies to Containers booked for a particular vessel but not shipped for whatever reason, and includes both data amendment and shifting charge.
- Over dimensional Container Fine includes cost of measuring cargo, decision of the Port is final in case of any dispute.
- Hazardous Cargo and over dimensional Container Fines are exclusive of any separate penalties that may be levied by Government Authorities.

A1.2.14 Charges for break bulk cargo at container terminal

Loading/Discharging of Break Bulk Cargo
Import or Export Cargo 9.00 per Freight Ton
Transhipment Cargo (Full Cycle) 14.50 per Freight Ton

Terms and conditions

- Charges as per C-11 Delays to Crane are applicable

A1.3 Charges at CFS (Container Freight Station)

A1.3.1 Composite rate CY to CFS

Up to 20' Over 20' 160,220

Terms and conditions

- Rate includes:
  - Inbound Container-shifting of loaded box from CY to CFS, unstuffing, and shifting of empty box back to CY;

  - Outbound Container-shifting of empty box from CY to CFS, stuffing, and shifting of loaded box back to CY.
- Data Amendment charge applies on inbound CFS boxes not declared prior to operational cut-off.
- Additional charges will be levied for un-stuffing or stuffing cargoes requiring additional labour or equipment.

A1.3.2 Goods receiving or delivering charge to/from CFS

All Cargo 4.15 per Freight Ton

Terms and conditions

- Free time and Demurrage at CFS applies as per General Cargo Terminal tariff.
- Free time and Demurrage Schedule.
- Additional charges will be levied for receiving or delivering cargoes requiring additional labour or equipment.

CHAPTER 6

PORT OPERATIONS

Despite the growing amount of research into ports and terminals, the relationship between theory and port operating practice has been less evident in the conventional body of port literature. Much of the theoretical literature on port planning, logistics, performance, strategy and regulation seem to be detached from the operating environment of modern ports and terminals particularly with regard to design configurations, handling systems, operating procedures and technology variations.

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 and sometimes multi-purpose units within ports.

The choice of the appropriate port layout and configuration is a long-term and strategic decision generally taken at the early stages of port planning and design. The relevant factors that can influence the layout and configuration of ports and terminals include:

- types, sizes and characteristics of ships calling at the port, for example the ship's length, beam, draft, superstructure considerations, cargo-carrying capacity, gears and derricks, etc,
- traffic's type (bulk, break-bulk, general cargo, unitised, passenger, etc) and proportions (import, export, direct-call, transhipment, etc),
- physical (oceanographic, hydrographical, topographic, climate, etc) and engineering (construction, dredging, pavement, etc) conditions,
- type (standard, special, hazardous, refrigerated, etc), weight and packaging dimensions (full-load, half-load, containerised, palletised, etc) of cargo categories,
- land and terminal's area, capacity and cost constraints,
- operating factors such as equipment and labour costs,
- the location and configuration of freight sites within or outside the port or the terminal.

Terminal type	Berth infrastructure	Handling equipment
Liquid	Loading platforms, pipelines, multi-boys, dolphins, single point mooring	Pumps, loading arms, hoses, etc
Dry bulk	Quay and platforms	Crane-mounted grabs, hoppers, belt conveyors, excavators, bulldozers, mobile hoppers, etc
Break bulk	Quay and platforms, scour protection	Ship ramps, shore ramps, roller and spiral conveyors, multi-purpose cranes
Container & general cargo	Quay and apron	Mobile cranes, jib cranes, portainers

Table 6.1: Different infrastructure and equipment of quay site systems

Within a single port, different terminals can share similar nautical infrastructure such as access channels, jetties and breakwaters, dredging, piers and quay structures. However, each terminal may be decomposed into three main operating sites namely the quay site, the yard and the gate. All such sites must operate jointly for efficient cargo handling and transfer. Figure 6.1 illustrates the different sites and equipment used in a typical container terminal.

1 THE QUAY SITE

The physical infrastructure of the quay site includes berth's length, draft and structure, which may differ according to the type of ship and cargo handled. In Ro-Ro and ferry ports, ramps (shore or ship based) are used for cargo and vehicle transfer between ship and quay. In most other terminals, the 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). In dry bulk terminals, cargo is usually transferred between the ships holds and the storage area (open storage, silos, sheds, etc) by means of belts or conveyors. For liquid bulk terminals, a distinction must be made between loading and discharging terminals. In loading terminals, loading arms and hoses are used as conveying devices between vessels and loading platforms, while buoy and single point moorings are used for vessel loading in off-shore terminals. In unloading terminals, cargo is normally discharged by ship's pumps, but terminals provide additional capacity in the form of booster pumps. Special consideration must be given to the handling of refrigerated or

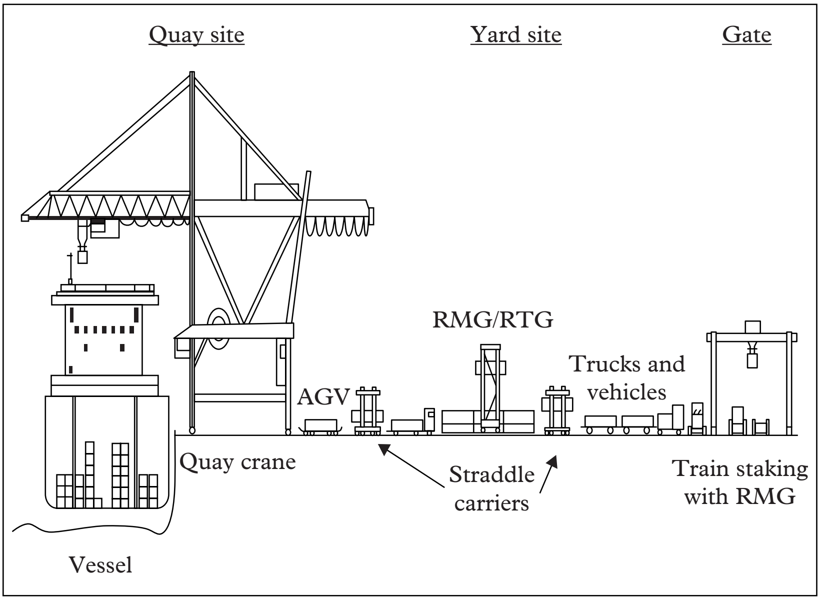

Fig. 6.1: Container terminal sites and main handling equipment

compressed liquid gases such as LNG and LPG. For break bulk and general cargo operations, ship's mounted cranes (gears or derricks) are employed in under-equipped ports or where there is limited containerised traffic. Where there is significant container traffic, STS container cranes (or portainers) are used instead.

Driven by the developments in container-ship size and technology, the size of STS container cranes has more than doubled since the introduction of the first cranes in the late 1950s. The main 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 (see Tables 6.2 and 6.3).

STS container cranes have 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 6.4 and 6.5).

Grain conveyor

Coal ship-loader

Loading palletised fruit ***Fixed***

Ro-Ro berth

Oil discharge

Off-shore oil loading/discharging arms

Container handling using mobile cranes

Container handling using portainers

Fig. 6.2: Quay site operations for selected ports and terminals

STS 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 20 ft (TEU)
	Twin twenties	The crane spreader can handle one 40 ft container or two 20 ft at once
	Tandem 40 ft / two twin 20 ft	Tandem containers are handled by one head block and two spreaders The spreaders can handle two 40 ft, four 20 ft, or each of both
	Triple 40 ft	Tandem containers are handled by one head block and three spreaders

Table 6.2: Types and characteristics of modern STS cranes

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 (eg 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.

Containership size and generation	**Panamax**	**Post Panamax**	**Super-Post Panamax**	**Super-Post Panamax Plus**	**Ultra-large container ships - ULCS**	
					Suez Max	**Malacca-max**
	Third generation	**Fourth generation**	**Fifth generation**	**Sixth generation**	**On-order**	**Concept design**
TEU capacity	3,000–4,000	4,000–6,000	6,000–8,000	8,000–12,000	13,000–15,000	16,000–20,000
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

Table 6.3: Relationship between container-ship size and requirements for STS cranes

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 6.4: Relationship between STS crane speed and productivity—data based on average productivity of 25–30 moves per hour
Source: Bhimani and Sisson (2002).

Crane productivity (move per hour)	Turnaround time in hours per vessel size (in TEU)			
	6,000	8,000	10,000	12,000
25–30	60	64	72	85
35–40	45	48	52	66
50	35	38	44	51
60	30	32	36	45

Table 6.5: Relationship between STS crane productivity and vessel turnaround time

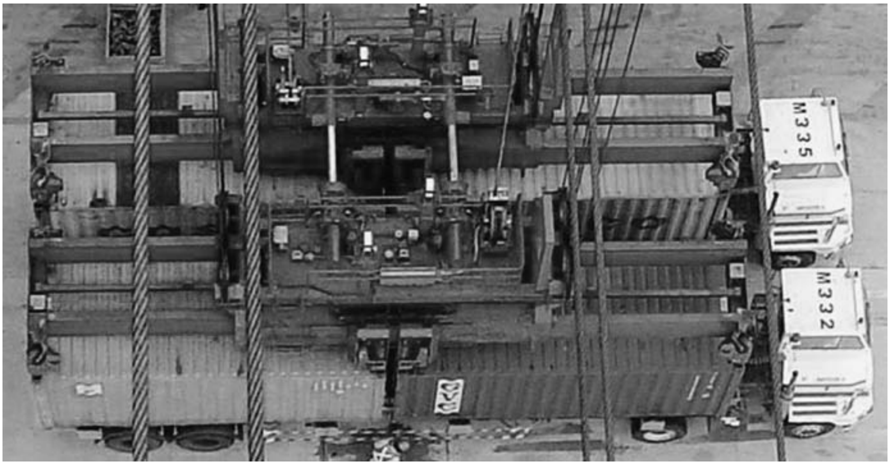

Fig. 6.3: Illustration of lifting capabilities of modern STS cranes

2 YARD AND GATE SYSTEMS

2.1 Yard System

A terminal's yard is the area where cargo storage, stacking, transfer and distribution take place. Not all terminals require separate yards (eg passenger and ferry terminals), but when they do the yard's configuration, layout and handling equipment will have a direct impact on the process-flow and efficiency of terminal operations.

From an operational view, yard operations may be categorised into horizontal transport and storage/staking modules. For instance, the yard area in liquid bulk terminals is used for intermediate and long-term storage of oil and other liquefied cargo, which is then transported by pipelines to refineries and inland destinations (eg the national grid). For car terminals, the yard serves as a warehousing and storage area for cars, trucks and other automobile vehicles before being sent to final customers. In dry bulk and liquid bulk terminals, the yard's transit and storage sheds are used for cargo storage and warehousing. The total storage area of sheds and warehouses depends on a number of factors, in particular the cargo stowage factor, the average stacking height, and the floor space required for cargo handling and access by the relevant equipment in use.

For container terminals, yard configuration and layout determines the stack profile and the movement of containers between stack and quay and between stack and gate, while handling equipment are the machines used for horizontal transport and stacking. The choice of the appropriate container handling system is based on several criteria such as the size of operations, required stacking density and land available, labour costs and availability of skilled labour. As discussed in Chapter 3, containers are stacked and stored in the yard according either to segregation or to scattering strategies, each using a range of container classification criteria such as destination (inbound, outbound, transhipped), status (FCL, LCL, empty), type (special, refrigerated, dangerous, etc) and size (TEUs, FEUs, non-standards).

In container terminals, three generic yard configurations may be identified:

- The tractor-chassis or wheeled system (as opposed to the grounded system). Yard systems using automated guided vehicles (AGV) also fall into this category.
- The straddle carrier (SC) and stacking handler systems, which can be based either on a direct system (SCD) or on a relay system (SCR).
- The 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.

For RTG and SC deployment, two policies may be used during any work shift: a sharing policy which exclusively assigns one crane to one block or a non-sharing policy which allows cranes to move around different yard blocks without restriction. For RMG and automated stacking crane operations, only a non-sharing policy is possible.

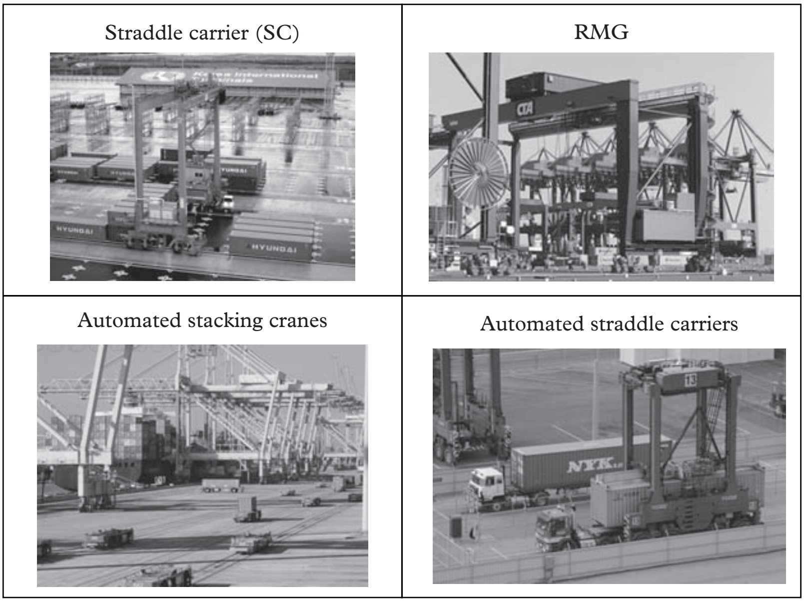

Fig. 6.4: Main cranes and handling equipment used in the yard

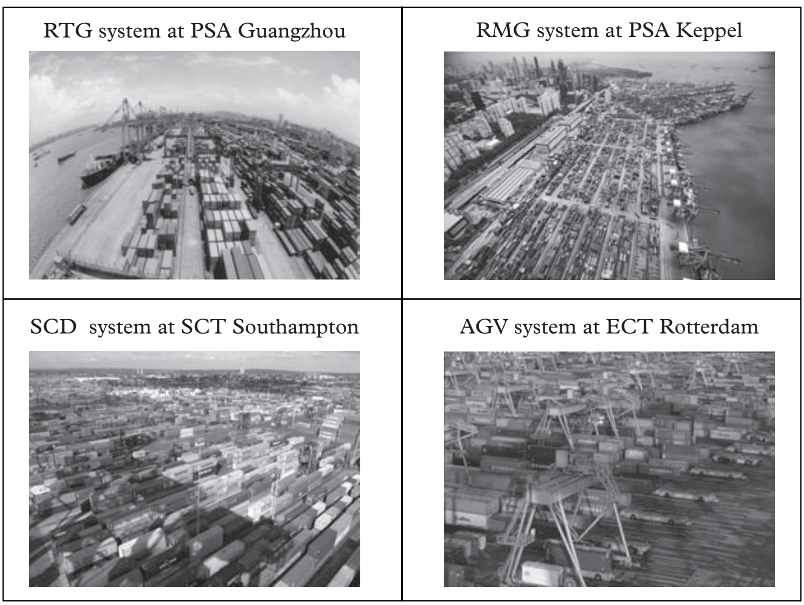

Fig. 6.5: Selected yard layout and cargo handling configurations

Table 6.6 depicts the typical operational features of major container yard handling systems while Figures 6.6 through 6.10 schematically illustrate their general layout and configuration based on simple export/import segregation rules. Sometimes, container yards are operated on a hybrid system, for instance when RTG or RMG-based configurations use SC or other supporting equipment such as reach stackers (RS) and front-end loaders (FEL) for stacking empty and special containers.

2.2 Gate System

Gate operations are designed to efficiently control access into and out of a terminal or port facility through land interfaces, which may be further subdivided into train and truck interfaces (or interchange points). Components of gate planning and management include advance booking, arrival schedule, pick-up and delivery, cut-off times, validation check and control, and gate-in/gate-out monitoring. Conventionally, the gate process is manual where a lane clerk identifies the import/export cargo and feeds information via radio or another hand device to the terminal's management system. In low labour cost areas, the manual gate system can be cost effective, however the system is also time consuming and prone to human errors. Today, modern gate operations are implemented and managed using electronic and automated solutions for truck and container detection, size recognition and verification, congestion status, cut-off control and other relevant operations. Available technologies include CCTV cameras, card readers, RFID tags and sensors and other mobile data and digital imaging technologies (see Chapter 8).

3 MODELLING TERMINAL OPERATIONS

The rationale behind modelling is to construct a mathematical or computer-based model that ideally mimics, or at least represents, real world situations in order to understand, improve and/or optimise them. In port operations and management, modelling has proven to be a powerful tool to design and analyse real world complex situations. In this section, we will discuss three main approaches used for modelling port and associated logistics systems namely analytical modelling, simulation modelling, and process modelling. Each approach could be relevant to one or a combination of port problems:static, dynamic, deterministic, and/or stochastic. Note the classification of terminal operations into vertical handling (quay and stacking operations) and horizontal handling (flow path and movements of trucks and equipment in the yard or through the gate).

Table 6.6: Operational characteristics of major container yard handling systems

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 over 0	1 over 2 (up to 1 over 3)	1 over 2 (up to 1 over 3)	1 over 5 (up to 1 over 7)	1 over 5 (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

(*Continued*)

Table 6.6: Operational characteristics of major container yard handling systems (*Continued*)

System features	**Tractor chassis systems (wheeled operations)**	**Straddle carrier (SC) systems**		**Yard gantry systems**	
		Direct	**Relay**	**RTG**	**Rail-Mounted Gantry (RMG)**
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.

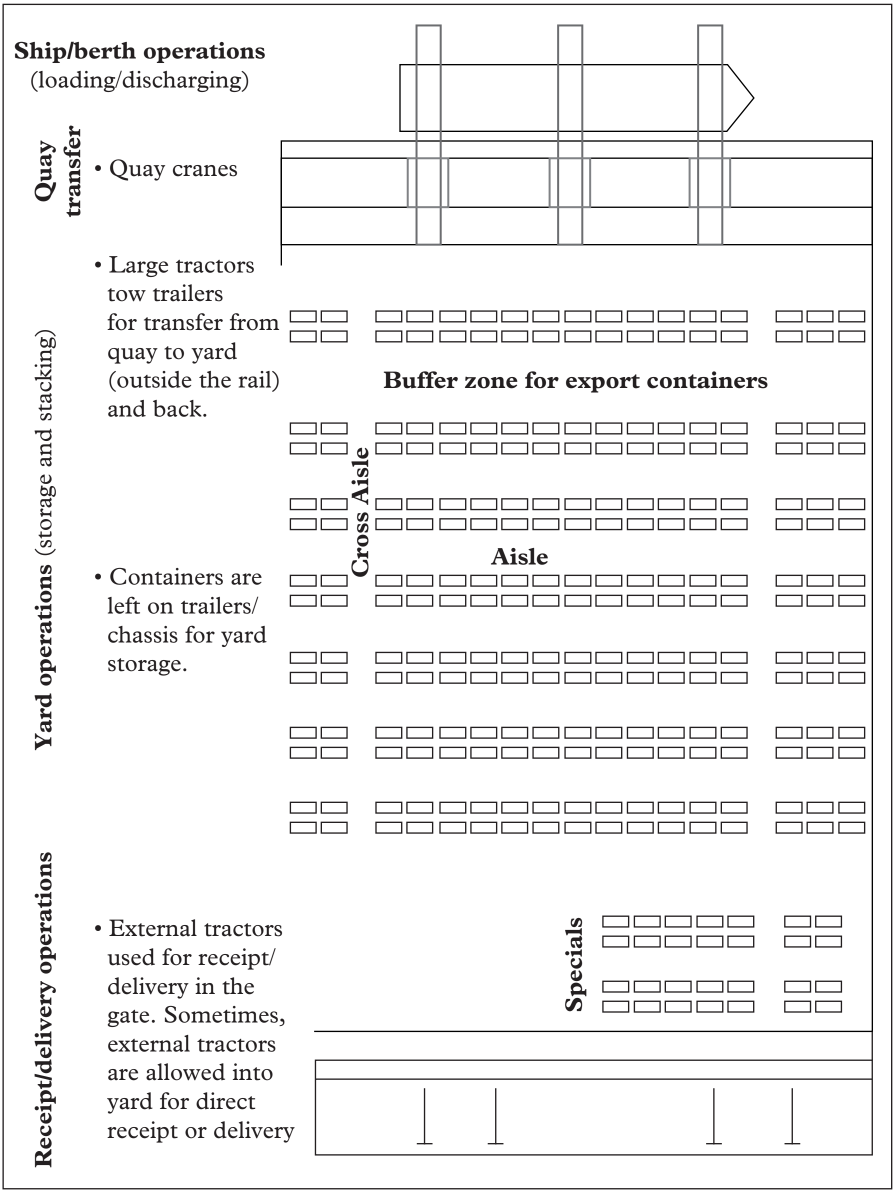

Fig. 6.6: Sample layout of tractor-chassis (wheeled) system

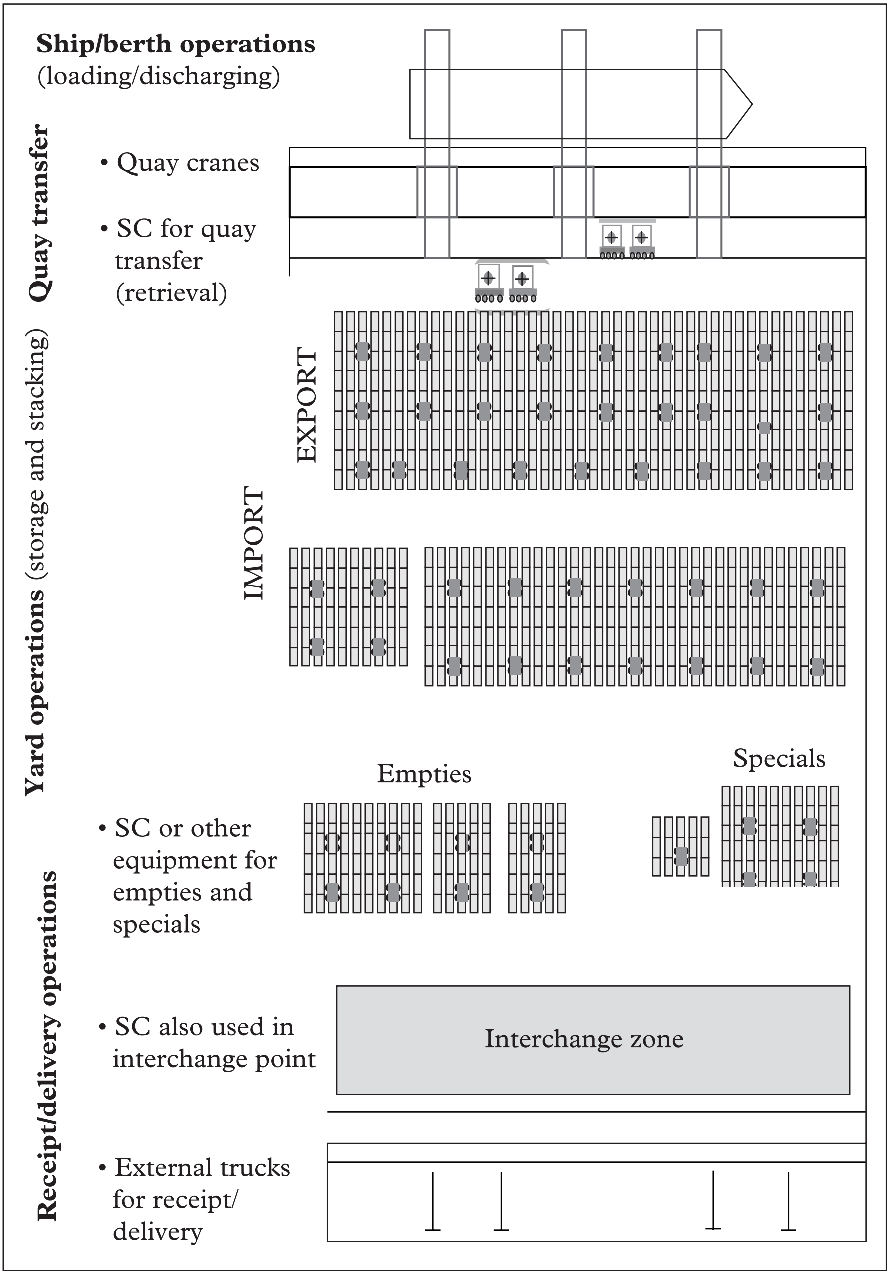

Fig. 6.7: Sample layout of straddle carrier direct system

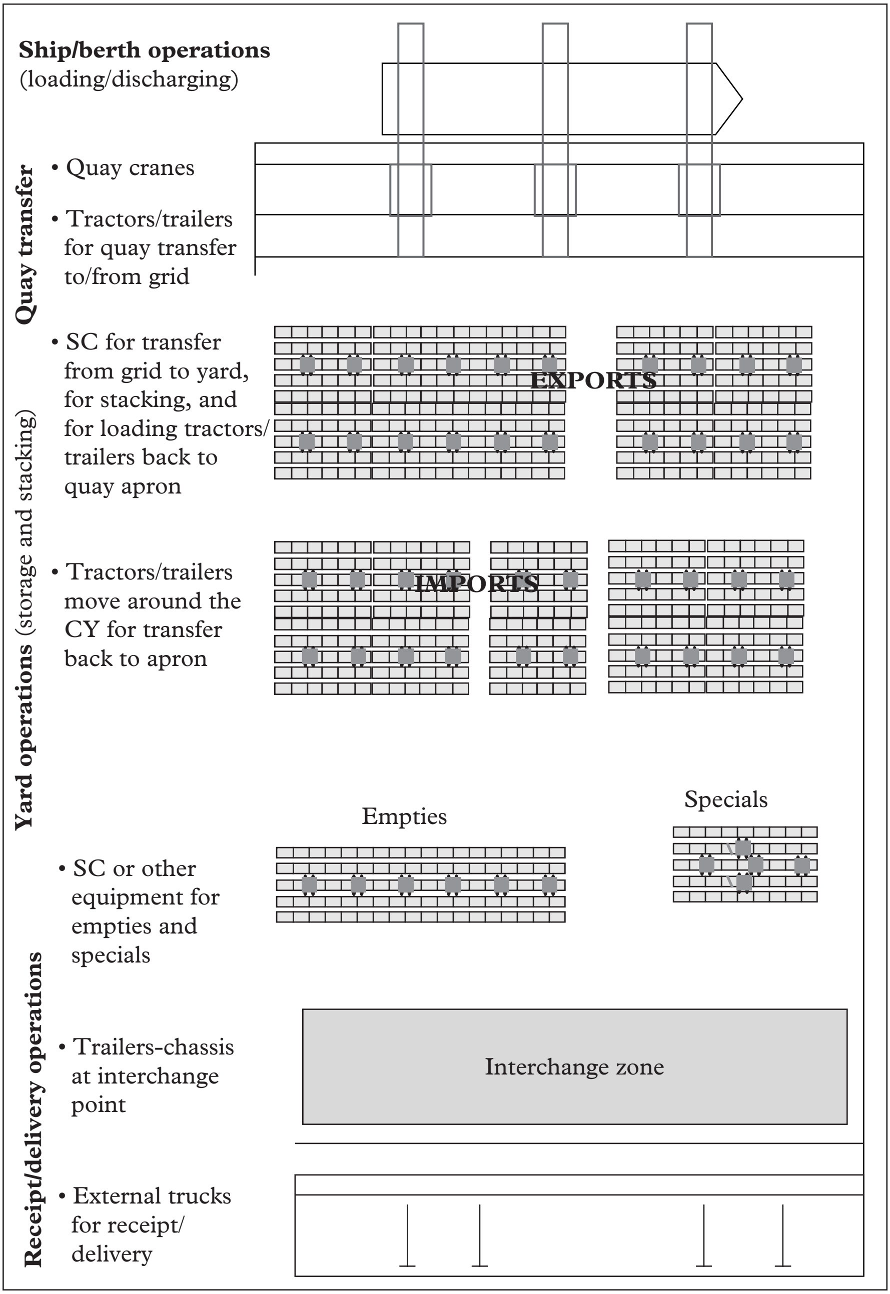

Fig. 6.8: Sample layout of straddle carrier relay system

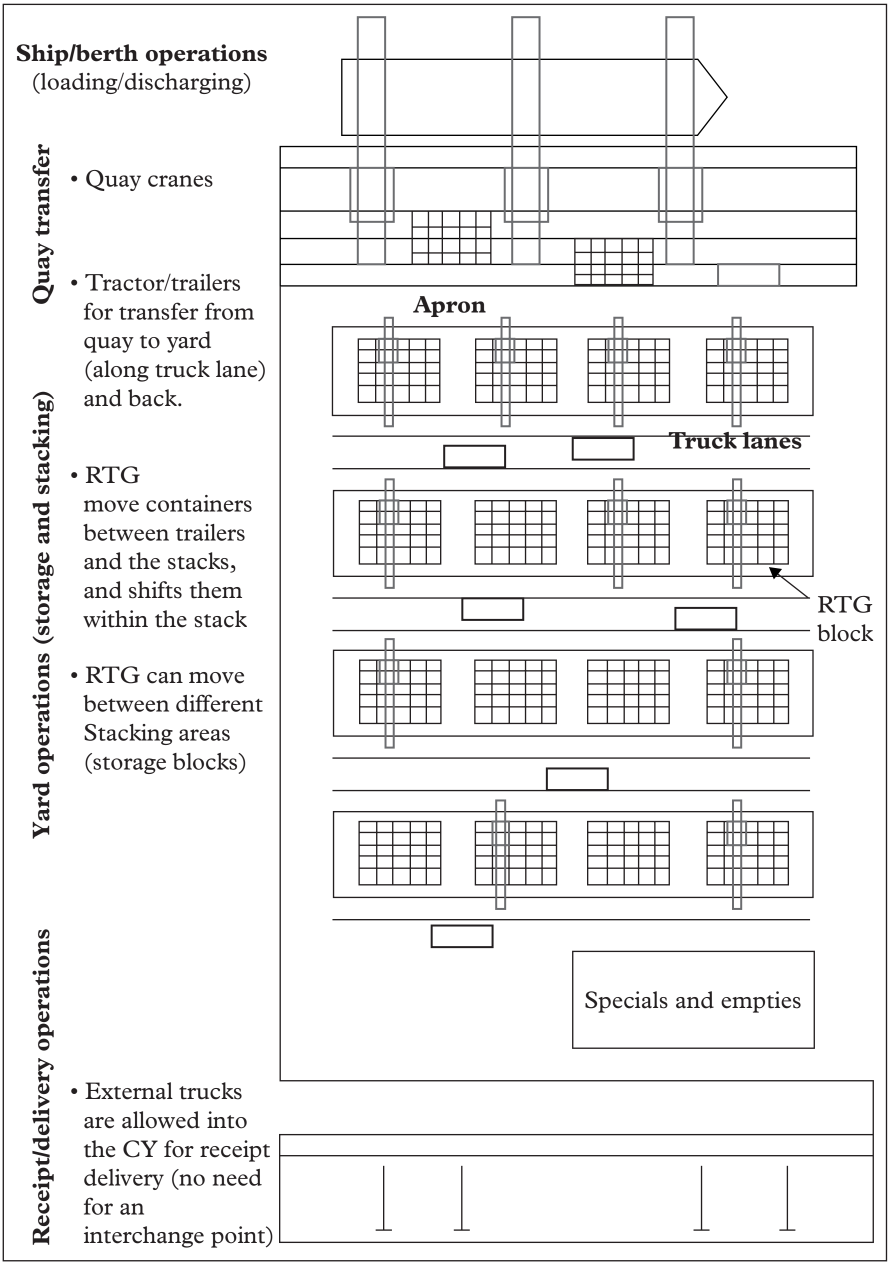

Fig. 6.9: Sample layout of RTG system

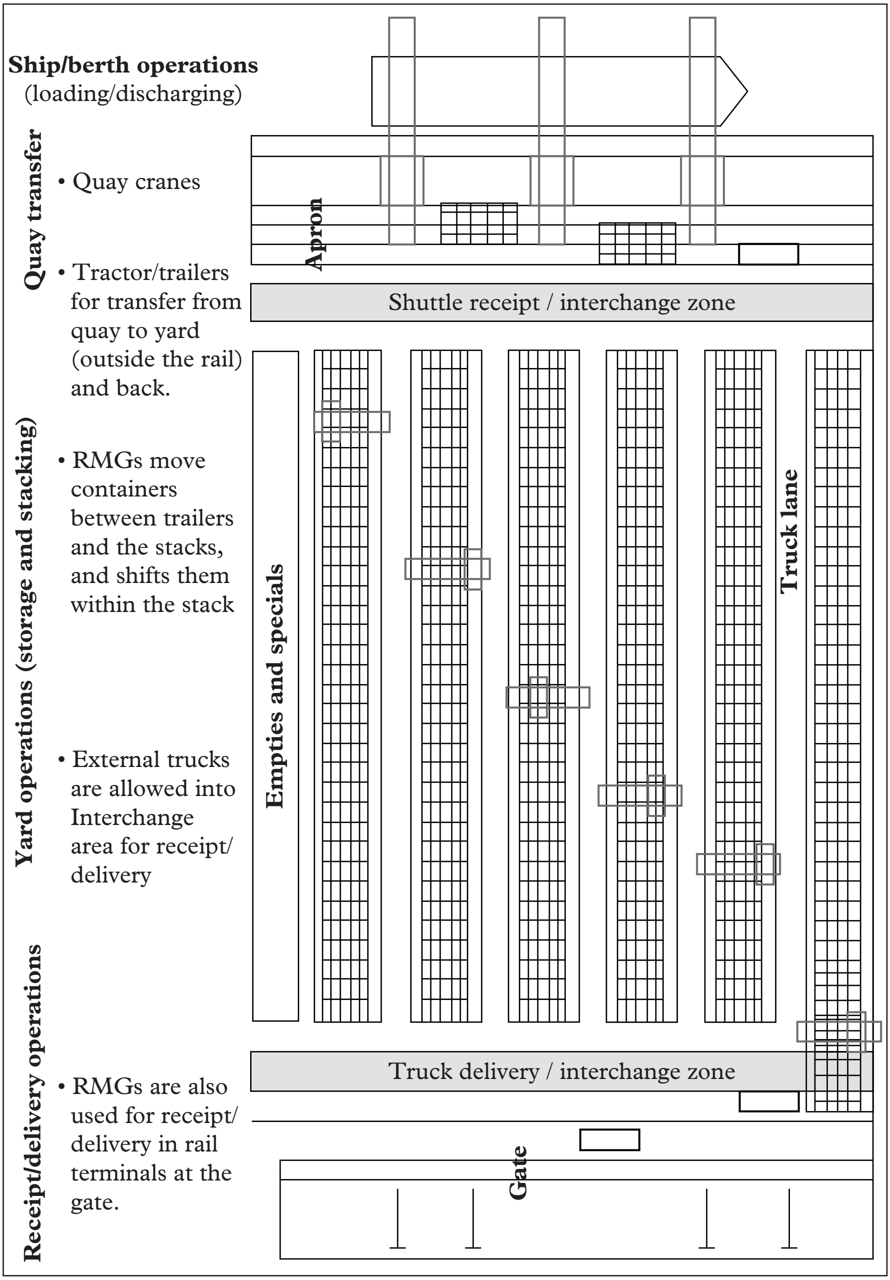

Fig. 6.10: Sample layout of RMG system

3.1 Analytical Modelling

Analytical modelling describes the system using mathematical relationships which are used to derive formulas, algorithms or computational procedures. A range of general techniques, most of which fall under the subject of operations research and/or management science, are used to solve optimisation problems, for instance linear, integer and/or dynamic programming. Optimisation starts with formulating the problem into a set of mathematical expressions with an objective function and a set of constraints.

Clearly, the choice of a particular technique depends on the type of the problem and the way it is formulated. Since most real-world situations involve large complex problems, optimisation experts nowadays use a range of computer solutions capable of handling the huge amount of computation required.[1]

The thrust of network modelling is based on representing a system as a network of linked activities. Since most network problems can be converted into equations in an operations research format, they constitute a special sub-class of optimisation modelling. The network design methods, for the most part, provide normative models for solving complex systems for the purpose of strategic decision-making. The network approach is particularly useful for analysing ystems with spatial (eg port and terminal sites) or temporal (eg ship's queues and cargo flow) applications. These models typically comprise nodes representing entities such as geographical or space-time locations and links or arcs representing routes, flows or movements between nodes.

3.2 Simulation

As an alternative to mathematical optimisation, simulation is used to analyse models of real systems that are too complex for direct mathematical analysis. As such, simulation can be applied to any type of problem where there is no other applicable quantitative method. Simulation is usually described as a "what if" approach to modelling since its main objective lies in testing and comparing alternatives to be used for decision making rather than finding the best feasible solution. An important feature of simulation modelling is the ability to incorporate stochastic (variability and randomness) factors into the model. This also means that simulation can be used as a statistical experiment to analyse probabilistic problems. By running a simulation model several times, it is then possible to obtain both the typical and atypical behaviours of the system along with the probability and robustness of system's performance to randomness and variations in system's components. Table 6.7 compares the benefits derived from simulation against those of mathematical modelling.

1. For more on optimisation software, the NEOS website provides an excellent resource guide: http://wiki.mcs.anl.gov/NEOS/index.php/Optimization_Software_Guide

Mathematical modelling	Simulation
– Yields insights and general principles – Validates simulation result – Shows variations in performance affected by system's parameters – Helps understanding a system that is hard to simulate	– Models complex dynamic systems, including those of non-linearity, stochastic and/or probabilistic nature – Breaks down complex systems into components and processes – Accommodates sensitivity to the timing, sequencing and interactions between events

Table 6.7: Comparing the benefits of mathematical modelling versus simulation

Although the level of detail in early simulation models was constrained by the limited computational power available at the time, terminal operators have used simulation for the design of new port facilities and the control of port operations. Accounts exist of the critical role that simulation held in the automation feasibility studies for the UK's Thames-port in the early 1980s. Since then, countless port simulation models have been developed for use by container terminal operators. Today, simulation is increasingly viewed by operators as an important asset in aneffort to streamline operations in the competitive container terminal market. Table 6.8 provides a list of some known simulation models that have been used by container terminal operators.

The efficiency of various port operations has been extensively investigated in the literature, with much of the work to-date being dealt with either through simulation or analytical calculations. Key port operations that have been mostly examined include ship and berth scheduling (Guan *et al.*, 2004; Imai *et al.*, 2001; Kim and Moon, 2003; Legato and Mazza, 2001), stowage plan and quay-crane efficiency (Shields, 1984; Daganzo,1989; Kim and Park, 2004), vehicle-flow dispatching and scheduling (Steenken *et al.*, 1993; Bish *et al.*, 2001; Narasimhan and Palekar, 2002), staking and storage in the yard (Chen, 1999; Cheung *et al.*, 2002; Kim *et al.*, 2000), empty container management (Jula *et al.*, 2005; Shintani, 2005), automated operating systems (Evers and Koppers, 1996; Meersmans and Wagelmans, 2001; Vis and Harika, 2004), and intermodal transport operations (Bostel and Dejax, 1998; Newman and Yano, 2000). A good review of decision problems in container terminal operations is provided by Vis and De Koster (2003) and by Steenken *et al.* (2004). Terminal operating systems (TOS) are the ultimate application of both analytical modelling and simulation.

3.3 Process Modelling

A process can be loosely defined as any set of interlinked tasks or activities. However, processes can be analysed from various perspectives including

Port/terminal	Tool used	Developers
Antwerp	Arena	RUCA
Durban	ITE	G2
Genoa	C/C++	ITIM
Genoa	Witness	CRT
Genoa	Arena	SET
La Spezia	Modsim III	IDSIA
Le Havre	Lisp	INSA Ruen
Multedo	Java	LSC & MISS
Riga	Arena	IFF *et al.*
Rotterdam	Must & Pascal	TU Delft
Savannah	Modsim/Java	Argonne NL
Savona	C/C++	SVTC
Singapore	Modsim Ill	CACI
Torres	C/C++	ITIM
Voltri	Arena & C	DIP & BC
Zeebrugge	Automod	Ghent University

Table 6.8: Selected industrial container terminal simulation tools
Source: Henesey (2004).

functional, behavioural, organisational and informational views. Unlike simulation languages that build predictive mathematical models, process modelling focuses on prescriptive mapping, description and design of business and process components and the interactions between them. Process modelling uses a variety of tools such as systems engineering, functional economic analysis, Petri-nets, and IDEF (Integration Definition) techniques. The IDEF family includes several tools, each for modelling a particular perspective of an enterprise. The main IDEF methods in use are functional modelling (IDEF0), information modelling (IDEF1), reference data modelling (IDEF1x), process description capture (IDEF3) and object-oriented design (IDEF4). Of these, IDEF0 provide the most possibilities for prescriptive mapping of terminal operations, workflow processes and safety/security procedures.

For container terminals, operating policies and work procedures include opening and service hours (for quay, gate, and/or terminal operations), booking arrangements, free yard storage policy, gate-in and gate-out procedures, cut-off times for loading and late containers, safety and security rules, and the procedures for container checking and inspection.

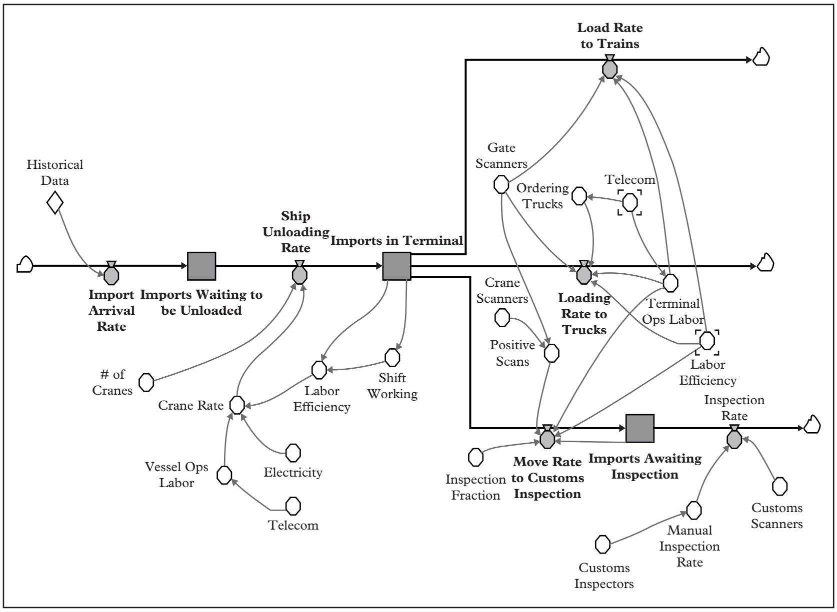

Fig. 6.11: Illustration of NISAC port operations simulator diagram
(*Source:* NISAC, 2005).

Productivity factors	**Solutions**
– Vessel characteristics – Equipment (quay and yard based) characteristics – Availability of cargo – Vessel scheduling – Berth length – Number of cranes – Yard area, shape and layout – Yard handling system – Dwell time – Number of containers grounded – Number and sequence of breakdowns – Labour productivity	– Information systems and management (TOS) – Simulation, eg for terminal development – Optimisation techniques – ITS and positioning information, eg RFID – Automated handling equipment – Automated features and driver assisting features

Table 6.9: Sample solutions for enhancing berth and yard productivity

Using an IDEF0 modelling approach, Figures 6.12–6.14 show a generic process map for container flows (import, export and transhipment) through various terminal sites.

3.3.1 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 planning and operations process. 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.

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 their operations 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

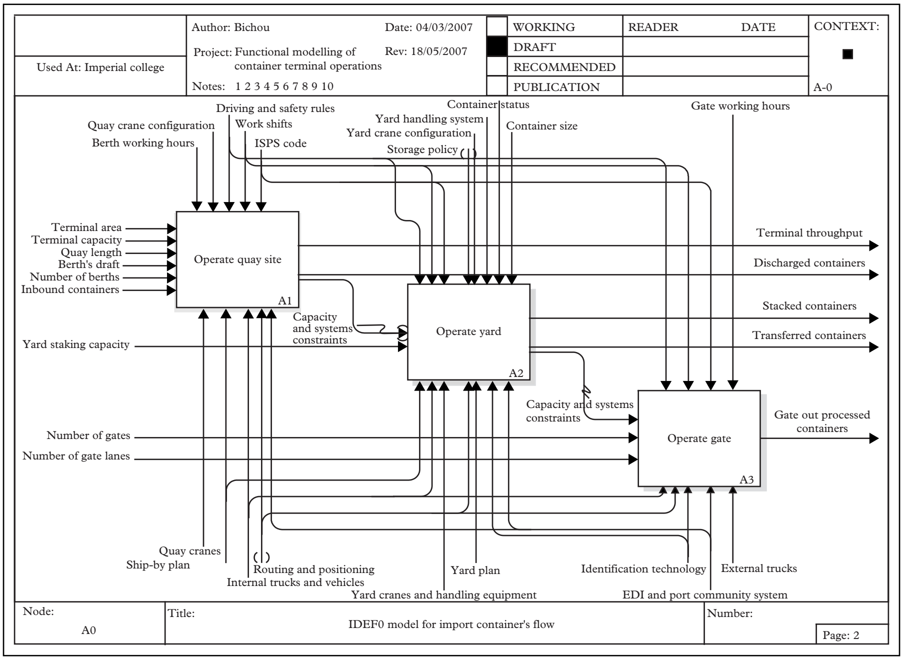

Fig. 6.12: IDEF0 model for import container's flow

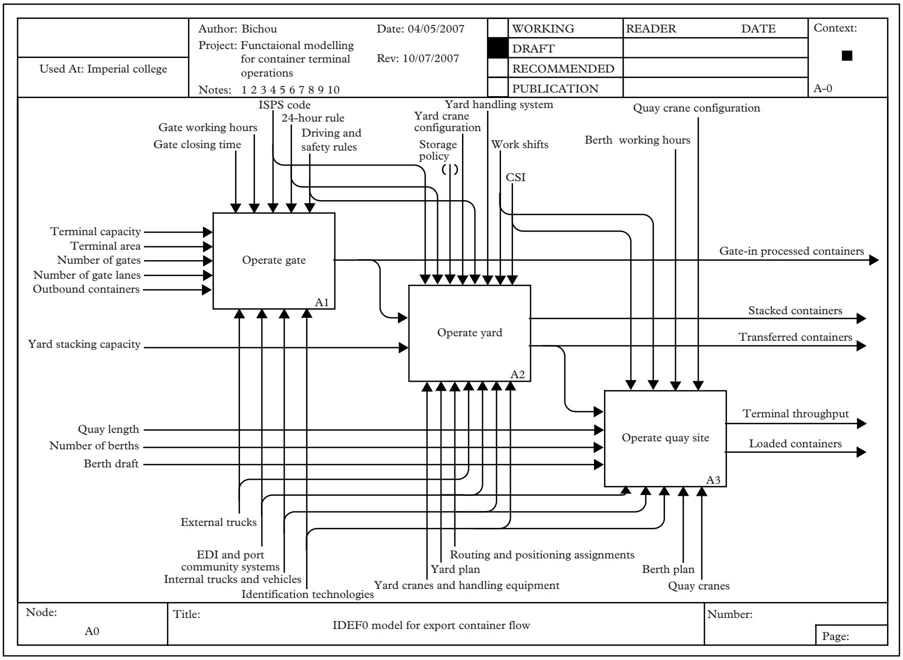

Fig. 6.13: IDEF0 model for export container's flow

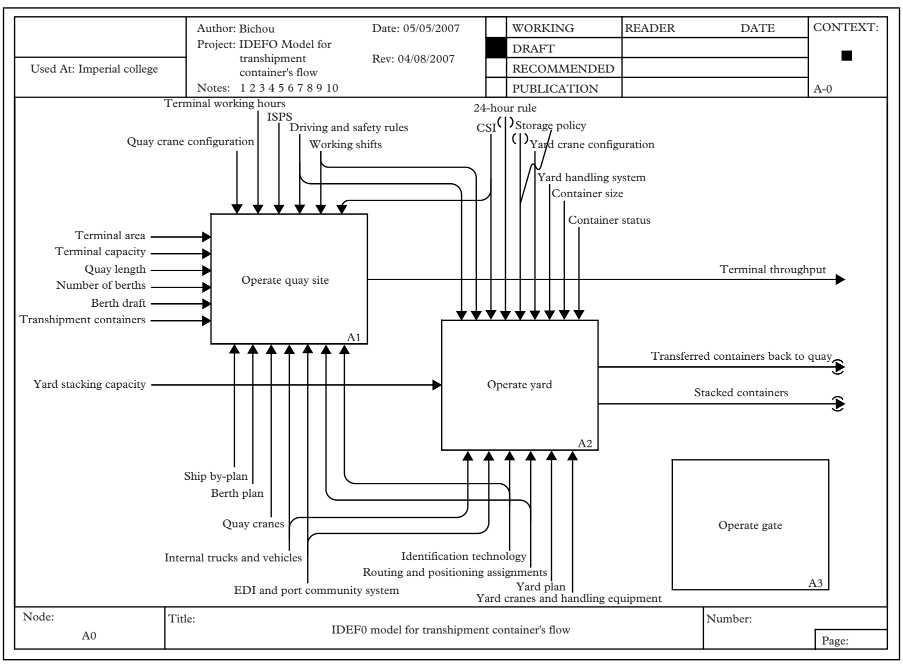

Fig. 6.14: IDEF0 model for transhipment container's flow

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 safety and security framework being put in place. In the context of the new security regime (see Chapter 12), 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 (eg 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.

3.3.2 Export flow

For the export flow, external trucks and vehicles carrying outbound containers enter 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.

3.3.3 Transhipment flow

For the transhipment flow, containers follow a sequence combining both export and import flows without using or passing through the gate site. Note the corresponding changes in the IDEF0 syntax and data objects, including the adjustment in the spatial scope of safety and security procedures.

3.4 Hybrid Approaches

3.4.1 Heuristics

Heuristics are rules of the thumb based on human judgement and experience rather than mathematical theory. As such, the technique does not guarantee an optimal solution but attempts to find a good solution in an efficient way, for example requiring less constraints and computational time. The approach is used across different disciplines and hence applies different techniques (quantitative versus qualitative). In port operations and management, reference is made to heuristic algorithms using mathematical or computer-based models. In the shortest path problem, path-finding heuristic refers to the function that estimates the cost of the cheapest path between a searched node in a tree and a goal node.

3.4.2 Expert systems

These systems use conventional logic or inferential techniques such as fuzzy logic or neural networks to find solutions and recommendations based on the analytical knowledge of an expert in the field. Fuzzy logic extends conventional logic by allowing fuzzy and qualitative definitions of inputs, while neural networks are models builds on the functioning of neurons in the human body.

3.4.3 Decision support systems (DSS)

DSS are a specific class of computer-based information system that supports the decision-making process. A DSS couples the intellectual property of users with the analytical and computational capabilities of the computer. The system comprises three main components: the input database and parameters, the analytical tools, and the presentation mechanism. DSS stand as a specific approach because the tools employed usually combine a range of techniques including operations research, simulation, flow analysis, cost calculators, artificial intelligence algorithms, and other embedded-logic procedures.

4 INTEGRATING TERMINAL OPERATIONS

When operating a port or a terminal, individual processes and components (waterside handling, horizontal transport, stacking process, gate control, etc) have to be in balance so as to achieve overall terminal efficiency. For instance, while the quay crane productivity may yield high performance levels, this may put a high burden on horizontal transport and undermine yard stacking operations. Terminal and port operators should design and implement terminal procedures and policies in ways that enhance overall efficiency rather than that of a single site or operational process.

To illustrate the relationships between different terminal sites, Figure 6.15 provides a general configuration of terminal flows across various operational sites. In particular, it 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 in studies on performance benchmarking and logistics integration.

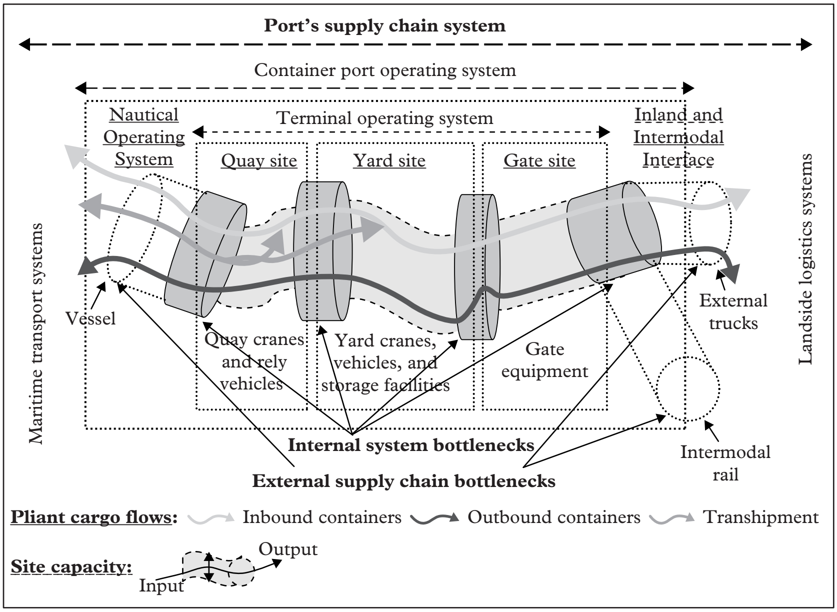

Fig. 6.15: Illustration of operational bottlenecks in container terminal operating systems

CHAPTER 7

PORT PERFORMANCE AND BENCHMARKING

In an environment marked by limited options for physical expansion, increasing cargo shipments and ship sizes, and intense competition between terminal operators and transport providers, ports today are under huge pressure to increase their productivity and operational efficiency. Productivity is usually defined as the ratio of output per unit to the inputs employed. In ports and terminals, high productivity can be achieved through maximising output production such as loading, discharging, storing, and dispatching, while at the same time optimising the use of available input resources such as machines, capital and labour.

Most practical and theoretical approaches to port performance and benchmarking are reducible to three broad categories: performance metrics and productivity index methods, frontier methods and process approaches. Table 7.1 provides a brief outline of the main analytical techniques used in each category. However, despite the plethora of port performance indicators and measurement frameworks, an integrative benchmarking approach is seldom adopted and performance measurements are often fragmented or biased towards sea access. This chapter reviews the main approaches and techniques for port performance and highlights the need for an integrative framework to measure and benchmark port performance and efficiency. Optimisation techniques in port operations, such as mathematical modelling and simulation, do not fall under the subject of performance benchmarking, and are therefore not covered here.

1 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: input measures (eg time, cost, resource), output measures (eg production, throughput, profit) and

Classification of literature	Technique/methodology	Disadvantages
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*: • Törnqvist & Fisher (superlative) indexes • 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*: Provides an activity measure rather than a performance measure *SFP/PFP*: Provides 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 and trends

Table 7.1: Main benchmarking techniques

ratio indices (eg productivity, efficiency, etc). Ratio indices 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 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.

1.1 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 (ROA), and the return on equity (ROE)—see Chapter 4 for more details. 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 ABC and 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.

1.2 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 cargo is unloaded from a ship until it leaves through the gate, or vice versa. 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.

1.3 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 (eg 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 that of another ($\prod_{A,B}$) in the same period.

$$P(A) = \frac{Output\ A}{Input\ A} = \frac{y_A}{x_A} \quad \text{and} \quad P(B) = \frac{Output\ B}{Input\ B} = \frac{y_B}{x_B}$$

$$\prod_{A(t+1),A(t)} = \frac{P(A_{t+1})}{P(A_t)} \qquad \prod_{B(t+1),\ B(t)} = \frac{P(B_{t+1})}{P(B_t)} \tag{1}$$

$$\prod_{A,B} = \frac{P(A)}{P(B)} = \frac{y_A/x_A}{y_B/x_B}$$

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. Take the case of 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.

$$
\begin{aligned}
P(A) &= \frac{Y_A}{X_A} = \frac{\omega_{o1} y_{1A} + \omega_{o2} y_{2A}}{\omega_{i1} x_{1A} + \omega_{i2} x_{2A}} \\
P(B) &= \frac{Y_B}{X_B} = \frac{\omega_{o1} y_{1B} + \omega_{o2} y_{2B}}{\omega_{i1} x_{1B} + \omega_{i2} x_{2B}} \\
\prod_{A,B} &= \frac{P(A)}{P(B)}
\end{aligned}
\qquad (2)
$$

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 (tonnes, 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 instead of monetary values. The literature in the field depicts a wide range of SFP and PFP indices. An example of a physical productivity indicator widely used in port operations is ship productivity, and is expressed as follows:

$$
\begin{aligned}
\textit{Ship productivity } (SP) &= \frac{\textit{Total Moves}}{\textit{Total Gross working time}} \\
SP &= \left(\frac{\textit{Total Moves}}{\textit{Total Gross Crane Hours}}\right) * \left(\frac{\textit{Total Gross Crane Hours}}{\textit{Total Gross Working Time}}\right) \\
SP &= \textit{Gross crane productivity } (GCP) * \textit{Crane intensity}
\end{aligned}
$$

Despite this, the relationship between variations in the number and type of physical indicators has been difficult to establish in the port industry. Furthermore, it seems that 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. More importantly, SFP and PFP measures are difficult to combine or aggregate. The problem with single and partial indicators is that under multiple-input and multiple-output port production, the concept of productivity measured by one or a subset of output–input volume ratios is 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 (TFP) because no account is taken of the quantities of other inputs and outputs.

1.4 Multifactor and Total Factor Productivity Indices

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

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:

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

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.

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

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

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

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
w_{mt} and $w_{m(t+1)}$ are the *m*th input cost shares in periods t and $t + 1$, respectively
w_{st} and $\omega_{s(t+1)}$ are the *S*th output revenue shares in periods t and $t + 1$, 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 such as the competitive characteristic of markets and the efficient behaviour of firms. 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 (MPI) constructed by estimating a distance frontier. The 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) proposed 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)). 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 (ie profit maximisation or cost minimisation).

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

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

Few studies have estimated or used a TFP index for ports. Early attempts were made by Kim and Sachish (1986) who proposed 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 economies of scale and technical change. Later, Sachish (1996) proposed a weighting mechanism of partial productivity measures while Talley (1994) suggested 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 and Ghosh (2003) used a TFP index to assess the total productivity growth in Indian ports over the period 1981–2003. Fewer studies exist in the literature on the application of the Malmquist index to port efficiency. Among these, Lui *et al.* (2006) applied the MPI to measure the productivity change of several container terminals in China during the period 2003–2004. Their MPI was decomposed into two sources of efficiency: technical efficiency (TE) change and technical change. Estache *et al.* (2004) decomposed further the MPI by adding a scale efficiency (SE) 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.

2 FRONTIER APPROACH

The frontier concept denotes the lower or upper limit to a boundary-efficiency range. Under this approach, a firm is defined as being 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.

Because OLS fails to construct a frontier, a function is estimated under corrected ordinary least square (COLS) and then moved so that all firms lie either on or above the cost frontier; or on or below the production frontier. Nevertheless, the efficiency frontier under COLS is parallel to OLS regression therefore implying that both frontiers depict the same structure. Furthermore, 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. This is because COLS specifies a one-sided distribution of the disturbance term, hence assuming that all the deviations from the frontier are due to inefficiency, but no account is taken for measurement errors or statistical noise.

The problems with OLS and COLS have led to attempts to construct a non-observable frontier constructed from a set of best obtainable positions. This has led to attempts to construct a non-observable frontier constructed from a set of best obtainable positions. This frontier can be either absolute or relative (best practice) depending on the method of parameter construction, respectively parametric estimation *versus* non-parametric estimation. In the simple example of one input and one output, Figure 7.1 depicts the main frontier approaches and how efficiency ratings differ from one approach to another.

The literature in the field depicts various efficiency concepts mainly TE, allocative efficiency (AE), SE and total economic efficiency (EE):

- Technical efficiency, 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 either because it is not using inputs in the proportions that minimise its costs or it is not producing outputs in optimal proportions to maximise its revenues, given 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 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.

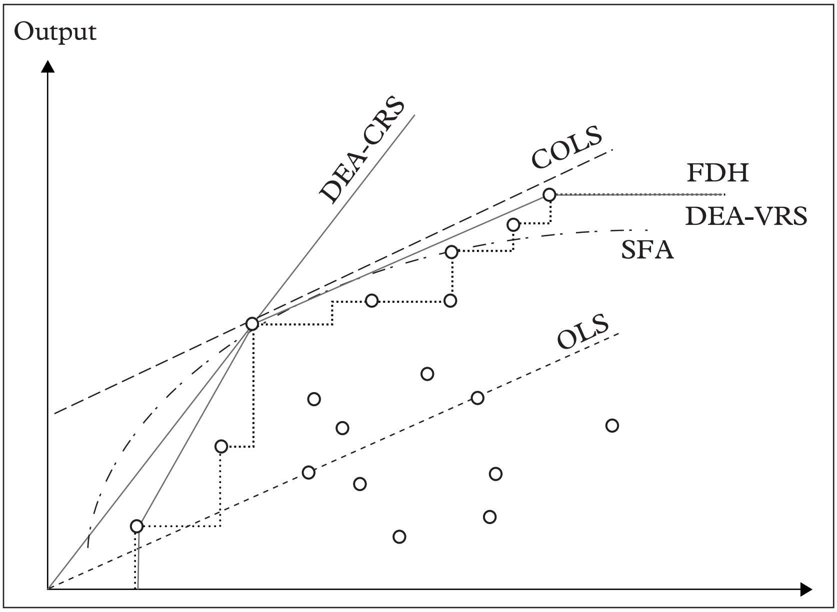

Fig. 7.1: Graphical illustration of frontier methodologies
DEA-CRS: data envelopment analysis (constant-returns to scale); COLS: corrected ordinary least square; DEA-VRS: data envelopment analysis (variable-returns to scale); OLS: ordinary least square; SFA: stochastic frontier analysis.

- Finally, SE reflects a firm's scale properties, ie 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 efficiency and benchmarking. *X-efficiency* applications for yardstick competition and benchmarking will be covered in Chapter 9. For a review of the port literature on this subject, the reader is referred to Grans and King (2003) and Defilippi (2004).

2.1 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) 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; Rekers *et al.*, 1990) and those estimating a cost function, be it single-productive or multi-productive (Jara-Diaz *et al.*, 2002).

Cost and production function presentations of technologies typically imply that firms are 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 for 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 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 an 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.

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

where:
U_n: TE component of firm (DMU) n
V_n: Statistical noise component

Among the numerous SFA applications to ports, worth mentioning is 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 depends 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 structures. 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 and 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.

2.2 Non-parametric (programming) approach

Unlike econometric models, non-parametric approaches do not require a predefined 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 DEA and the FDH. FDH is a non-parametric technique but differs from DEA by excluding linear combinations of production units from the analysis. Primarily, DEA seeks to measure 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 AE.

Assuming a set of $N(n = 1,2,\ldots,N)$ DMUs (decision-making units)[3] in the sample, each observation, $DMU_j(j = 1,2,\ldots,n)$, uses m inputs $x_{ij}(i = 1,2,\ldots,m)$ to produce s outputs $y_{ij}((r = 1,2,\ldots,s)$. The efficiency ratio of DMU_j can be defined as the ratio of its weighted sum of outputs over its weighted sum of inputs:

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

where:

x_{ij} and y_{rj} are the respective amounts of ith input and rth output consumed and produced by DMU j; while $\lambda_j(j = 1,2,\ldots,n)$ are non-negative scalars representing input and output weights such that $\sum_{j=1}^{n} \lambda_j = 1$.

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:

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

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).

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

In Equation (10), each DMU selects input and output weights that maximise 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. 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 $\sum_{j=1}^{n} \lambda_j = 1$.

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

The choice of orientation depends on the objective of benchmarking (input conservation *versus* output augmentation), and 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.

In the simple scenario of a single-input and a single-output, Figure 7.2 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 7.2, 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.

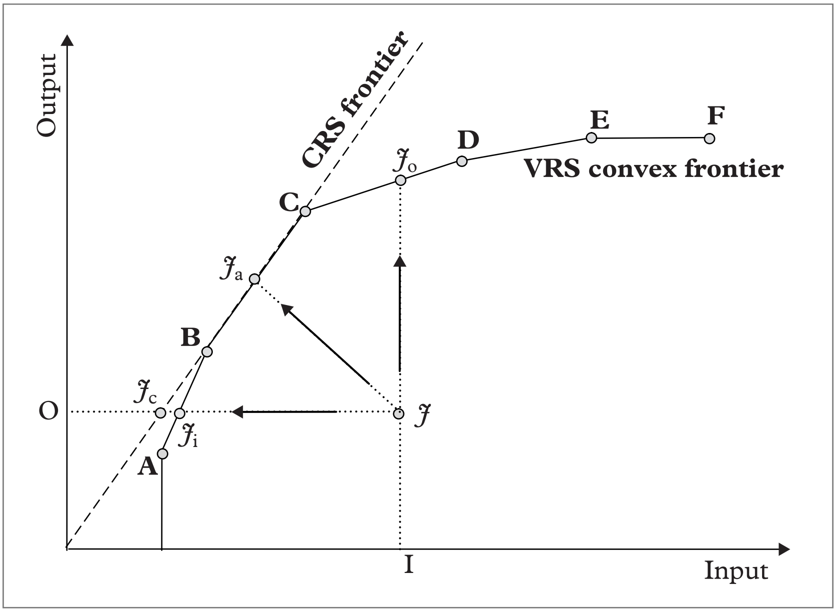

Fig. 7.2: DEA production frontier under the single input and single output scenario

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

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 7.3 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

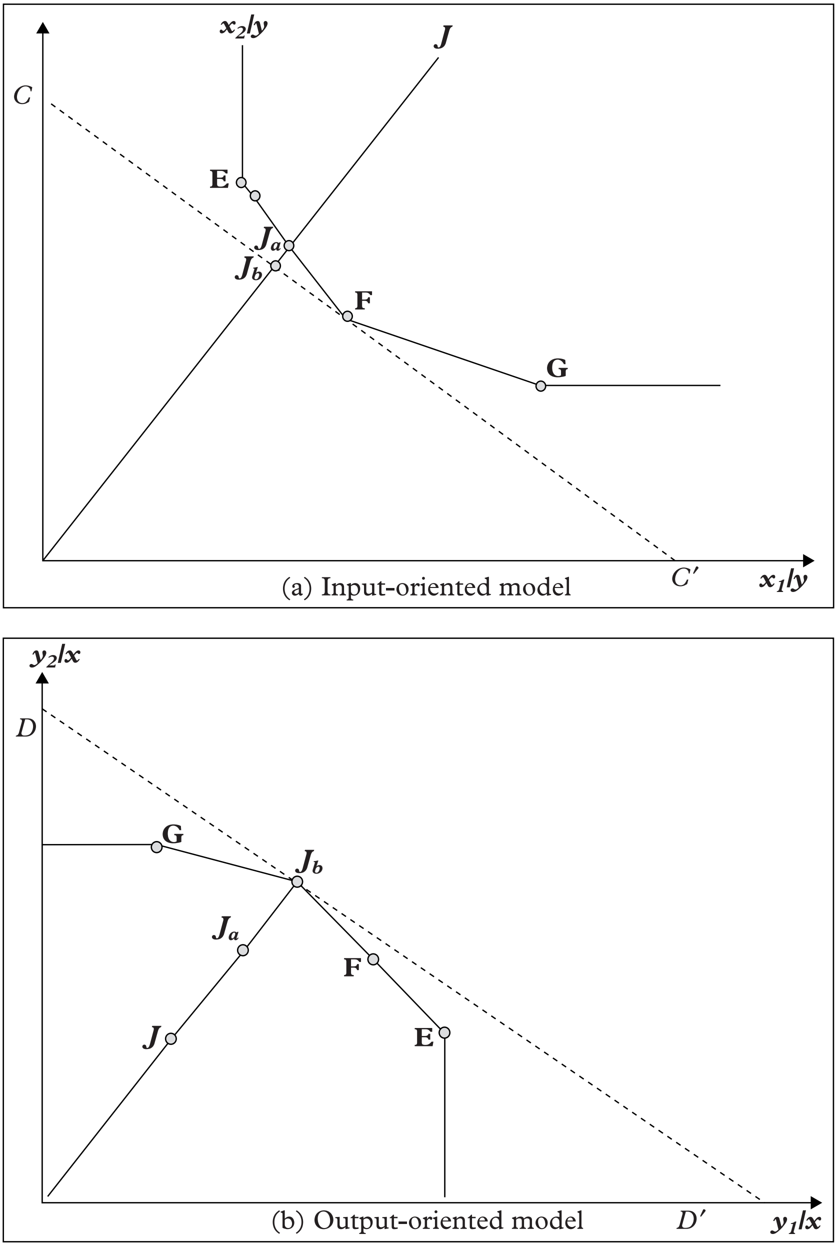

Fig. 7.3: (a) Illustration of DEA input orientation (excluding the effect of technological change). (b) Illustration of DEA output orientation (excluding the effect of technological change)

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.

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), 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 (Culinane *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, eg 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 academic interest in 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 of 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; 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).

2.3 Issues with Frontier Applications in Container-port Efficiency

Most applications of both parametric and non-parametric frontier methodologies to container-port efficiency have proved difficult and sometimes controversial with very limited discussions on the potential distortions stemming either from the limitations of the selected methodology or from the difficulty in modelling container-port operations. Some shortcomings of the frontier port literature are highlighted below:

- 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 benchmarking analysis is provided in Chapter 4.
- As for variable definition, only a few studies (eg Rios and Gastaud Mecada, 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 lacks clarity as to factors which should be included in the input set and those to be included in the output set.
- Even when variables are clearly defined, researchers tend to exclude other port services (eg 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, overlooking 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).
- In relation to 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 (eg terminal size) and output (eg number of containers to be handled) bundle under his control. Despite this, 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.

- Traditionally, most port benchmarking studies focus 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, ie a 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; Lui *et al.*, 2006; Bichou, 2009).
- 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 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 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 (eg 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 input and output, but this is hardly performed in the port literature.
- 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, the variations in production technology and handling configurations across container terminals (see Chapter 4) 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 (eg 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; Bowlin, 1997). Despite this, 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 (eg Wang and Cullinane, 2005; Cullinane *et al.*, 2005, 2006) do not satisfy the positivity property with regard to variables with zero inputs, and such assessments are likely to show DMUs with zero-inputs as being more artificially efficient than they are:

- 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.
- Another drawback of much of the port literature is that only TE 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 (eg Yan *et al.*, 2007) have attempted to calculate AE 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-mentioned deficiencies 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).

3 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.

3.1 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 optimisation-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).

3.2 Engineering and Process Benchmarking Methods

Engineering and process benchmarking is a modelling and process-oriented exercise for assessing internal or 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.

3.2.1 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 optimisation 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, see Chapter 6.

3.2.2 Process benchmarking

Benchmarking is a tool for improving performance by identifying and learning from best practice in relation to both the products (and services) and the processes by which those products and services are created and delivered. The search for best practice can take place inside a firm (internal benchmarking), within a particular industry (functional benchmarking), and/or in other industries (external benchmarking). Other types of benchmarking include performance or competitive benchmarking (assessing relative performance vis-à-vis others), strategic benchmarking (realignment of business strategies), and process benchmarking (assessment of key processes vis-à-vis others).

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). The latter is composed of key measures which reflect the specific factors that are expected to drive

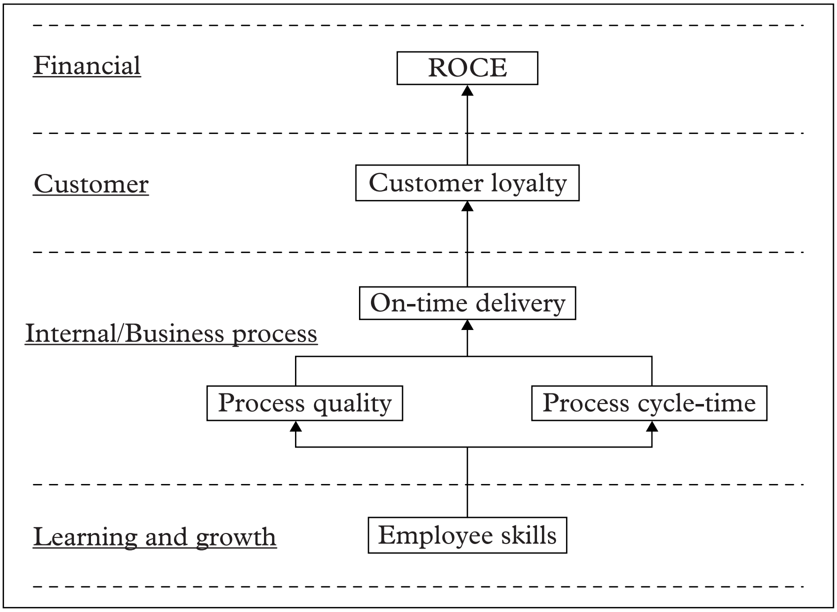

Fig. 7.4: Linear cause-and-effect BSC relationships (Kaplan and Nortan, 1996)

future performance. Kaplan and Norton's (1996) original BSC model includes both financial and non-financial measures through combing four dimensions of performance measurement: financial, customer, internal business processes, and learning and growth.

In 2008, Germanischer Lloyd, in cooperation with the Global Institute of Logistics, introduced 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 KPIs for measuring terminal's performance and includes four components: management systems, internal factors, external factors, and performance evaluation (KPIs). Terminals are scored on a 100-point scale and receive certification if they achieve 50 points or more. Analytically, the CTQI is reduced to a compilation of snapshot indicators which are weighted subjectively. As such, the CTQI fails to produce a productivity or efficiency index for ports' comparison and benchmarking.

4 CONCLUSION—BENCHMARKING METHODS

The above literature review on benchmarking techniques has shown that while there are advantages and disadvantages to each, the application of these

Table 7.2: Components and weighting of CTQI

Component	**Weight**
Performance	
Ship productivity > 750 moves	16
Gross crane productivity	14
Berth working index > 750 moves	14
Ship service quality index	20
Road service quality index, rail service quality index, barge service quality index	36
Internal factors	
Terminal superstructure	
Ship-to-shore equipment	16
Handling equipment	12
Truck handling, rail handling, barge handling	18
Barge service availability	2
Organisation	
Work organisation	10
Training	4
Inspection area	6
Failure response	2
Handling of reefer containers	2
Handling of IMDG cargo	2
Planning	11
Communication	15
External factors	
Rail connectivity, barge connectivity, road connectivity	60
Power supply	5
Data communication lines	5
Terminal operations restrictions	25
Maritime restrictions	5
Management system	
Mission statement	3
Appointment of CTQI manager	3

(*Continued*)

Table 7.2: Components and weighting of CTQI (*Continued*)

Component	Weight
CTQI manual developed and implemented	3
CTQI policy	3
Development and maintenance of a TOS	3
Document control/records kept	3
Determine responsibilities/authorities of relevant personnel	3
Performance of relevant training	3
Implementation of mandatory CTQI practices	3
Subcontractors and suppliers conformity	3
Claims/non-conformities/failures/customer complaints policy	3
Annual internal audits performed	3
Annual management review performed	3
Annual external audits	3

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:

- Fundamental disagreements on both the definition and port applications of performance dimensions, eg efficiency, productivity, utilisation, effectiveness, and so on.
- 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.
- Wide variations between the analytical specification of benchmarking models, including in the levels of economic disaggregation (macro *versus* micro levels), spatial scope (national *versus* regional areas) and temporal analysis (cross-sectional, time-series, pooled).
- Perceptual differences among multi-institutional port stakeholders (regulator, operator, user/customer, etc) and the resulting influence on the objective, design and implementation of performance and benchmarking frameworks.
- 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.

4.1 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. A valid performance metric should also be comprehensive and practical. It should be designed to capture all appropriate activities in the process with the purpose of guiding and influencing the decision-making process. Table 7.3 summarises the characteristics of good performance metrics.

A performance metric can fall within one or a combination of three main categories, namely input measures (eg time, cost, resource), output measures (eg production, throughput, profit), and relative or ratio measures (productivity, efficiency, effectiveness, 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.

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

Characteristics	**Description**
Quantitative	Can be expressed as an objective value
Easy to understand	Conveys at a glance what is measuring
Visible	Measures effects that are readily apparent to all involved in the process
Defined/understood	Defined and agreed to by all key process participants
Covers input/output	Integrates factors from all aspects of the process measured
Measures only what is important	Focuses on a key indicator that is of real value to managing the process
Multi-dimensional	Properly balanced between utilisation/efficiency/effectiveness
Effort economies	The benefits of the measure outweigh the costs of collection and analysis
Facilitates trust	The measure validates participation among the various parties

Table 7.3: Characteristics of a good performance measure (Keebler *et al.*, 1999)

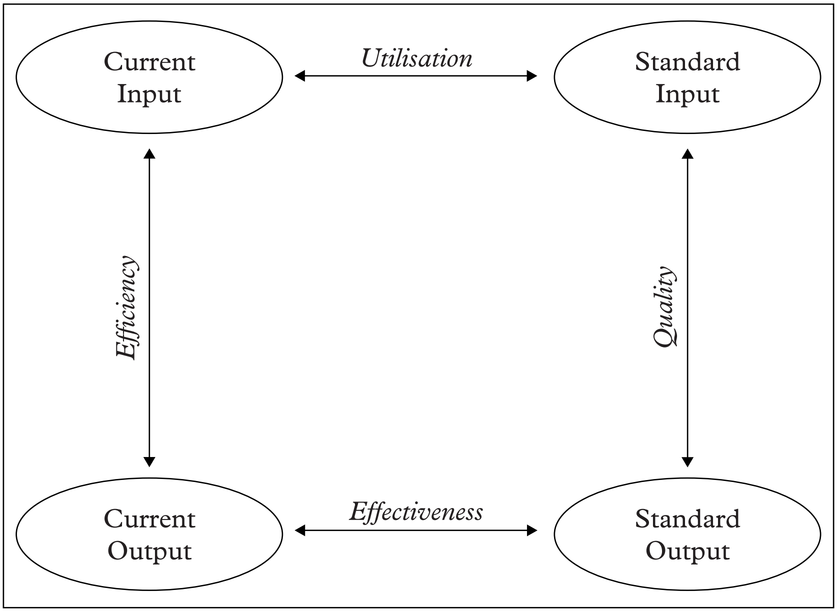

Fig. 7.5: Basic matrix of performance–ratio dimensions

engineering concept (relationship between the actual and the potential output of a process). A sample of the taxonomy of ratio–performance measurement dimensions is depicted below. The list in Figure 7.5 is for illustration only, and is neither authoritative nor exhaustive.

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 and management fields. Another significant issue is that the relationship between variations in the indicators and performance dimensions has been difficult to establish in the 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 productivity to ship

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	$\frac{Cummulated\ ST}{Unit\ Time\ (eg\ month)}$
	Dwell time (DwT)	$\frac{Units\ (eg\ tonnage) * Dwelling\ Time}{Units\ stored\ or\ stacked}$
Efficiency	Crane move	$\frac{Volume\ of\ cargo\ handled\ (eg\ TEU)}{Unit\ Time\ (eg\ hour)}$
	Labour productivity	$\frac{Volume\ of\ cargo\ handled\ (eg\ TEU)}{Total\ number\ of\ gangs}$
	Ship output	$\frac{Tonnage\ of\ cargo\ handled\ (eg\ TEU)}{Total\ worked\ hours\ per\ ship}$
Effective-ness	Work reliability	$\frac{Effective\ worked\ hours}{Scheduled\ worked\ hours}$
Quality	Punctuality ratio	$\frac{Total\ delayed\ time}{Number\ of\ calls}$

Table 7.4: Sample of port metrics and their corresponding performance dimensions

productivity. Furthermore, metrics such as ship service time and cargo 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.

4.2 Controllable Factors and Operating Procedures

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. Take for instance terminal configuration and capacity expansion factors, which are considered by most researchers as being controllable factors, 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 such as equipment and warehouses.

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 inter-modal facilities. Shipping lines that own and/or operate container terminals, including as dedicated facilities, are 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 of the port benchmarking exercise.

In a similar vein, operating and terminal procedures also impact port productivity. They 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.

4.3 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,

Controllable factors	Uncontrollable factors
• Service and port time/vessel queuing and waiting • Dedicated/priority berthing arrangements • Capacity development and expansion • Terminal layout and configuration • Terminal procedures (including safety and 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

Table 7.5: Controllable and uncontrollable factors in port operations and management

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, 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 7.6 draws on their discussion to link major approaches to ports with the corresponding performance benchmarking methods.

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		

Table 7.6: Various approaches to ports and their corresponding performance models (adapted from Bichou and Gray, 2005b)

4.3 Differences between Stakeholders' Perceptions

A significant issue in port operations and management is the complex interplay 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 in terms of service time at berth or total time in port. Another approach considers the regulator's (eg port authority) perspective in terms of socio-economic and regional development, but even port authorities may have 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) or Dubai Ports World (DP World), operates a range of port facilities worldwide, including its 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.

4.4 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 a port's core business 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 port benchmarking literature to provide stable and consistent results over time and across researchers. 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 integrative framework is therefore required.

CHAPTER 8

INFORMATION AND COMMUNICATION TECHNOLOGIES IN PORTS

Ports today operate in an environment marked by a high degree of operational complexity, service provision, stakeholders' interactions, and time-based competitive pressures. This creates the need for a fast and efficient exchange and processing of a vast amount of data and information between port stakeholders and community users.

Information and communication technology (ICT) is an extremely broad subject area that could be described as anything dealing with communications (radio, TV, phone, computers, fax, internet, etc) and in particular the handling and processing of information and data. In the context of this book, we define ICT, also referred to as Management Information Systems (MIS), as the system designed to collect and process data, and provide it to managers for use in decision making. An information system is comprised of all the components that collect, manipulate, and disseminate data or information. It usually includes hardware (computers, mobile phones, personal devices, CCTV, RFID, card readers, etc), software systems (device drivers, operating tools, programming tools, servers, etc) and applications (office suites, business software, databases and computer games), communication platforms (eg home networks, web services, intranet, extranet, internet), people and users, and the data itself.

There are many ways of categorising information systems used within a firm or across a network of firms and organisations. One definition is based on functional application domains such as operations, finance, human resources, etc. Another classification is based on the underlying technology or programming language used, for example file management, database management, C++, HTML and Visual Basic. These classifications have their limitations since many domains or technologies can be embedded in a single information system. A good way to classify information systems is in terms of their intended scope, hence three types of information systems: local information systems, functional information systems and enterprise information systems. In this chapter, we review major port MIS and ICT applications in ports focusing in particular on emerging technologies for terminal operations and management.

Information	Categories
Product	Ship (ETA/ETD, vessel characteristics, stowage plan, etc), Cargo (type, categories, handling and storage requirements, etc), truck/rail (arrival schedule, delivery order, etc)
Community	Customers and users (shipping line, inland carrier, agent, consignee, freight forwarder, etc), stevedores and terminal operators, port authority, customs, etc
Process	Processes and documentation, work and safety rules, legal and security procedures, etc
Inventory	Equipment and vehicles, workforce, terminal and yard capacity, etc
Operations	Resource allocation, traffic and navigation, terminal planning (ship, berth and yard), vessel control, cargo management, gate operations, etc
Management systems	Billing and invoicing, equipment maintenance, statistics and analysis, performance and productivity, quality, customer satisfaction, etc
Competitors	Competitive offerings, market share, benchmarking, market research, business intelligence, etc

Table 8.1: Summary of information categories used in port operations and management

1 SOFTWARE AND COMMUNICATION PLATFORMS

1.1 Electronic Data Interchange (EDI)

EDI is essentially a computer-to-computer exchange of business and administrative documents in a standard electronic format between two or several organisations. EDI is also used to refer to the standards used for data interchange and to the operating systems that create, transfer and receive these data. Web-based EDI generally refers to the use of XML (Extendable Markup Language) to deliver the EDI through the internet, but information exchange can also take place using virtual private networks (VPN).

The main barrier to EDI is an agreement on common global standards and protocols. The main global standard in use is the UN/EDIFACT (the United Nations or Electronic Data Interchange for Administration, Commerce and Transport). Other standards exist for specific regions or industries, for instance the American National Standards Institute (ANSI) X12, the ODETTE (Organization for Data Exchange by Tele Transmission in Europe) standard used within the European automotive industry, and the TRADACOMS (Trading

Benefits of EDI
• Quicker information processing and access • Reduced errors in data entry and transmission • Better customer services • Reduced clerical and paperwork costs • Improved communications and information management • Increased productivity • Improved tracking, tracing and expediting • Improved billing • Reduce (or eliminate) corruption

Table 8.2: Benefits of EDI

Data Communication) (UN/GTDI) standard which is predominant in the UK retail industry.

The main utilisation of EDI in ports is in Port Community Systems (PCS), a system or an entity that delivers relevant data and information to port community stakeholders (users and customers). It is difficult to provide an exact description of PCS as these differ from port to port—see for instance Hamburg's Dakosy, Rotterdam's Info-link, the ADEMAR-Port system used in French ports, and the e-modal system used in a range of US ports and terminals. However, most modern PCS use central databases which store and structure messages (management systems) from where users can access information using authentication, authorisation, password-based and other security tools. Depending on the type of agreement between users and the range of information exchanged, modern information exchange models can either by centralised or decentralised depending on whether one or several service providers and exchange brokers are used.

1.2 Terminal Operating Systems (TOS)

Terminal operating systems (TOS) are purpose-built software products used for the planning, execution and control of terminal operations. Most commercial TOS are organised in terms of separate functional modules such as yard and vessel planning, loading and unloading operations, gate control systems, and EDI systems for information exchange with customers and outside institutions. TOS are either developed in-house or bought off-the-shelf and can offer powerful optimisation and integration tools for both terminal planning, management and control. NAVIS (Zebra), COSOMS, and CITOS software products are the most widely used commercial applications for container terminal planning and management with full interoperability, flexible data transfer, and user-friendly graphical interfaces.

Document	**Usage**	**Sender**	**Receiver**
CALINF	Call information	Carrier or agent	Terminal
BAPLIE	Bay plan	Carrier/agent (terminal)	Terminal (carrier or agent)
COLDLT	Container loading list	Carrier or agent	Terminal
MOVINS	Stowage/load instruction, including restow	Carrier or agent	Terminal
COPRAR	Load/discharge order	Carrier or agent	Terminal
COARRI	Load/discharge report	Terminal	Carrier or agent
VESDEP	Vessel departure	Terminal	Carrier or agent

Table 8.3: EDIFACT messages used in planning berth and loading–unloading operations

1.3 Enterprise Resource Planning (ERP)

ERP is basically a collection of applications designed to process and integrate operational and management functions of a firm using a common architecture that links the firm to both customers and suppliers. ERP has evolved from earlier MRPI (materials' requirement planning) and MRP II (manufacturing requirement planning) applications for planning and control to include non-operational functions such as accounting and finance, customer resource management (CRM), and human resource management (HRM). The aim is to provide instant access to timely information and better visibility across operational areas, leading to improved efficiency. In the past decade or so, ERP systems have become extremely popular owing to their ability to integrate application modules and make data accessible throughout the enterprise.

A key feature of ERP is that the software is integrated around a common user interface and around a shared database so that data can be shared between different applications. Another key feature is the modularity of the software allowing users to choose the application(s) they want to process. Figure 8.1 presents the generic architecture of an ERP system. ERP systems act as the informational hub integrator linking together all such operations, with spokes to other "bolt-on" (or application-specific) systems, and provide specialised functionalities such as customer relationship management. From a supply chain perspective, ERP allows a firm's internal system to be integrated within the entire supply chain by providing a platform that allows informational flows to be exchanged across the different departments of the firm, and between the firm and other supply chain members. Currently, there are two main ERP software vendors: SAP and Oracle. Most applications in ports seek to integrate TOS and planning software into ERP systems.

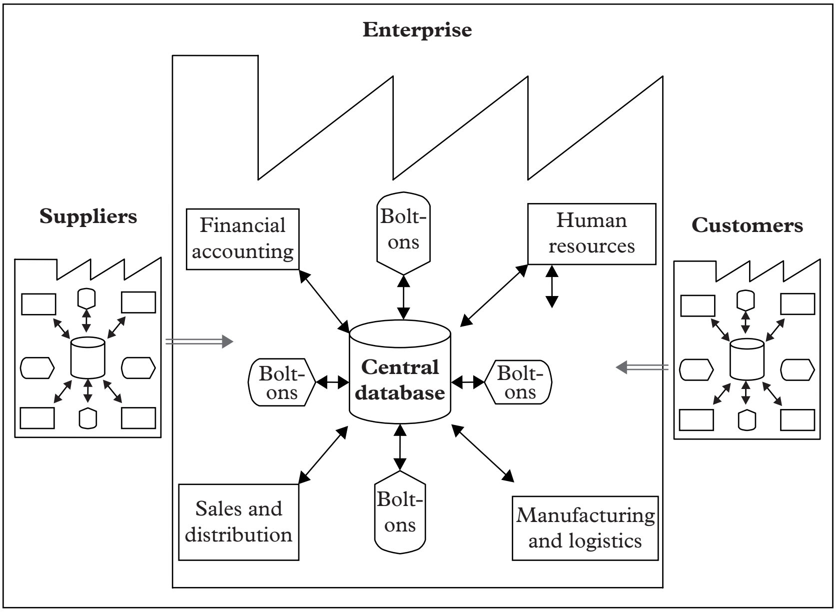

Fig. 8.1: Generic system architecture for an ERP system

2 AUTOMATIC IDENTIFICATION AND DATA CAPTURE

Automatic identification and data capture (AIDC) is the broad term given to a diverse family of technologies that are used to help machines identify objects, capture information about them and store this information into a computer without human involvement. Technologies under the umbrella of AIDC include bar codes, card technologies, voice and vision recognition, biometric technologies, optical character recognition (OCR), optical mark reading (OMR), and radio frequency identification (RFID) systems.

Many of the above technologies and others are being used across different areas of port operations and logistics, but the most widely used technologies may be classified into four main categories: cameras and OCR, card technologies, positioning systems, and radio frequency equipment. Most of these technologies offer suitable interface with both EDI and TOS systems.

2.1 Cameras and OCR

The CCTV cameras installed in port and terminal areas are probably the first and most widely operated automated system aimed at the efficient control and monitoring of terminal assets and transaction processes, especially for claim handling, safety and security purposes.

Fig. 8.2: OCR gate portal

Optical Character Recognition (OCR) is a new breed of digital imaging technologies originally designed to read and scan stylised text on documents and tickets.

Typical applications of the OCR technology in terminal operations and management involve the deployment of digital cameras within specific portal structures such as crane equipment and gate lanes. Crane OCR systems are used for identifying container numbers, stow positions, and equipment type code while gate OCR portals are mainly used for reading container numbers, chassis and truck license plates. Modern OCR systems offer image archival and review and the ability of integration and data exchange with TOS and other terminal software and equipment. Other OCR systems have an in-built radiation scanning technology which provides a suitable solution for container handling while safeguarding against the threat of radiation and terrorism. Elovic (2003) provides a summary of OCR uses and benefits in container terminal operations.

2.2 Card Technologies

Card technologies are mainly used to provide access and may be categorised into magnetic stripe, smart and optical cards. Common applications in port and terminal management include access control and identity checks for port workers and truck drivers. Several ports and terminals have introduced

Description	OCR elements	Benefits
Portal gate	Container, LPR (truck plate) and chassis (optional)	Increased throughput and productivity, as well as accuracy in data entry; reduced operating costs. Container number can be identified at downstream pedestal gate by LPR or chassis alone
Pedestal gate	Container, LPR and chassis optional	Increased throughput and productivity, as well as accuracy in data entry. Reduced operating costs
Gate with damage inspection	Container, chassis and LPR (optional)	Archiving of container images for evidence of container condition at terminal entry and exit gates
Quay crane	Container	Increased throughput and productivity, as well as accuracy in data entry; reduced operating costs
Quay crane with damage inspection	Container	Archiving of container images for evidence of container condition at shore entry and exit cranes
RTG	Container	Tracking of container position as it is handled and stacked in yard
Container handling equipment	Container	Tracking of container position as it is moved from one vehicle to another
Crane loading	Truck-LPR	Can automatically identify incorrect containers before handling by crane
MIV	Container	Automatically updates yard inventory; reduced operating costs
Rail portal	Container	Automatically reads and records container inventory at rail station points; reduced operating costs and trackside personnel

Table 8.4: OCR uses and benefits
Source: Elovic (2003).

Fig. 8.3: A self-handling gate kiosk

comprehensive ID card systems such as Cargo-card in Rotterdam and Alfa-pass in Antwerp, but the most comprehensive scheme to-date is the US Transportation Worker Identification Credential (TWIC) programme whereby port workers and all other personnel requiring unescorted access to US port facilities must have a TWIC card. The cards are tamper-resistant biometric credentials which use biographic and biometric information data and contain the applicant's photograph and name, an expiration date, and a serial number. To obtain a TWIC, individuals must also pass a security threat assessment conducted by the US Transport Security Administration (TSA).

Another practical application of smart cards in ports is the driver's gate kiosk concept. Gate kiosks are widely used in the USA and allows for driver's self-handling and automated processing of gate transactions based on pre-booking and paperless customs procedures.

2.3 RFID

Radio frequency identification (RFID) is a generic term that is used to describe a system that transmits the identity of an object using radio waves. An RFID system offers high-speed and remote electronic identification of equipment.

A standard RFID structure consists of a tag (or transponder), which has a unique code or serial number, and is located on the object to be found or tracked, and a reader (sometimes referred to as a programmer or interrogator) which is used to retrieve the data stored on the tag. A typical reader, which can be either fixed or mobile, is a device that has one or more antennas that emit radio or electromagnetic propagation and receive signals back from the tag. The reader then passes the information in a digital form to a computer system through the savant or middleware, the latter is the generic term used to describe the software that resides between the RFID reader and its applications. There are three main types of RFID tags: active, semi-active and passive. Active tags contain a battery to boost the reading range. Passive tags do not work with a battery but are powered by electromagnetic radiation generated by reader antenna. Semi-passive tags can work with both battery and wave generators.

RFID technology has been used extensively in port operations for automatic data capture and storage. Areas where RFID can be most useful include access control, cargo identification, location and tracking, and cargo and port security.

Active RFID	**Passive RFID**
– Wide range (up to 100 m) – Battery – More storage of information (up to 32 Kb) – HF or UHF (over 100 MHz – typically 455 MHz, 2.45 GHz, or 5.8 GHz) – Used for tracking	– Short range (up to 2 m) – No battery – Less storage but much more than bar code (2 Kb) – LF or HF (usually 13.56 MHz) – Used for identification with proximity card, warehouse management

Table 8.5: Types of RFID tags

Usage of RFID
• Monitor container security and integrity • Verify that a container was loaded at a secure loading point • Reduce the likelihood of tampering • Gather enough data to conduct a virtual inspection in advance of arrival • Container security and control • Ensure exact location of containers • Tracking and tracing • Minimise the overall cost

Table 8.6: Usage and benefits of RFID tags

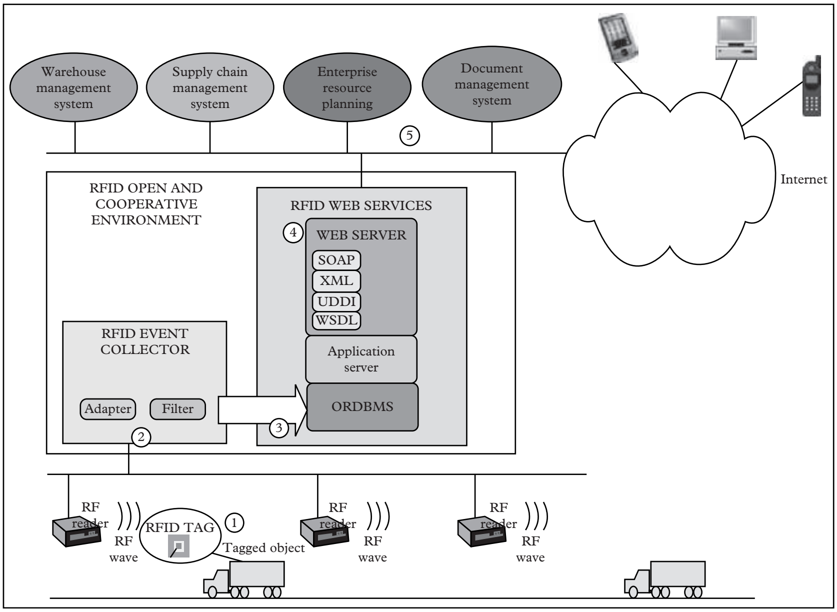

Fig. 8.4: Typical RFID architecture in terminal management

Typically, RFID tags are attached to containers while readers are installed in mobile equipment such as stackers or fixed areas such as gate entry lanes. A wireless LAN system is installed in the container yard or depot, which allows the reader to communicate with the backend system.

CHAPTER 9

PORT COMPETITION AND MARKETING

1 FEATURES AND ELEMENTS OF PORT COMPETITION

Historically, seaports used to be the exclusive gateway of their hinterlands. Earlier port selection was a dependent choice of seaborne trade and freight flow origins and destinations. Furthermore, ports were controlled and managed by public institutions that not only provided substantial financial resources and subsidies, but also secured regulatory and trade protection against non-local and foreign port competition. Within this context, ports enjoyed a high degree of monopoly with limited scope of competition and rivalry.

Over the last three decades or so, competition among world ports has increased dramatically in both scope and nature, owing to several factors such as growing deregulation and privatisation practices, the globalisation of commerce and trade logistics, and the development of transport and cargo-handling technologies. Today, port markets are contested by a range of competing ports and other transport suppliers, each offering an alternative for shippers, shipping lines and logistic intermediaries. Furthermore, as competition between global carriers and logistics providers increases, so does the rivalry between seaports and other potential competitors.

The growing consolidation practices and the rise of global port operators generate a high degree of concentration in the port industry, which is often associated with monopolistic behaviour and technological lumpiness. When there is a risk of monopolistic behaviour, governments and port authorities can stimulate competition in various ways. In the case of public ownership, the port authority should move away from the public-service model to the landlord model, where it retains ownership of the basic infrastructure but divests itself of managerial and financial responsibility for commercial facilities. In the case of private ownership, governments and port authorities should aim to limit the number of dedicated operations in favour of common-user port operations. Notwithstanding the terms of the public-versus-private port ownership, restrictive working practices and barriers to entry should be removed in favour of free competition and price/service deregulation.

Through the different stages of port development, port competition has shifted from a cost-centred competition to a competition for faster, better and more cost-effective access to international markets. During the period when global transport chains were still fragmented, uncoordinated and inefficient, port competition was mainly driven by cost. Later on, following the process of trade globalisation and the rise of emerging economies, port competition has shifted towards trade-offs between cost and quality of service. Location and port charges remained important competitive factors but the aspects of port efficiency and reliability, quality of port infrastructure, range of port services, frequency of shipping services, and connectivity to trade routes became important factors as well. Today port competition is moving to a further level: ports are competing not only on the basis of internal strengths and weaknesses, but also on the basis of the efficiency and quality of port links with external supply chain partners and by the performance of all supply chain partners. The objective is to overcome traditional arm's-length arrangements and seek co-operation, synergies and converging interests between different players in the port supply chain in order to guarantee efficiency and reliability and deliver competitive advantage throughout the supply chain.

1.1 Market Structure and Forms of Port Competition

While ports themselves may have natural monopoly characteristics, this is less so for many of the services provided within them. In Chapter 1, we pointed out the multi-product character of ports, which creates scope for unbundling and competition. A case in point is the example of towing and related services, where most of the capital costs relate to tugs. As there is an active international market for tugs, these may be bought, sold or leased quite easily. Since the cost of acquiring a tug is not a significant barrier to entry, towing is a contestable activity.

Unbundling in the port sector generally follows a thorough analysis of market structure and of the costs and benefits of introducing competition and reform. Unbundling can take the form of either a horizontal separation or a vertical separation. The horizontal separation consists in dividing geographically a port monopoly, such as a national port authority or a port with several

	Excludable	Non-excludable
Rival	***Market Goods***	***Open-Access Resources***
Non-rival	***Toll Goods***	***Pure Public Goods***

Fig. 9.1: Markets, products and competitive dynamics

container terminals, into separate companies, which may either retain a geographic monopoly or compete directly in the market. The vertical separation consists of breaking up a port monopoly into several activities or functional components, for instance nautical versus cargo handling activities, or infrastructure versus superstructure services.

Today, ports face growing competition both within and outside the port sector, resulting in different forms and levels of port competition. *Competition for port markets* (freight and/or passengers) involves a process of competitive tendering for the award of port concessions and franchises. Sometimes, licensing requirements limit the number of competitors for each service which may reduce the competition for port markets to a *competition for the exclusive right to provide services*. On the other hand, *competition in port markets* can be seen either as inter-port competition or as intra-port competition:

- *Intra-port competition* between terminal operators. This model requires the port to be large enough to justify the existence of several terminals of similar traffic type. When intra-port competition between terminal operators is not feasible, *intra-port competition between service providers* may take place in areas such as stevedoring, warehousing, and forwarding.
- *Inter-port competition* in the form of direct competition between ports situated in a shared range or hinterland where major shipping lines are adept at playing one port against another. Inter-port competition also involves the competition between port ranges when multiport, transhipment and feeder ports are used, as well as the competition between inter-modal systems when ports are in direct competition against inland transport systems such as land-bridges. Inter-port competition may also be extended to the competition between port supply chains where the competitive position of a port depends on planning and strategic decisions of supply chain members using them.

Where there is competition in the market, the government's role may be limited to ensuring proper market regulation so that the market functions properly. Where there is a monopolistic supplier, the government may introduce competition for the market through designing, managing and organising competitive bidding between the potential suppliers of port services. Yardstick competition may also be introduced in order to oversee the operations of regulated port operators and benchmark their technical and allocative *X*-inefficiencies. The fundamentals of X-efficiency and allocative efficiency and their methods of measurements are described in Chapter 7.

The nature of competitive policies depends also on the size of the port and on the type of traffic and commodities handled. For large ports, inter-port competition may take place between different terminals and facilities. In single terminal ports, it is possible that intra-port competition may take place between different berth/quay operators. For smaller ports, where neither multiple terminals nor multiple-terminal operators are possible, competition can be stimulated by introducing short-term operating leases or management contracts. In a similar vein, competition is easiest to achieve for general cargo, small scale bulk and multipurpose operations, and automotive and Ro-Ro operations. It is most difficult to achieve for liquid bulks such as LNG and dry bulks such as coal because of the requirement of special equipment and economies of scale.

1.2 Generic Competitive Strategies

In order to compete successfully, firms must develop competitive strategies that strengthen their market share and position vis-à-vis rivals and achieve above-market average profitability. There are two basic types of competitive advantage a firm can pursue: low cost and differentiation.

1.2.1 Overall cost leadership

The objective of this strategy is to become the low overall-cost producer in the industry. In seeking to achieve overall cost leadership, a company may pursue a variety of strategies ranging from tight control of cost drivers to under-pricing tactics. Sources of cost advantage include scale economies, low salaries, tax exemptions, preferential treatment, proximity to customers and suppliers, proprietary technology, and other factors. Examples of cost leadership in ports

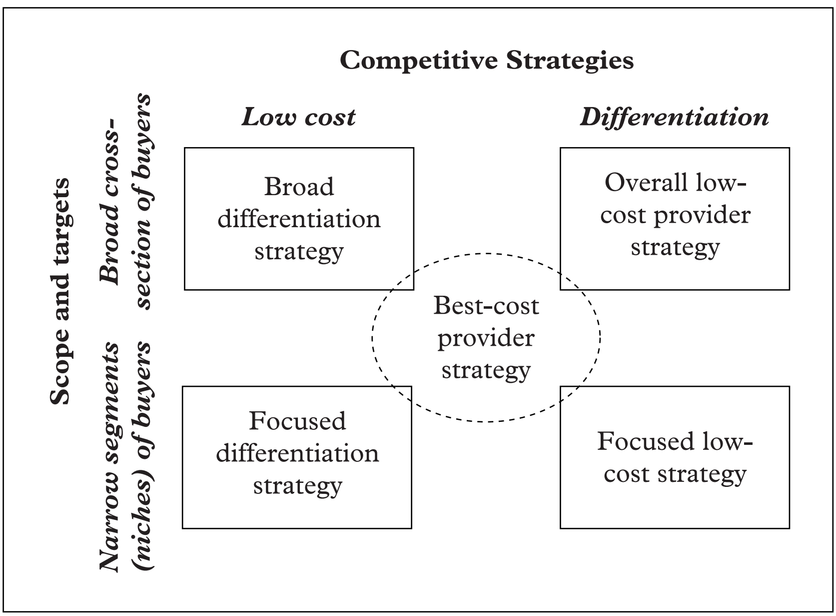

Fig. 9.2: Generic competitive strategies

include proximity to cargo sources and destinations, proximity to transport routes (both maritime and inter-modal routes), integration with other transport modes (door-to-door pricing rates), economies of scale, fast turn-around, and low tariffs and port dues.

Low cost strategy is most successful where buyers are price-sensitive and there are low switching costs and there is limited scope for differentiation. The main advantage of this strategy is that lower costs protect companies against the bargaining power of customers. On the other hand, low cost strategies can sometimes be detrimental as companies become too fixated on cost reduction and control while ignoring the changes in product design and technology, under-investing in marketing, research and development, and overlooking the importance of quality of service, safety, security, and other factors.

1.2.2 Differentiation

The basis of this strategy is to create something unique that will establish a clear distinction from other competitors' products and services. Sources of competitive advantage through differentiation include brand image, technological leadership, prestige, customised products, quality and reliability, superior service, etc. Differentiation allows firms to command a premium price, build a brand loyalty, and lower sensitivity to price; but this strategy can also be risky when customers sacrifice brand and loyalty to low cost products. Examples of differentiation strategies in ports include services to special cargo and vessels, dedicated terminals, depth of access channels, recognised security standards and quality assurance programmes (good compliance with the ISPS code, ISO series, etc), free-port and export processing zones, and value-added logistics activities.

1.2.3 Focus

This is a relatively new strategy in the port sector. It can be achieved when a port tries to create niche markets or serve a specific customer. Through specialisation, the level of improvement and know-how in a particular traffic or operation becomes higher, thereby reducing operating costs and enlarging the port's portfolio of captive customers. However, this strategy may yield opposite results if loyalty is not assured, in situations of seasonal fluctuations, or when competitors successfully specialise in the same niche of the market.

1.3 Strategic Positioning

One of the fundamental strategic problems of firms is how to position themselves in those markets in which they can achieve the maximum competitive advantage. Strategic positioning looks at ways in which a firm can outperform its rivals either by performing different activities or by performing the same activities but in different ways. It is different from operational efficiency which focuses on the benchmarking of firms undertaking similar activities. Several tools have been developed for understanding the competitive dynamics of an industry and conducting strategic positioning analyses for a firm and its environment.

1.3.1 SWOT analysis

Competitive strategy must be built through identifying the sources of competitive advantage. SWOT is an abbreviation for Strengths, Weaknesses, Opportunities and Threats, and denotes a widely used approach for auditing the overall strategic position of a business and its environment. Strengths and weaknesses focus on the internal factors while opportunities and threats focus on external issues. Needless to say that SWOT analysis can be very subjective but focus groups and factor-weighting criteria can be used to increase the validity of the methodology. These techniques can also be used in conjunction with other tools for audit and analysis, such as Porter's five forces analysis, PEST analysis, ANSOFF analysis, portfolio analysis and the BCG matrix.

1.3.2 Porter's five forces model

Porter's (1980) generic forces model is widely used to assess the competitive intensity and attractiveness of a firm based on five competitive forces; two from vertical competition: the bargaining power of suppliers and the bargaining power of customers; and three from horizontal competition: threat of entry, threat of substitution, and rivalry between competitors. Governments and the public (eg pressure groups) may be considered as a sixth force.

Strengths and weaknesses	***Opportunities and threats***
• Location • Nautical constraints • Hinterland connections • Assets • Port and distribution costs • Manpower • Performance and efficiency • Experience and know how • Adaptability and resourcefulness • Value added services	• Market identification • Assessment of port customer's value chain • Technological assessment • Legal and regulatory assessment

Fig. 9.3: Key factors in a SWOT analysis of ports

Threat (and barriers) of entry

New entrants to an industry can bring additional resources and capacity and raise the level of competition. The threat of new entrants largely depends on the barriers to entry. Examples of entry barriers in ports include:

- *Economy of scale* is a barrier of entry for many port operators in that it forces new competitors to face the entrance in a large scale. In port markets with significant economies of scale (eg the container-port industry), new competitors with small-scale operations may incur a cost disadvantage.
- *Cost advantage independent of scale* include such aspects as proprietary and product technology, favourable location, know-how, quality assurance, and learning curve.
- *Capital requirements* are another barrier to entry. New players in the port industry must invest large amounts of financial resources in areas such as infrastructure, equipment, and technology. Furthermore, given the high entry costs, there is limited scope for new entrants to break into port markets. This is particularly the case in the container port market where growing concentration and consolidation practices have led to the emergence of global container terminal operators and the risk of oligopolistic behaviour on the back of confirmed network and scale economies, growing market power, free-riding practices, and the inclination to create surplus capacity.
- *Customer loyalty* can be a barrier to entry for new players who have to compete against established competitors with a large loyal customer base and a strong brand image. The growing number of dedicated terminal infrastructure reflects the port's commitment towards premium shipping lines with the objective of increasing their loyalty and reducing the risk of footloose mobility. However, this may discourage other customers from using port facilities.
- *Contractual and restrictive arrangements* such as in the case of dedicated terminals and exclusive agreements for the provision of port services.
- *Vertical integration* such as in the case of services bundling when, for instance, a terminal operator performs other related business interests such towage, ship agency work, container lashing, off-dock storage, container trucking and container repair. Vertical integration also occurs when shipping lines own and/or operate ports and terminals, hence acquiring market power and discouraging independent new entrants.
- *Switching cost* is the cost incurred by the buyers who switch from one supplier (eg a port) to another. The higher the switching cost, the higher the barrier of exit of suppliers, and consequently the barrier to entry for new competitors. Some segments of the port industry have significant switching costs because of the requirements of specialised equipment, new technology, high exit fees, etc.
- *Distribution channels and network effects* may prevent new competitors to enter port markets where exiting players have a direct access to waterways

and inland distribution systems as well as an established network of port customers and users.

- *Government policies* are also an important barrier of entry into the port market. Governments can establish a statutory port monopoly, require licences and permits for service operation, provide subsidies to local and national operators, prevent foreigners from investing in port markets, impose capital and labour requirements, or simple delay the planning and approval process of port projects.

Threat of substitution

This refers to the extent to which port customers can substitute a port with another but also with other competitors such as the inland transport system (elasticity of substitution). Shipping lines, shippers, and global terminal operators often play-off ports, and even regions, against each other. Customer loyalty, switching costs, and government policies are key factors that influence the threat of substitution. Sometimes, excessive barriers of entry in one port can constitute a source of competitive advantage in another. For instance, in a country where the approval process of port projects takes an unreasonably long time, carriers and operators may be tempted to invest in or divert the traffic to another port, possibly in a neighbouring country, consequently causing all positive external effects to be lost.

Bargaining power of buyers and suppliers

Port buyers (customers) may have a strong bargaining power over ports under the threat of footloose mobility. This is particularly true in the case of standardised port services (commoditisation) and in situations where few buyers (eg ocean carriers) dominate the market and threaten to integrate into the industry by owning and/or operating their own ports and terminals. On the other hand, the suppliers of port services such as tug operators, stevedoring and cargo-handling companies, labour and workforce, and so on can also exercise strong bargaining powers over ports and port authorities. Following the process of internationalisation and consolidation of the container-port industry, few dominant terminal operators have emerged with considerable bargaining power vis-à-vis port authorities.

Rivalry between competitors

This denotes the intensity of competition between port incumbents. While certain port assets and activities are characterised by non-rivalry, and sometimes by non-excludability, others are not. Factors that influence industry rivalry include switching costs, differentiation, the structure of industry costs (eg fixed vs variable costs), and levels of exit barriers.

1.3.3 PEST analysis

The objective of PEST (Political, Economic, Social and Technological) analysis is to identify the external factors that could influence the strategic development of a business and develop responsive strategies to these influences. Table 9.1 lists some factors that could indicate important environmental influences for a business under the PEST headings:

1.3.4 ANSOFF matrix

The ANSOFF product/market matrix is a tool designed to help businesses decide about their product and market growth strategy. The approach suggests that a business' attempt to grow depends on whether it markets new or existing

Policy/legal	Economic	Social	Technological
Environmental regulation and protection	- Economic growth (overall; by shipping or port sector)	- Income distribution, disposable income and savings	- New technology (eg automation), - Government spending on research & development
Government policy and taxation	- Monetary policy (interest rate, exchange rate, devaluation) - Fiscal policy and subsidies - Consumer protection	- Life-style changes - Education and training of workforce - Employment law - Salaries and remunerations	- Incentives to innovation and technological efforts - Energy use and costs
International trade regulation	- Trade barriers versus deregulation - Globalisation of markets	- Labour and social mobility	- Technology transfer and penetration
Competition regulation	- Market regulation - Price control - Yardstick competition	- Living conditions - Goods' affordability	- Technology as a barrier - Impact of changes in Information technology

Table 9.1: Main components of PEST analysis

products in new or existing markets. Depending on which market-product combination is used, the output from the matrix is a series of suggested growth strategies (market penetration, market development, product development, and diversification) that set the direction for the business strategy.

1.3.5 Product portfolio analysis (PPA)

The business portfolio is the collection of businesses and products that make up the firm. Product portfolio analysis (PPA) analysis combines the measurement of market shares, growth rates and diversification. There are several methods for portfolio planning and analysis, the most cited of which is the business-consulting group (BCG) matrix, also called the growth-share matrix. The BCG methodology combines the measurement of actual industry market share for each of the firm's strategic business units (SBUs) with related growth

	Existing products	New products
Existing markets	***Market penetration***	***Product development***
New markets	***Market development***	***Diversification***

Fig. 9.4: ANSOFF matrix

		Market share	
Market growth	High	***Question marks***	***Stars***
	Low	***Dogs***	***Cash cows***
		Low	High

Fig. 9.5: BCG matrix

rates by identifying four distinct market positions. In ports, an SBU can be conceived as operational units (nautical operations versus cargo handling operations), spatial units (quay-sites versus yards and storage facilities), traffic categories (bulk, break-bulk, Ro-Ro, container, etc), or any other relevant categorisation. The McKinsey/General Electric Matrix is a variation of the BCG Box where market attractiveness replaces market growth rate and competitive strength replaces market share.

1.4 Market Power and Concentration

Market power exists when suppliers are able to maintain prices above competitive levels, or above the economic cost of supplying goods and services. Identifying the existence of market power involves examining whether market conditions and outcomes are inconsistent with those expected in the presence of effective market competition. An example of the factors that can contribute to the creation of market power is shown in Table 9.2.

1.4.1 Measures of concentration

There are several measures of market concentration, the most common of which are the concentration ratio, the Hirschman-Herfindahl index, and the Lerner index.

Concentration ratio

The concentration ratio measures the relative size of firms in relation to the industry as a whole. The two common used ratios are the four-firm concentration

Factors	***Description***
Market concentration	*Concentration of market shares in the hands of a small number of big suppliers*
Barriers to entry	*Barriers to entry to markets*
Elasticity of demand	*Sensitivity of demand to changes in prices*
Elasticity of substitution	*Sensitivity of demand to the availability of substitutes*
Countervailing power	*Buyers switching suppliers or threatening to bypass them*
Vertical integration	*Buyers (Suppliers) exerting market power though upstream (downstream) vertical integration*
Prices and profit margins	*Returns sustained above competitive levels*

Table 9.2: Example of factors behind market power

ratio (CR4) and the two-firm concentration ratio (CR2). CR4 is the combined market share of the four largest firms in the market, and the CR2 is the combined market share of the two largest firms in the market. CR4 thresholds are often used to classify market forms, for instance oligopoly is believed to have a CR4 above 60% while competitive monopoly takes place below a 40% CR4. Despite this, empirical studies have found that CR2 is a better indicator of market power.

The Hirschman-Herfindahl Index (HHI)

HHI is calculated as the sum of the market share of each firm in the market.

$$HHI = \sum_{i=1}^{N} s_i^2$$

where:
N: Number of firms in the market
S_i: Market share of firm i in the market

HHI is used widely in the USA and elsewhere to evaluate the potential effects of mergers and alliances on market concentration. For instance, the US Horizontal Merger Guidelines use the following thresholds: an HHI below 1,000 for non-concentrated markets, an HHI between 1,000 and 18,000 for moderately concentrated markets, and an HHO above 1,800 for concentrated markets.

The Lerner Index (LI)

LI is a measure of market power and is based on the ratio of marginal cost of supply (MC) and the price charged (P). LI ranges from a low of 0 and a high of 1.

$$LI = \frac{P - MC}{P}$$

1.4.2 Recent concentration and consolidation practices in the port industry

Global strategies of vertical and horizontal integration evolving around port ownership and operations are undertaken by a variety of market players, both within and outside the international shipping and logistics markets. In the last two decades or so, there has been a trend towards the internationalisation and consolidation of port operations. This has led to the emergence of global terminal operators with extended bargaining power, higher performance levels, and standardised management and operating practices. For instance, it has

	TEU handled (in Millions)	% of global TEU throughput
HPH	50.4	9.6
APM Terminals	34.4	6.6
PSA	33.8	6.5
DP world	32.9	6.3
COSCO Ports	11.1	2.1

Table 9.3: Top five container terminal operators in 2008 and 2007
(*Source:* Drewry (2009): Based on terminal facilities in which operators have ≥10% shareholding.)

been reported that 20 top operators have handled over 70% of the global container throughput in 2007 (Drewry, 2008).

As shown in Figure 9.6, four types of market players in international port operations may be identified:

- *Terminal operating shippers (TOS):* Shippers involved directly, or through subsidiaries, in the management of terminals mainly for non-containerised cargo operations such as for handling oil and car shipments. Against the trend of logistics outsourcing, many global shippers have decided to retain full control over their distribution channels, including such activities as transport and port operations. Global firms such as Shell, Cargill and Hyundai own their own fleet of vessels (industrial shipping) or operate them through long-term lease (bareboat chartering), and so is the case for dedicated terminals.
- *Terminal operating shipping lines (TOSL):* Ocean carriers which operate a range of port facilities (predominantly container terminals) either through single or joint long-term lease and concession agreements. Depending on the nature of the agreement, terminals are operated either on a dedicated or common-user basis although variations to these arrangements exist, for instance when a dedicated terminal provides services to other members of the shipping alliance the terminal operating carrier belongs to. The management of such terminals is usually separated from that of the shipping line (COSCO Ports) and is sometimes undertaken by established subsidiaries (eg APM Terminals, APL Eagle Marines).
- *Terminal operating port authorities (TOPA):* Service operating port authorities such as Singapore and Dubai ports which have expanded their activities, usually through new organisational entities (eg PSA International and DP World respectively) to ports and terminals beyond their initial spatial bases.
- *Terminal operating companies (TOC):* Firms, other than shippers, ocean carriers or port authorities, whose origins are in logistics operations,

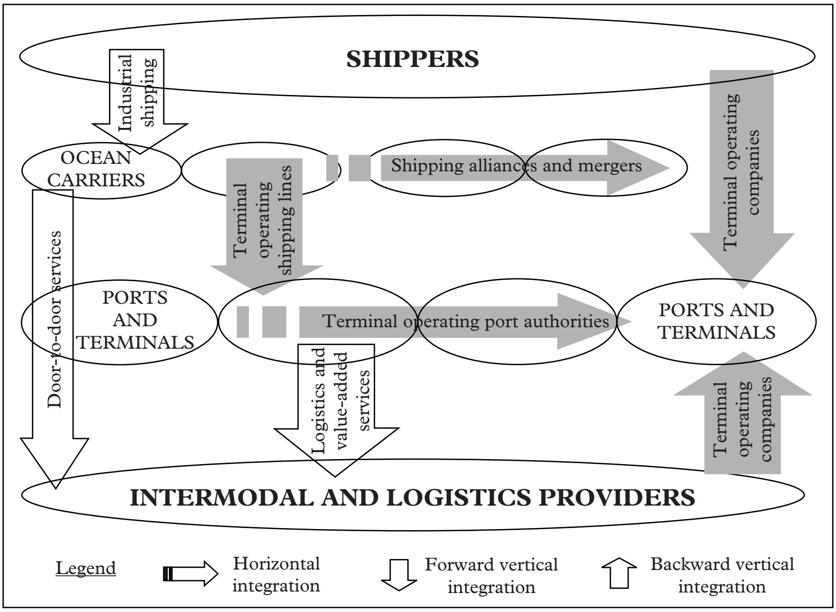

Fig. 9.6: Main cooperation and consolidation structures in international shipping and ports

property development or any other related business venture but have expanded their activities into international port operations and management. Firms such as HPH, Eurogate, SSA Marine, ICTSI, ABP and the former CSX World Terminals (now part of DP World) belong to this category.

1.4.3 Channel conflict and power in international shipping and logistics

Traditional channel relationships in the port industry have for long been marked by arm's-length arrangements and the quasi-dominance of shipping lines vis-à-vis other channel members, mainly individual ports and terminals. However, recent studies on the subject suggest that global shippers and retailers are increasingly gaining control of the international logistics channel. Adversative relationships are associated with specific aspects of channel behaviour, such as conflict, control and power.

Channel conflict

Channel conflict occurs when one member of the channel interferes with another member's objective with the purpose of causing harm or achieving gains at the latter's expense. The marketing literature depicts different sources of channel conflict including goal incompatabilities, role incongruities, resource scarcities, perceptual dissimilarities, and expectational differences. Evidence of goal incompatibilities in international logistics occurs between ports seeking maximum utilisation of their assets (berths, cranes, yards, etc) versus shipping lines in quest of the shortest time in port. Ports and ocean carriers may also get into conflict because of resource scarcities, for instance when dedicated terminals are allocated to a single shipping line, hence pushing other carriers to operate via ports elsewhere. Similar footloose arrangements take place in opposite situations such as when shipping lines desert a port because they could not have dedicated berths there, for instance when Maersk/Sea-land decided to shift their transhipment operations from the port of Singapore to the port of Tanjung Pelepas in Malaysia. Another source of channel conflict is role incongruities. For example, a transhipment port may consider regular customers (carriers, freight forwarders, shippers, etc) as partners while they may view the role of the port as being similar to that of any other stopover point.

Perceptual and expectational differences are also a source of conflict in international logistics. An instance of conflicts resulting from perceptual differences is when a port displays generous pricing promotional tools in an attempt to attract more lines but fails to appreciate that such discounts are seen by shipping lines as a small fraction of the total cost incurred by them, including for the time-in-port cost. Similar perceptual differences occur in instances where carriers offer discounted freight rates to shippers. For conflicts

Advantages	**Disadvantages**
– Additional traffic, particularly transhipment – Reduced shipping line mobility[a] – Secure traffic base facilitates financing – Strong commitment to improving productivity – More attention paid to the needs of the eventual customer (importers and exporters) – Better integration into global supply chains – Greater interest in developing logistics services	– Discourages competing shipping lines from using the terminal – Risk of discriminatory treatment of competing shipping lines – Potential problems with confidentiality of information (shipping documents) – Risk of transfer pricing for tax reasons – Lower utilisation of terminal if used mainly for own business

Table 9.4: Advantages and disadvantages of shipping line participation in ports

This is no longer entirely true of large shipping lines with global networks, for example APM Terminals has recently withdrawn its transhipment traffic out of Kingston (Jamaica).

caused by expectational differences, examples include situations where a port sets specific operational arrangements and targets (number of cranes per vessel, average crane move per hour, minimum reporting-time-to-gate, holidays and working day pattern, etc) that are not approved of by ocean carriers and other port customers.

Channel power

Channel power is closely associated with conflict as it can be either the cause of or the solution for it, and sometimes both. In the context of this book, power is defined as the ability of one party to impact, control or change the market behaviour and objectives of another party. Because of specialisation and channel interdependence, it is believed that each channel member holds a certain degree of power over other members. Examples of channel power frequently observed in shipping and ports include coercive, reward, expert and legitimate power. Coercive and reward powers denote opposite ability of channel behaviour towards other members, respectively by punishing or rewarding them, for instance through demurrage and charges versus rebates and discounts. Channel members that have extensive coercive and reward power are global shippers, but they have for long chosen to focus on their core businesses and outsource key transport and logistics operations to global shipping and logistics providers. However, this trend is quickly changing in the past few years as we have witnessed greater control being exerted by global retailers over the international logistics channel. Expert power stems from the degree of expertise and specialisation held by a channel member, for instance a shipping agent or a freight forwarder, and is seen by many as a counter-balance to extensive coercive powers usually held by channel leaders. Legitimacy is another source of power usually held by Governments. An instance where legitimate power has been used is the recent decision of the US authorities to block Dubai Ports World (DP World) from operating US ports as a result of its takeover of P&O Ports.

Power and conflict could be, either independently or concurrently, the cause as well as the consequence of variations in channel structures and configurations. In the context of the international consolidation of the port industry, conflicts may instigate vertical integration strategies leading to the emergence of global port operators, but other conflictual relationships could also result from such strategies. For instance, terminal operating shipping lines may hold greater control over the logistics channel, but this may be undermined by rising powers of terminal operating companies and port authorities. An examination of structural shifts in channel conflict and power relationships is therefore needed in order to assess the impact of consolidation arrangements on channel performance and mobility (footloose) behaviour of ocean carriers.

1.5 Regulatory Framework of Port Competition

The issue regarding the way in which market failure occurs or port competition becomes distorted has been widely discussed in the context of regulatory oversight and reform. National and regional regulatory agencies such as the US Federal Maritime Commission (FMC) and the European Commission (EC) have laid down policy rules and procedures for port competition. In the EU, two important documents shape the current port policy framework: the *green paper* on sea ports and maritime infrastructure and the *white paper* on fair payment for infrastructure use. In 2006, a second (revised) proposal for an EC directive on market access to port services (port services directive) has been rejected by the European Parliament and then withdrawn by the EC following a lengthy consultation process and a series of strikes and demonstrations by dock labour unions. This was seen by many as a major setback against an EU wide open and transparent competition in provision of port services.

Globally, port competition falls under the WTO rules and guidelines of the General Agreement on Trade and Services (GATS). However, port services are not captured by a dedicated category, but are spread over a series of CPC codes under section 11H for auxiliary services to all modes, for example *11Ha* for cargo-handling services, *11Hb* for storage and warehouse services, and *11Hc* for freight transport agency. Despite existing specific commitments by individual country members, no international agreement on liberalising and regulating port services has been established to date. Recent controversial decisions to block DP World and HPH accessing the US and Indian ports' markets, respectively, clearly substantiate a case of favourable and discriminatory treatment.

1.6 Port Cooperation

There is a long tradition of cooperation both within and between ports, as well as between ports and other transport and logistics operators. Different forms of port cooperation can be found in most ports of the world, and it is not the purpose of this book to go through different types and forms of port cooperation. However, two forms deserve particular attention: collaboration between international terminal operators and collaboration between port authorities. In the first case, there are growing signs of close collaboration between global port operators, particularly in the container market segment, including through joint-ventures and even mergers and acquisitions. In the second case, several ports and port authorities have entered into formal collaborative arrangements ranging from information sharing and joint marketing to the transfer of technology and operational know-how. A case in point, which is believed to be still the first joint-venture between two ports from different countries, is the merger back in 1998 between the former port of Malmoe in Southern Sweden and the port of Copenhagen in Denmark to create the new Copenhagen Malmoe Port (CM Port).

2 PORT PROMOTION AND MARKETING

With the increasing pace of competition within and between ports, marketing is becoming an essential tool in port competition with most ports having specialised marketing departments. Marketing in ports covers a number of activities mainly market research, promotion tools, and marketing strategy and implementation.

2.1 Port's Marketing Information System

A port's marketing information system may be defined as the system of people, equipment, procedures and practices employed in the continuous and systematic collection, processing, analysis, evaluation and dissemination of relevant data and information for use by port decision makers for marketing purposes. In addition to internal reporting systems, a standard marketing information system includes both marketing intelligence and marketing research components, both of which can be performed internally or commissioned to outside marketing and research agencies. However, while marketing intelligence systems are concerned with gathering general data and information, marketing research systems seek out specific information for the purpose of addressing a particular marketing problem.

Depending on the marketing objective of the port or terminal, marketing information needed in ports includes, but is not limited to:

- Internal information about port activities and services, operational and financial performance, costs and prices, targets and strategic plans, marketing research reports, customer satisfaction and complaint data, etc.
- External information about port customers, competitors, community users, etc.
- Information about relevant political, economic, social, and technological trends and developments. This may include information about the future trends in production, trade and logistics systems, the evolution of ship's size and technology, the variations in cargo volume, origins and destinations, the developments in handling equipment and technologies, government policies and regulatory frameworks, etc.

Marketing information system models cover both quantitative and qualitative data and use a variety of techniques ranging from statistical and economic models to mathematical and simulation models. Market segmentation is a technique usually performed in markets with a variety of products, customers and services. For instance, the port market can be segmented by type of, traffic, facility and customers. Modern marketing information systems use purpose-built ICT and computerised models which are usually categorised into executive information systems for information display and delivery and decision support systems (DSS) for problem solving and data analysis.

2.2 Port Marketing Tools

Marketing tools are those elements that influence the sales of a product or a service. Marketing decisions generally fall into one or a combination of the marketing mix tools, which are widely referred to as the 4P's; price, product, promotion and place. Place, or the fourth P in other businesses, may not apply in ports since they are immoveable assets.

2.2.1 Product

Product in the port business refers to the range of operations and services performed or offered by a port or terminal operator. A review of the factors behind port choice and selection is provided in Chapter 3, and the importance of these factors depends on the type of port services and customers, for example shippers versus shipping lines.

2.2.2 Price

Pricing in ports is a complex and multi-faceted subject and a detailed review of pricing strategies in ports is provided in Chapter 5. Among these, strategic port pricing rely on the contestability of port markets and on the elasticity of demand to port prices and tariffs.

2.2.3 Promotion

Promotion is a marketing tool for communication between the port and its customers and users with a view of informing them and influencing their market and choice attitudes. Promotion is important because, although a good pricing and strategic plan may be in place, it success or failure depend also on the perception of targeted customers and users.

Advertising: Press, radio and TV ads, direct mailing, telemarketing, online marketing, brochures and catalogues, direct listing, sponsorship, etc.
Personal selling: Sales presentation, representatives or agencies, etc.
Direct marketing: Establishing direct relationships with targeted customers
Sales promotion and networking: Incentives and rebates, international exhibitions, fairs and trade shows, organising or speaking at conferences and seminars
Public relations
Other tools

Table 9.5: Tools of promotional mix

A port can choose between one and a variation of different promotion tools depending on the targeted market or customer, the type of products/services to be promoted, and the amount of financial resources available for promotion. Table 9.5 lists the major tools of marketing communications, or promotional mix, for ports.

CHAPTER 10

PORT LOGISTICS

Although there is widespread recognition of the importance of the logistics and supply chain dimension to ports, few theoretical frameworks or practical applications exist on how to conceptualise and manage ports from a logistics and supply chain management (SCM) approach. Much of the literature advocating the future of ports as logistics centres highlights their nodal role in the changing patterns of maritime and intermodal transport (eg hub and spoke systems), but overlooks logistics integration of the various activities performed within the port organisation itself. For instance, the question of the total cost incurred on a cargo through the various stages of port operations up to the final customer or user does not appear to have been discussed thoroughly in the academic literature. Most published articles on the subject address different aspects of port management (cost-analysis, marketing, strategic planning, etc) separately without incorporating them into an integrated logistics framework of total cost reduction and customer satisfaction. In a similar vein, the subject of competitive benchmarking between logistics management of seaports and that of other entities with similar operational features, such as airports and regional distribution centres, have received scant research attention. For many, this failure is mainly due to the complex organisational structure of ports although recent schemes of port privatisation have made it easier to apply an integrative logistics approach to port operations and management.

1 PORTS AND LOGISTICS SYSTEMS

1.1 Ports as Nodal Systems and Interchange Points

Most transport and distributions systems are composed of a link-node combination although some distribution systems still use direct transport-link structures with no nodal connection. In a link-node distribution system, links represent the transport system while nodes are locations for cargo transfer, multimodal interchange, storage and warehousing, and eventually value-added logistics. Physical nodes in transport and distribution systems are usually referred to as terminals. Terminals are nodes in a shipper-carrier distribution network. They perform various functions to facilitate the movement of freight and passengers. All modes of transportation use terminals in one way or another. A terminal can be any point within a transport chain where the movement of cargo is stopped or paused for modal interchange, storage and warehousing, and/or any value-adding activity. In this section, we describe the basic function of terminals as interchange points.

1.1.1 Road freight and road terminals

Trucking and road transport systems are operated by smaller vehicles and a wide variety of special equipment. The list in Table 10.1, although neither exhaustive nor definitive, depicts the main types of freight road vehicles currently in use. From an operational perspective, trucking vehicles are either line-haul used to transport freight over long distances, or local transport services within a limited spatial area. The latter are mostly performed for LTL shipments and consist mainly of pick-up and delivery (PUD) services or delivery of freight on peddle-runs. These are routes driven daily out of the PUD terminal in order to collect/deliver freight for outbound or from inbound movements. There are two main components of a peddle-run: the stem time and the peddle-time. Stem time is the time that has elapsed from when the driver leaves the terminal until s/he makes the first pickup or delivery, or from when the driver makes the last pickup/delivery until s/he returns to the terminal. This is a non-revenue-producing time as trucks run empty throughout the

Vehicle types by commercial attribute	
PUD	Collection/delivery of shipment from/to multiple destinations, also called multi-stop step vehicle
Line haul	Collection/delivery from/to one destination. May be deconsolidated /reloaded into PUD vehicle
Vehicle types by technical attributes	
Straight truck	One-unit track
Truck trailer	Straight truck + one trailer
Truck tractor	Used with converter dolly to haul different set of trailers, including double or triple trailer units
Other descriptions	
Platform and flatbed, pole and logging, dry van, open top, high cube, dump truck, grain body, tank trailers, refrigerated vehicles, livestock van, and other special vehicles	

Table 10.1: Major types of road freight vehicles and equipment

stem time. Peddle-time is the time during which the driver is actively involved in the pickup, transportation and delivery of freight. Thus, hauliers will seek to minimise the stem time and maximise the peddle-time.

Many truckload (TL) movements are performed on a one-shipment basis between two destinations and as such do not require interchange points. TL terminals, when they exist, only provide dispatching, maintenance, and fuel/supply services, and are reducible to truck stations or truck stops. On the other hand, less-than truck load (LTL) movements require the use of one or multiple terminals since they usually fall within the scope of hub-and-spoke systems. The most common type of terminal found in the LTL system is the pickup and delivery (PUD) terminal. The basic service provided at this terminal is the pick-up and/or delivery of freight on peddle runs which are routes driven out of the PUD terminal so as to collect and deliver freight from inbound or for outbound movements, respectively. The relay terminal is another type of road terminal used by LTL networks. Relay terminals do not handle freight, but provide a layover between two PUD terminals, or between a PUD and a final destination.

1.1.2 Rail freight and rail terminals

Although rail freight has a relatively longer transit time than road services, it is suitable for longer distance journeys in larger countries such as the USA, Canada or Australia. Many countries have a single state-owned railway company operating both rail infrastructure (rail tracks) and superstructure equipment (rail vehicles), a model very similar to the service model in the port industry. Issues over labour arrangements, operational efficiency, and competitiveness have somehow retarded the process of privatisation in the industry in comparison with other modes of transportation. Railways in the USA have always been privately owned and provide a good model of an efficient and privately managed rail freight system. In the USA, each railroad company owns the track over which it operates, sometimes jointly (interlining) with another operator. In the UK, rail services are privatised through regional franchises awarded by the government to private train operating companies. Elsewhere, several countries have introduced measures to reform rail services, eg commercialisation, corporatisation, partial privatisation, but with different degrees of operational and management success.

Wagonloads (also called trainloads or carloads) form the basic unit of freight handling in the rail system. They can vary in size, capacity and dimension depending on the type of shipment transported and equipment being used. Nowadays, wagonloads are highly specialised and designed to meet the requirements of individual shippers. The most frequently used are boxcars (plain or equipped), hoppers (covered or uncovered), flatcars, refrigerated cars, and tank cars. Services for most rail freight tonnage are arranged by contract between carriers and their customers. Contracts are normally written on predictable

Wagon type	**Use and example**
Covered	Box-type wagon for the transport of palletised goods
Open-top	Gondola-type wagon for the transport of scrap metal
Hopper	Hopper wagon for the transport of solid bulk cargo (eg coal)
Tank	Tank wagon for the transport of petrochemical products
Inter-modal	Flat or deep-well wagons for the transport of containers and trailers

Table 10.2: Basic rail wagon types

Point-to-point	**Hub-and-spoke**
– Consists are shuttled between a fixed O-D pairs – Consists mostly unaltered between O and D – Few or no intermediate handlings required – Services typically run according to a schedule – Services are typically long-distance or trunk services – Services are also typically block train services – Less resources required relative to hub-and-spoke services – The focus of emerging European carriers	– Combination of feeder and trunk services – Less-than-trainload requirements consolidated into trainload move – Feeder services convey blocks to yard – Blocks are consolidated for the trunk move – The trunk service is then deconsolidated again – Services cater to a mix of traffic rather than one traffic segment – Resource-intensive due to blocking requirements – Traditionally operated by incumbent carriers

Table 10.3: Main routing strategies for freight rail services

levels of cargo moving at predictable times and recurring conditions, for example at a predefined rate. A fraction of rail freight tonnage, essentially low volume shipments hauled on the spot market, is priced through common carrier rates, price lists that are the same for all users.

Routing in the rail system is straightforward, apart probably from the use of relay terminals and Inter-modal platforms. Generally, the movements can be either point-to-point or hub-and-spoke and can use both train-load and less-than-train load wagons or only one of them. The introduction of piggybacking has revolutionised rail freight, and is behind much of rail/road Inter-modal success. Piggybacking consists of purpose-built road semi-trailers capable of being bottom lifted when fully loaded on to specially built rail wagons (pocket,

Fig. 10.1: Melnik's rail terminal in Bulgaria

swing-bed, or spine wagons). The system operates both trailer-on-flatcar (TOFC) and container-on-flat-car (COFC) traffic. The shuttle service, sometimes called rolling motorway, is another operating system used in this mode, although it may be seen as part of a combined transport. It is a system whereby complete road vehicles are carried on special drive on/drive-off low-height rail wagons so as to ensure the transport of freight on a regular basis over short mile-track distances, for example the shuttle service in the English Channel.

The most common form of rail terminal is a hump or marshalling yard. This is an interchange point which allows switching between freight cars (wagon-loads), trains, and tracks in a coordinated way. The hump is an artificial point that uses gravity and readers to direct or reclassify cars to a new train or a new track. For Inter-modal movements, the railroad industry uses what are usually referred to as trans-loading terminals, where both TOFC and COFC units are moved to and from rail flatcars.

1.1.3 Water and sea terminals

Commercial seaports are the predominant category of water terminals and are sometimes combined with other purpose-built terminals (eg military ports, leisure ports, and so on). Although composed of many berths, terminals are usually treated as sub-units of the port system (eg container terminals, bulk terminals, multipurpose terminals, and so on). Yet, there is no definitive categorisation as a port can be composed of multiple terminals, or reduced to only one terminal. The classification of seaports as water terminals along with road and rail terminals may be somewhat confusing, since ports mostly operate as an interface between sea and land transport systems and should therefore be conceived as multimodal or intermodal terminals.

1.2 Ports as Inter-modal Centres

The combination of two or more transport modes requires the use of terminals at one point or another. Inter-modal transport is sometimes used interchangeably with multimodal,[1] combined, and/or through transport. In the context of this book, we define inter-modalism as being the process of moving goods by more than one transport mode in a single loading unit such as containers. All other concepts do not necessarily involve the same unit of loading or transport packaging. Far from being just a combination of two or several modes of transport, intermodal transport is an integrated process where all parts of the transport process, including organisational and technological arrangements, must be well connected and coordinated.

Inter-modal transport has many advantages, proven by its success in such areas as container traffic. Compared to the one-mode transport, the combination of

Exterior Dimensions W x H x L (in inches)	Interior Dimensions W x H x L (in inches)	Interior Cube Capacity (in cubic ft)	Weight Capacity (in 1000 lbs)
8 x 8 x 20	92 x 87 x 230	1.065	40
8 x 8.6 x 20	92 x 93 x 230	1.138	40
8 x 8.6 x 24	92 x 94 x 282	1.411	45.9
8 x 8.6 x 35	92 x 93 x 415	2.054	50
8 x 8 x 40	92 x 88 x 473	2.216	50
8 x 8.6 x 40	92 x 93 x 473	2.342	55
8 x 8.6 x 40	92 x 105 x 473	2.644	55
8 x 9.65 x 45	92 x 106.5 x 534	3.035	64.3

Table 10.4: Characteristics of dry cargo containers (compiled from ICHCA and ISO)

1. For more information on legal aspects of multimodal transport and the requirement of a single multimodal transport operator (MTO), reference may be made to the United Nations Convention on International Multimodal Transport of Goods (UNCIMTG), available at *Manual on modernization of inland water transport for integration within a multimodal transport system*, New York, 2003.

two or several transportation modes has lowered both costs and transit times for goods and improved the quality of transport services. Enclosure of the goods in a single unit load device, such as containers, through a door-to-door movement has also made the transit time more secure, and has reduced damage to the goods transported. About 90% of all containers in the world are standard dry freight and general purpose containers (almost equally split between TEU and FEU sizes). The rest can be classified as special containers which are mainly comprised of high cube, open-top, flat-track, platform, tank, refrigerated and ventilated containers.

Although the first commercial application of intermodal services can be traced back to the 1950s, the real revolution of the intermodal transport system started in the mid-1980s with the introduction of double stack train services. Today, intermodal services intersect different interfaces mainly road/rail (piggyback), air/road (birdy-back), sea/road (fishy-back) and sea/rail combinations. The land-bridge is a particular form of intermodal transportation offered as an alternative to ocean transportation. Its main advantage lies in the organisational simplicity from the standpoint of the shipper. A shipment moving over a land-bridge does not usually require more than one single document along the entire destination. The US overland route forms a land-bridge for traffic between the Far-East and Europe, and so does the Trans-Siberian railway between Asia and Europe, but the latter suffers from the use of different train gauges and the lack of freight and multimodal terminals. The literature provides three basic types of land-bridge services, namely:

- the land bridge, involving, two seas joined by land or transcontinental transport systems,
- the mini-bridge, which uses a transcontinental land-transport system as a substitute for moving cargo to the final destination coastal port, (eg the rail canal between Mexican pacific ports and Central/Northeast ports of the USA, as an alternative to Asia-North America Maritime routes), and
- the micro-bridge, which is essentially the same as a mini-bridge, but the origin or destination is at an interior inland port.

The North American intermodal transport system is by far the biggest and probably the most efficient. Improvements of both infrastructure capacity and technology (eg double stacking, block-trains and so on) offered excellent opportunities for intermodal development. Interchange points (including inland terminals and ports) are equally important in the intermodal system. Furthermore, there are significant economies of scale gained through the use of 40 ft equivalent unit (FEU) containers instead of 20 ft equivalent unit (TEU) containers. Equally important are the economies of scope, made possible by the large geography and long transport distances in the USA. The success of any intermodal system also requires advanced communication and IT systems, cooperative arrangements (eg through interlining), and a favourable and unified regulatory system.

Origin	Route	Length in km	Border crossings	Break-of-gauge points
Russian Far East	via Russia –Belarus – Poland – Germany	11,600	3	1
Ports of North-East China	via China – Kazakhstan – Russia – Belarus – Poland – Germany	9,200	5	2
Ports of North-East China	via China – Mongolia – Russia – Belarus – Poland – Germany	9,500	5	2
Ports of South Korea	via China – DPRK – China – Mongolia – Russia – Belarus – Poland – Germany	10,950	5	2

Table 10.5: Main Europe-Asia railway routes

Fig. 10.2: Calgary CPR intermodal terminal

It is worth mentioning that inter-modalism is most developed on the North-North trade routes. The conditions in many developing countries, including the so-called North-South and South-South routes, are still not favourable for an integrated inter-modal system. Often, the transport infrastructure such as ports, road, and rail systems are inadequate. Similarly, the communication and electronic infrastructure may be insufficiently developed, and there may be other bottlenecks such as regulatory restrictions and customs bureaucracy.

1.3 Ports as Distribution and Logistics Centres

Given the emphasis placed nowadays on the flow of products and materials, modern production and distribution systems rely more on inventory management and less on traditional storage and warehousing. This has led to the emergence of new type of facilities such as regional logistics centres which can perform a number of functions including the activities related to materials management, materials' handling and physical distribution. Logistics centres are sometimes confused with regional distribution centres (RDCs), but the latter are more associated with physical distribution systems for outbound movements.

In international shipping and logistics, seaports can be treated as maritime logistics centres where they provide logistics services at the seashore and shoreland interfaces. Many ports in the world have an established body of knowledge and experience in providing value-added logistics activities for ship-cargo consignments, but not all ports can claim a logistics centre status. Typical logistics functions of ports include cargo handling and transfer operations, storage and warehousing, break bulk and consolidation, value-added activities, information management, and other related services.

1.3.1 Storage

Storage management is the traditional function of warehousing for managing physical stocks (warehouse configuration, stock layout and placement, space determination, cross-docking, etc), and should not be confused with inventory management which is related to the opportunity cost of time. Types of stock or inventory include production inventory resulting from the production and industrial transformation processes, in-transit inventory or stock in the pipeline, cycle stock, safety stock, speculative inventory, promotional inventory, seasonal stock and dead or obsolete inventory. Holding inventory ties up money that can be used to generate cash flow and other types of investments, but there are several reasons for holding inventory at various locations and times during the logistics process.

Achieve *economies of scale* via: - Quantity *purchase* discount - Reduction of volume *transport* per unit-price - Reductions of *production* runs and cycles for single products
Protect against *supply and demand uncertainties* by holding *buffer* or *safety stock*
Speculate in order to make profit at favourable market conditions
Link supply with demand in *seasonal* situations (Christmas toys) or for product ageing (wine)

Table 10.6: Reasons for holding inventory

1.3.2 Cross-docking

Cross docking is associated with product assortment or product mixing in the required combinations for shipment to customers. In this context, the terminal or warehouse is more a transfer location than just a storage point.

1.3.3 Consolidation and break bulk

Smaller consignments are consolidated (or concentrated) and subsequently dispatched as a larger volume shipment units. The reverse operation is called break-bulk or dispersion and can be combined with consolidation.

1.3.4 Value-added logistics (VAL)

In ports, the term VAL is sometimes used interchangeably with value-added services and general logistics services (GLS) but the latter are closely associated with aspects of storage, consolidation, break-bulk and cross-docking. In the context of logistics management, added value is being pursued in the post-production/pre-distribution process, including, but not limited to, the following activities:

- *Postponement*: This refers to the deliberate delay of an activity until the last possible moment, particularly when adopting a general product to a customer or country-specific product, for example labelling, ticketing, and customisation. In this context, breaking bulk can be considered as a variation of postponement when it proves cheaper to transport commodities in bulk over long distances than in consumer-ready packaging.
- *Reverse logistics*: This is the process of managing the movement and storage of returned goods (eg damaged, used or outdated products). Such a process is considered as an added value since it deals with the repair and disposal of returned products (eg the repositioning of empty containers).
- *Packaging*: Packaging is also associated with postponement and breaking bulk, and is usually discussed as an aspect of materials handling. It is seen

as a VAL when it adds value to the transport and logistics attributes of a commodity. For instance small, fragile, or dangerous commodity shipments can be neither safely nor economically transported (and handled) without proper packaging.

- *Information technology*: Modern logistics centres also offer information management services to customers such as real-time tracking and tracing for cargo distribution and inventory levels, on-line documentation and payment services, and other information related to customs clearance and administrative procedures.

In an effort to assess logistical potentials of ports, the World Bank distinguishes between general logistics services (GLS) and value-added activities (VAL), with the latter being a common feature of containerised and general cargo. It goes on to highlight the increasing role of ports as 'Distriparks', a dedicated area where both GLS and VAL can simultaneously be performed. Furthermore, the World Bank publishes annual performance indices to benchmark logistics efficiency for a large number of countries (currently around 100). Based on a survey of logistics operators, countries are scored against seven indicators (customs, infrastructures, international shipments, logistics competence, tracking and tracing, domestic logistics cost, and timeliness) on a scale of 1–5, with the best performances receiving the highest scores. The scores for each indicator are then aggregated by means of principal component analysis (PCA) into a composite *logistics performance index* or *LPI*.

1.4 Ports as Free Zones

Free zones, also referred to as free trade zones (FTZ) or export processing zones (EPZ), are special areas offering a range of customs and tax breaks and

Port (or host country)	**Users**
- Attract foreign investment - Currency flows and trade development - Generate direct and indirect jobs - Transfer of know-how and technology - Opportunities for cargo consolidation and hub services - Competitiveness of local industries - Reduction of informal activities	- Close to markets, shorter transit time - Reduction of investment/project risk - Minimum customs and procedural bureaucracy - Opportunities for relocation and logistics outsourcing - Reduction of warehousing and inventory cost - Lower exchange risks - Economies of scale - Wide range of services and facilities

Table 10.7: Advantages of Freeport zones

additional administrative incentives with a view of attracting foreign investments. In ports, a free zone (or free port) can range from a small bonded warehouse to a large logistics hub. Successful cases of port free zones include Jebel Ali, Iquique, Aqaba, Mauritius, Kaohsiung and Shenzhen.

1.5 Port Landside Logistics

Design and planning schemes for seaport development strategies have traditionally focused on seaside links such as nautical approaches, seashore infrastructure, ship and cargo handling equipment, and other related quayside superstructure facilities. As a result, much of port operational and management concepts and practices were centred on or around the maritime and seashore interface. Port design and operations, management and performance monitoring, marketing and competition, and public policy and governance were almost entirely directed towards the sea transport and shipping services with little emphasis on land transport flows and network organisation, and much less on inland freight distribution and logistics systems.

In recent years, the inland component of the port system has become a key factor in shaping performance and competitive strategies of seaports. Physical and capacity constraints at berths, along with the trend of optimisation and standardisation of quay-side operations, suggest that more focus must now be placed on land-interface logistics operations. On the one hand, the increase in trade volumes and the emergence of new distribution patterns means that the demand on port seashore infrastructure, and the immediate land behind it, is nearing capacity, hence the need to expand land-wise to accommodate future volume growth and the expanding demand for value-added logistics services. On the other, reported inefficiencies in ports indicate that landside logistics operations are far behind their optimal efficiency with most observed malfunctions (unproductive moves, congestions, delays, etc) currently taking place at the inland and intermodal port interfaces. Furthermore, many ports, especially in developing countries, suffer from peripherality and poor inland transport links which limit their multimodal/intermodal accessibility and proximity to inland markets. Standard indicators used for measuring accessibility include travel costs (accumulated travel cost to a set of activities), daily accessibility (accumulated activities in a given travel time), and potential accessibility (accumulated activities weighted by a function of travel cost). These measures and others can be used to estimate the locational advantages and landside competitiveness of ports and terminals.

Although landside expansions are a cornerstone of strategic port planning, inland infrastructure/superstructure development plans are usually designed to satisfy the needs of shipping services, for example through the provision of container freight stations and marshalling areas to accommodate ships' cargo. Similarly, the segmentation of the port market has traditionally been oriented towards the sea-leg component of the transport chain; with port marketing and competitive strategies being typically formulated to meet the requirements of sea transport and related shipping services. This situation is far from being desirable because it not only disintegrates the port system from the total transport and logistics chain but it also unnecessarily binds the entire port business to sea transportation and stops ports from integrating land interface operations and management.

Figure 10.3 depicts the interaction between sea, land, and inter-modal systems and the scope for ports to integrate all three interfaces. Port landside integration can be undertaken through many strategies, including as intermodal terminals, warehousing facilities, logistics centres, and/or a combination of one or all of these. Cargo flow can take different transport routes and may be processed at maritime logistics centres, inter-modal interchange points, and/or inland logistics interfaces. At the seashore interface, maritime logistics centres operate and provide value-added logistics services for sea-bound goods at both origins and destinations. The intermodal system intersects with both the inland and maritime interfaces but its role is limited to a modal interchange point. The inland logistics interface is primarily concerned with managing physical flows for inland cargo, but can also process sea-bound or intermodal cargo without being physically linked to the sea such as in the case of dry or inland ports.

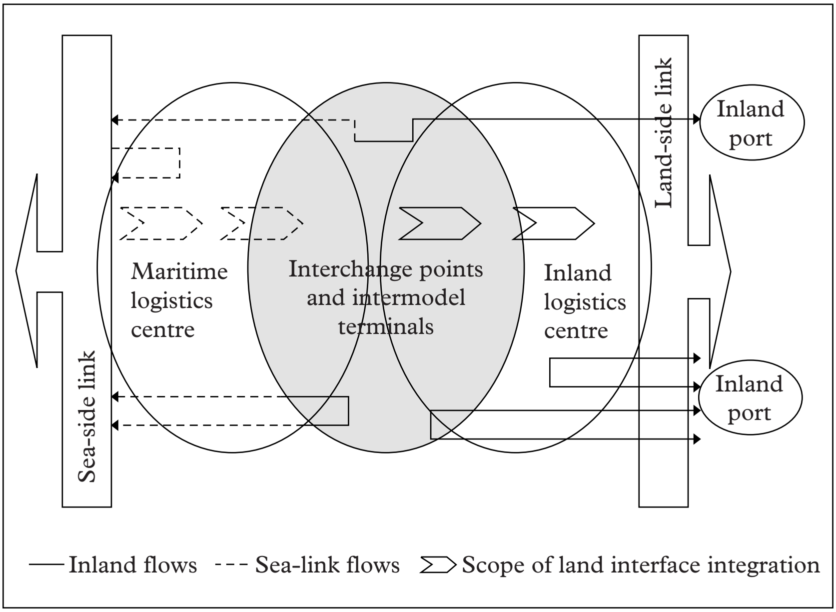

Fig. 10.3: Scope and potential for ports to develop beyond a maritime logistics centre

New opportunities for ports may arise through operating inland distribution centres located outside the port area, but linked to it via rail/road networks. Inland terminals providing multimodal and logistics services are sometimes called dry ports, inland freight stations, or inland ports. They have a proven advantage over seaports since they can virtually be located anywhere provided that there is a transport link. The concept of processing cargo at sites even further removed from port's perimeter has been recognised for its economic benefits. In regional trading blocs such as the EU or NAFTA, these sites could even handle import/export cargo away from border crossing points such as conventional seaports. Practical illustrations already exist in Western Europe and North America,[2] and are generally backed by governments keen to ease traffic and urban congestion around seaport locations. On the other hand, many ports in the world may find their inland development plans and strategies restricted by regulatory, spatial or competitive constraints. Sometimes, ports have sizeable land capacity but cannot develop it to undertake other non-shipping related activities. This is because ports may be tempted to shift their operations to more lucrative businesses, such as leisure and real estate property development, if allowed to expand freely landside. Evidence of such practices can already be found in many ports in the world, particularly those operating in a fully deregulated environment.

Unlike strategies for sea and nautical developments, port landside expansion plans are likely to have further implications on land transport systems, urban and spatial planning, land use, and environmental standards, with the likely involvement of politicians along with other economic and community interests. Variations between restrictive, protective, and promotion-led policies will largely shape the development of port landside logistics. As illustrated in Figure 10.4, ports are better positioned to act as facilitators by creating a platform of joint planning and management with various stakeholders and market players.

The integration of inland networks could constitute an additional core mission for ports, but this requires an appropriate strategy directed towards inland transport and logistics providers. Strategies of inland integration whereby seaports seek to either pull outside cargo operations into the port base or geographically expand beyond traditional maritime spatial bases are uncommon in the port industry. Legal, spatial, institutional, and even functional constraints may prevent ports from adopting such strategies, with three main issues being at stake: (i) the extent of port's roles, functions and missions, (ii) the geographical limit (perimeter) of port inland expansion, and (iii) the operational and organisational models that can accommodate such strategic orientation.

2. For instance, Rotterdam has invested in railroad infrastructure linked to inland distribution centres in Germany. In North America, examples include the inland port of Albany selected to receive freight containers barged from the port of New York /New Jersey.

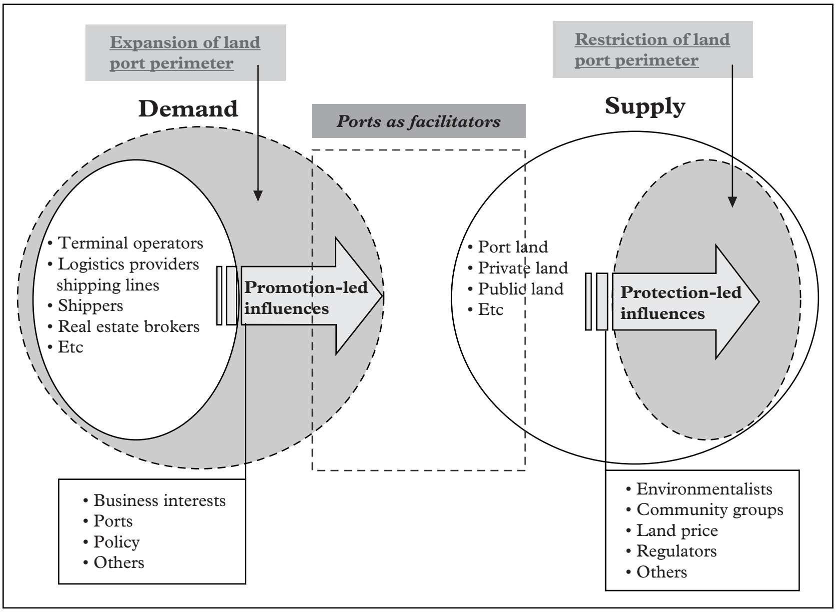

Fig. 10.4: Actors and the port role in the system of inland port expansion

2 PORTS AND SUPPLY CHAIN NETWORKS

A supply chain is often described as the network created from (i) the combination of a sequence of organisations from production to consumption; suppliers, manufacturers, distributors, retailers and customers, and (b) the physical, information, and financial flows that move within and between these organisations. SCM covers the design, planning, execution and control of the different business processes and flows of materials, information and services. The scope and size of global supply chains create new types of problems and challenges because of the complexities and uncertainties associated with designing and managing large-scale tasks and processes that cut across functional, organisational, and spatial boundaries. For instance, a typical global movement of containerised cargo is estimated to involve as many as 25 parties, hence creating multiple physical and non-physical flows and transactions across the supply chain network.

While SCM advocates partnership and integration, traditional arrangements in international shipping and logistics seem to favour conflict over collaboration. For instance, integration between shipping lines and ports is difficult to implement if both parties try to optimise the use of their respective assets (ships versus berths and warehouses) by transferring costs to each other. Other types of conflict may be between freight forwarders and shipping lines or between freight forwarders and ports. A collaborative supply chain is not only an alignment of participating firms but also an integration of their activities and processes. Successful models of supply chain collaboration often incorporate several components of supply chain planning and implementation such as stakeholders, levels of collaboration, business strategy, topology, processes, and enabling technology.

- *Stakeholders* refer to the primary participants in a supply chain which usually include suppliers, manufacturers, wholesalers, retailers and customers. Stakeholders are closely associated with supply chain topology since the latter determines which participants are involved and how.
- *Topology* refers to the way supply chain processes are organised and linked to each other. There exist at least three types of flows in any topology type: single route flows (single customer/single supplier), divergent flows (a firm supplying two or more customers), and convergent flows (a firm having two or more suppliers).
- *Levels of collaboration* refer to the degree (not the type) of partnership among stakeholders and can be strategic, managerial, operational, or any combination of some or all of these.
- *Business strategy* denotes the strategy of the collaborative supply chain (not that of a single firm in the chain) as determined by market dynamics.
- *Processes* often refer to cross-functional and inter-organisational flows and interactions within a collaborative supply chain.
- *Enabling technology* refers to the information systems used to run and support collaborative supply chains. Researchers often distinguish between three types of collaborative information systems: transaction processing systems (TPS) supporting routine transactions at the operational and/or functional level (eg transportation or warehouse management), management information systems (MIS) supporting medium-run management planning, control and coordination along the supply chain (eg MRP, ERP), and executive information systems (EIS) which are an extension of MIS, the difference being that with strategic supply chain decisions such as facility location, supply chain configuration, and collaborative restructuring.

2.1 Towards a Supply Chain Orientation of Port Operations and Management

It is possible to explain port management systems by investigating the individual and aggregate strategies of port supply chain members. This book distinguishes between logistics, trade and supply channels. In international shipping and port operations, a chain or channel may be defined as the route or pathway tracing the movement of a cargo-shipment (and people) across a number of organisations, while flows are the physical, information and financial transactions associated with goods and people.

As illustrated in Figure 10.5, the logistics channel consists primarily of specialists (eg shipping lines, freight forwarders, ports, 3PLs, and so on) that do not own the goods but facilitate their efficient movements. Today, services such as sea and intermodal transport, cargo handling and storage, and consolidation and break bulk are typically performed by third parties including shipping lines, ports, logistics providers, shipping agents and other intermediaries. Unlike the logistics channel, both the trade channel and the supply channel are associated with the ownership of goods moving through the system, with the difference that the trade channel is usually perceived to be at the level of the trade or the nation (eg the oil trade, the containerised trade, the US-Canada trade, the intra-EU trade) while the supply channel is perceived at the level of the firm (eg Toyota and Wall-Mart supply chains). For instance, bulk maritime transport has traditionally been analysed by trade (crude oil, iron ore, etc) and this dimension still explains much of the distribution patterns of bulk commodities including the location and operations of bulk ports and terminals. On the other hand, several aspects of container transport such as routing and transhipment decisions are still being controlled by shipping lines and major 3PLs. In either case, a fundamental distinction should be made between institutions and functions when designing supply chains in shipping and ports. Often, a single institution undertakes various functions for instance when a shipper (cargo owner) also acts as a carrier or a port operator. Despite

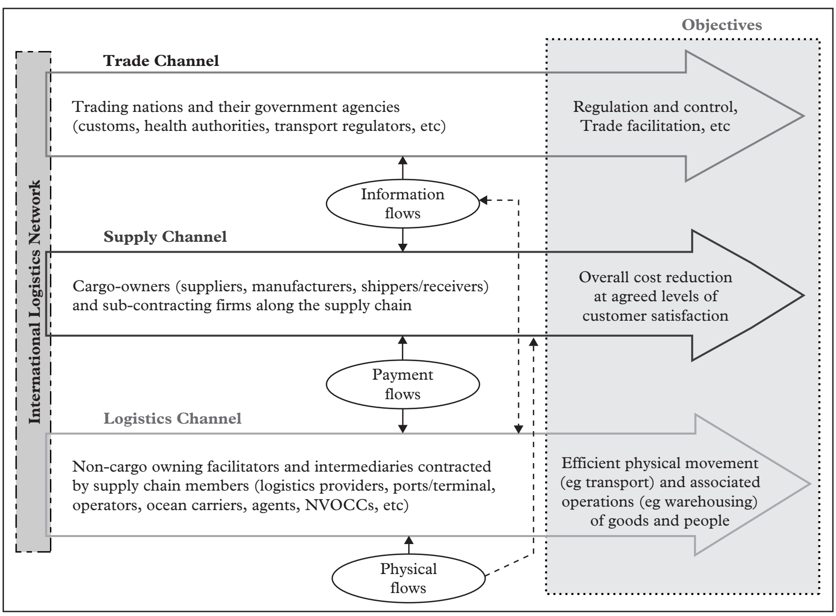

Fig. 10.5: Channel typologies and components of the maritime network

this, the interaction between functions and institutions is often overlooked in international shipping and port operations.

The channel approach described above provides a basis for linking the spatial (both land and sea interfaces), the functional (processes and operations), and the institutional (channel members and stakeholders) attributes of a port's supply chain. Ports have an important role to play in the integration of all three types of channels. There are many organisations occupied (or potentially occupied) with logistics and supply chain integration within and around ports, mainly in the role of logistics channel facilitators, trade channel merchants (including shippers), and supply channel members. Ports offer a unique location in which members of different channels can meet and interact:

- From a logistics channel standpoint, the port is a very important node since it serves as an inter-modal/multimodal transport intersection and operates as a logistics centre for the flows of goods (cargo) and people (passengers).
- From a trade channel perspective, the port is a key location whereby channel control and ownership can be identified and/or traded.
- From a supply channel approach, the port not only links outside flows and processes but also creates patterns and processes of its own. At this level, ports are one of the very few networking sites that can bring together various members in the supply channel.

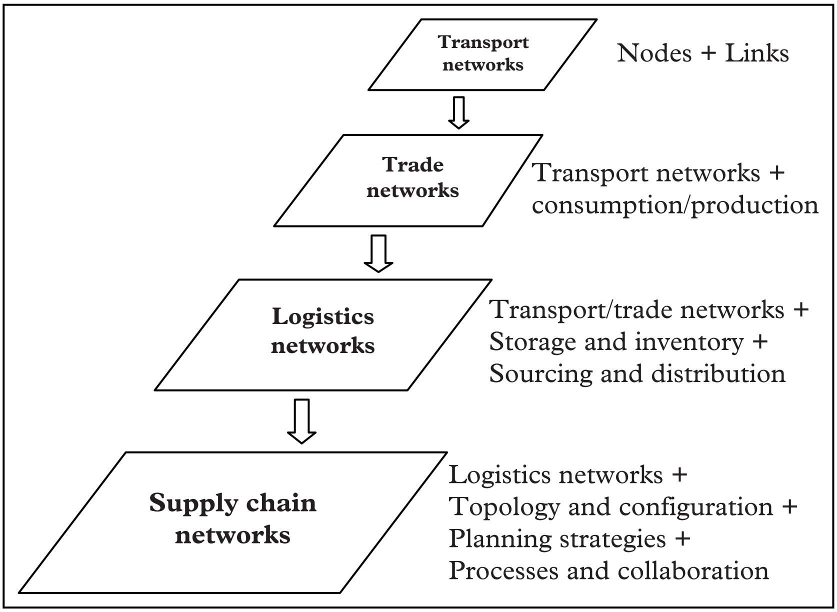

Fig. 10.6: Levels of channel and network analysis in ports

In conceptualising ports from a supply chain approach, port planning, operations and strategy will shift from the fragmented institutional, functional and/or spatial levels to the integrated supply chain management level:

- In the area of port planning and operations, the above framework allows the extension and integration of port systems into the logistics and supply chain dimensions by integrating factors such as storage, inventory, sourcing, and supply chain decisions.
- In the area of port performance and benchmarking, the channel approach allows performance measurement and management to be analysed, valued, and assessed in terms of a port's contribution to the overall combined channel added-value; and thus port competition will shift from the institutional, functional and/or spatial levels to the channel management level.
- In the area of port security, the above approach explains the use of a multi-layered approach to monitor the security of maritime and port operations (see Chapter 12), for instance through regulations such as the CSI and the 24-hour rule. The point here is that total tracing and visibility of cargo movements cannot be undertaken by a single actor within a single channel. For instance, trade channel stakeholders (regulators, customs, health authorities, etc) may be able to scrutinise and monitor the logistical segment within their own national territory, but would have little or no control over arrangements taking place in a foreign country including at transit and transhipment locations.
- In the area of port strategy, the channel approach offers new opportunities for ports in terms of competitive advantage, long-term planning, organisational strategy and development.

As an illustration on how ports can plan and redesign their strategies towards supply chain integration, the following section discusses how ports can position themselves as elements of value-driven supply chains by identifying and integrating different topologies and configurations of supply chain systems. Key features of supply chain configuration are the nature and degrees of network centralisation and segmentation:

- An instance of the impact of network centralisation on port and mode choice is the recent development of a £20m dedicated import logistics facility for ASDA at Teesport in 2006, following a strategic decision of the retailer's to reconfigure its distribution network by reducing by half the number of its central warehouses.[3] This is referred to as the horizontal dimension of network centralisation which describes the number of facilities within each tier, for instance the number or size of warehouses and retail stores, as opposed to the vertical dimension which corresponds to the number of logistics tiers across the network, for example supply, production,

3. Joint ASDA and Teesport communication (2005).

distribution and sale. According to ASDA, the new facility allows 70% of its non-food imports to go directly to the North by sea rather than by road from Felixstowe with an expected annual saving of more than 2 million road miles. The other major advantage of this facility is the creation for a demand of direct deep-sea call to Teesport which is why the port has started developing the Northern Gateway Container Terminal (NGCT)—a £300 million new deep-sea container terminal. Recently, PD Ports (the owner of Teesport) has recently reached an agreement with Tesco (and below) to build a similar logistics centre expected to be four times larger than ASDA's. The first phase of Tesco's facility at Teesport is expected to open next year. PD Ports is pioneering the concept of *port-centric Logistics* in the UK. This concept has already been successfully developed and implemented elsewhere (see for instance the US ports of Galveston/Savannah) and consists of concentrating on shippers, rather than ocean carriers, by providing value-added services (consolidation, break-bulk, postponement, customisation, etc) that integrate their logistics and supply chain processes.

- In supply chain configuration, the degree of network segmentation is closely associated with inventory policies and the nature of supply chain planning processes. Approaches used in network segmentation include process segmentation in terms of lean and agile processes whereby the former focuses on cost efficiency and long-term forecasts while the latter focuses on customer responsiveness and shorter lead times. The differentiating factors between these two processes include the type of products or service (mass-customised and standardise versus customised and innovative), the design and life cycle of the product, the variability of demand, and the volume of production. Clearly, both locational and inventory policies will differ according to the strategy adopted for each type of process; mass customisation, postponement, continuous replenishment, and the planning strategies such as make-to-order (MTO), make-to-stock (MTS), and assemble-to-order (ATO). Each of these factors will impact the decisions on mode and port choice, but ports can be proactive by positioning themselves as key locations for decoupling points. A decoupling point may be defined as the physical point which separates lean processes from agile processes. By identifying shippers' distribution strategies, products' types and alignments, and other relevant aspects on supply chain structure,

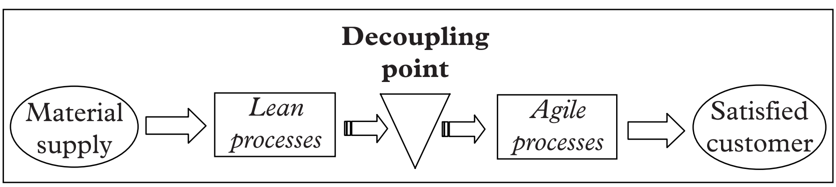

Fig. 10.7: Leagile supply chain configuration (from Towill *et al.*, 2000)

ports can provide platforms for shippers, distributors and logistics providers for locating and managing their product differentiation and customer order decoupling points.

From the discussion above, it can be seen that port management teams are required to redefine their core businesses and competencies so as to accommodate and integrate modern distribution, logistics and supply chain systems. On the one hand, the transport, economic and trade paradigm of ports has a limited capacity to explain the evolution of port operations and management in view of the developments in global logistics and supply chain systems. On the other, the maritime orientation of ports limits their functional and spatial attributes, whereas in a typical port setting a wide portfolio of multi-institutional and cross-functional operations can be undertaken at different spatial dimensions (including at the inland interface) and sectoral and supply chain dimensions. The integration of inland, logistics and supply chain networks could constitute an additional core mission for ports, but this not only requires a new conceptualisation of ports as logistics centres and as elements of value driven supply chains, but also requires a suitable strategy specifically targeted at logistics providers and supply chain stakeholders.

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CHAPTER 11

PORT SAFETY

1 SYSTEM'S SAFETY FOR RISK ASSESSMENT AND MANAGEMENT

Risk can be loosely defined as the exposure to the chance of loss. In the context of port safety, this corresponds to accident risk defined here as the chance, in quantifiable terms, of a hazard or an accident occurrence. It therefore combines a probabilistic measure of the occurrence of an event with a measure of the consequence, or impact, of that event.

$$Risk = Probability * Impact$$

The process of risk assessment and management is generally based on three sets of sequenced and inter-related activities, namely:

- The assessment of risk in terms of what can go wrong, the probability of it going wrong and the possible consequences.
- The management of risk in terms of what can be done, the options and trade-offs available between the costs, the benefits and the risks.
- The impact of risk management decisions and policies on future options and undertakings.

Performing each set of activities requires multi-perspective analysis and modelling of all conceivable sources and impacts of risks as well as viable options for decision making and management. The empiricist approach regards accidents as random events whose frequency is influenced by certain factors. Under this approach, the immediate cause of an accident is known in the system safety literature as a *hazardous event*. A hazardous event has both *causes* and *consequences*. The sum of the consequences constitutes the size of the accident. Hazardous events range in *frequency* and *severity* from high-frequency/low-consequence events, such as road accidents and machine failures, which tend to be routine and well reported, to low-frequency/high-consequence events, such as earthquakes and terrorist attacks, which tend to be rare but more complex. Several analytical tools have been developed for hazard analysis. The choice of tool depends on (i) whether the causes or the consequences of a hazardous event are to be analysed, and (ii) whether the techniques used take into consideration the sequence of the causes or consequences.

	Consequence analysis	**Cause analysis**
Sequence dependent	*Event Tree Analysis*	*Markov Process*
Sequence independent	*Failure Mode and Effects*	*Fault Tree Analysis*

Table 11.1: Major hazard analysis tools

Fig. 11.1: Example of a port accident: crane collapse

The causes of a hazardous event are usually represented by a fault tree which is a logical process that examines all potential events leading up to a critical accident. A popular methodology that relates the occurrence and sequence of different types of incidents is the *Fault Tree Analysis* (FTA). Under the FTA, a mathematical model is fitted to past accident or incident data in order to identify the most influential factors (top events) and estimate their effects on the accident rate. The model is then used to predict the likelihood of future accidents while controlling factor causes. The extent to which the tree is developed (from top to basic events) is usually governed by the availability of data with which to calculate the frequencies of the causes at the extremities of the tree, so that these may be assigned likelihoods. From these, the likelihood of the top event is deduced. FTA has a number of limitations. For instance, the approach assumes that the causes are random and statistically independent but certain common causes can lead to correlations in event probabilities which violate the independence assumptions and could exaggerate the likelihood of an event fault. Furthermore, the method assumes that the sequence of causes is not relevant and that missed or unrecorded causes may equally bias the calculated likelihood of a hazardous event.

The consequences of a hazardous event may be analysed using an event tree. *Event Tree Analysis* (ETA) is a logical process that works the opposite way of FTA by focusing on events that could occur after a critical incident. Under ETA, a statistical analysis of past accidents is performed to estimate the consequences of each type of accident in order to predict the risk of future accidents. This is achieved by multiplying the predicted likelihood by the predicted consequences. However, when estimating the risk of new systems, laboratory tests are used instead of historical data. The event tree approach implies that the events following the initial accident, if they occur, follow a particular sequence. Where a particular sequence is not implied, *Failure Modes and Effects analysis* may be used. This technique seeks to identify the different failure modes that could occur in a system and the effects that these failures would have on the system as a whole.

Most of the general tools described above have been successfully applied across many areas of maritime and port safety, with the Formal Safety Assessment (FSA) being the most standardised framework of risk analysis in regulated maritime systems. The FSA was first developed by the UK maritime and Coast Guard Agency (MCA) and later incorporated into the IMO guidelines for safety assessment. The FSA methodology consists of a five-step process: hazards

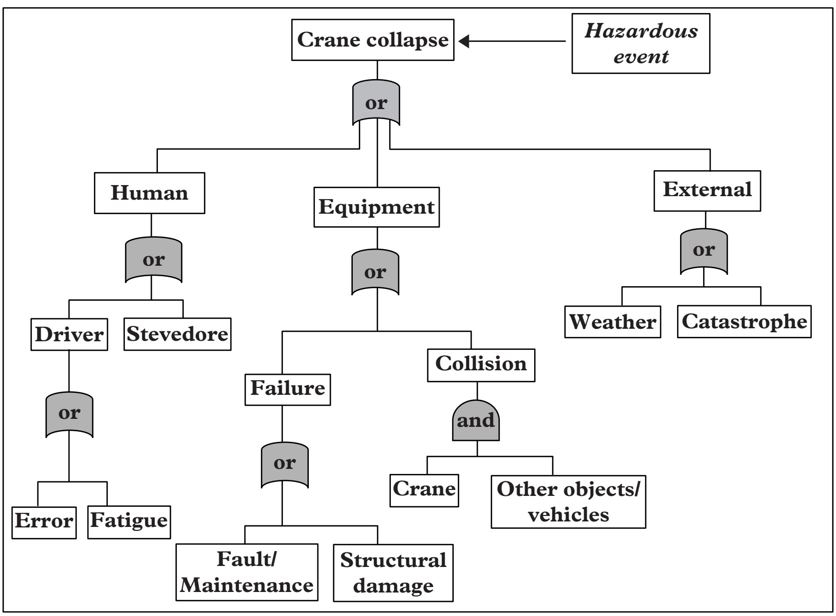

Fig. 11.2: Example of a fault tree analysis

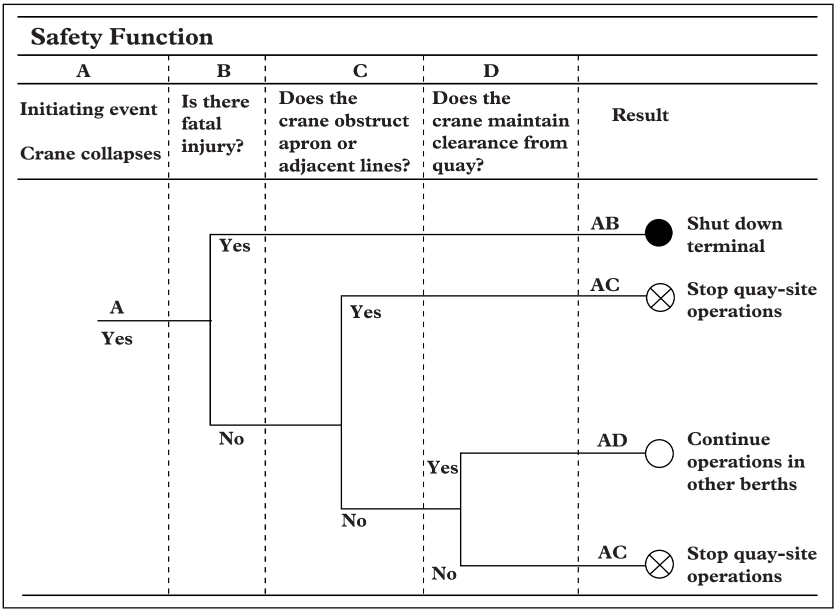

Fig. 11.3: Example of an event tree analysis

identification, risk assessment, risk management, cost benefit analysis, and decision making (MCA, 1996). In risk identification, both individual hazards and their causes should be identified and disaggregated to appropriate levels of detail. FSA tools for hazard identification include the brainstorming technique for hazard identification and the Delphi method for soliciting and collating expert judgement. Primarily, there are no quantitative criteria in FSA but quantitative tools such as quantitative risk assessment (QRA) and probabilistic risk analysis (PRA) can be used as well. Once identified, the level of seriousness of a hazard or an event should be traced down as far as relevant, and should account for various types of impact: human, environmental, economic, social and cultural. Risk assessment is then calculated by combining hazard probability and the magnitude of the impact.

A useful way of classifying and prioritising risks is to use a risk matrix as shown in Figure 11.5 to produce risk ranking numbers or thresholds. Based on the outcome of risk assessment, risk management takes preventative action to reduce the probability of accident occurrence (pre-accident intervention) and/or minimise the probability of fatalities when accidents occur (post-accident intervention). Risk management is usually combined with cost benefit analysis for optimal decision making.

Despite its wide application, the FSA and other similar risk assessment models involve a substantial element of subjective judgement for both the

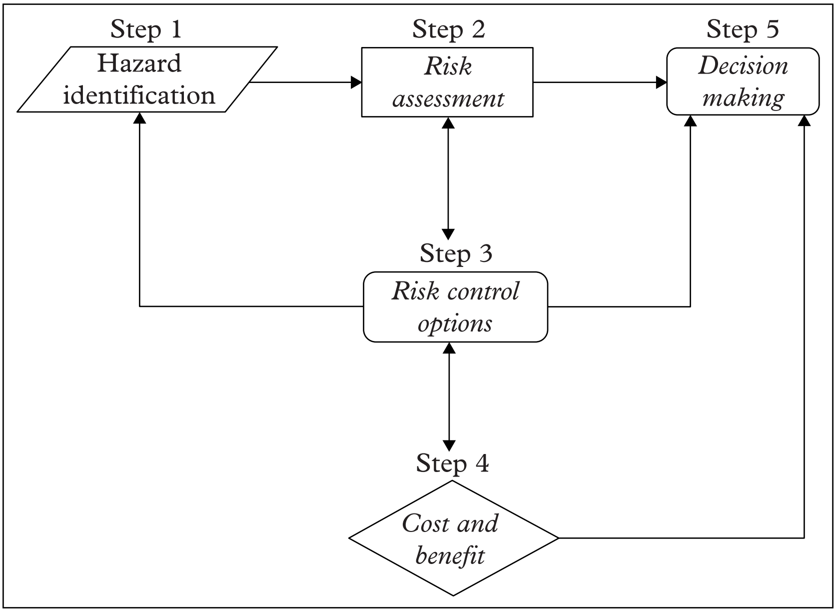

Fig. 11.4: FSA Methodology (MCA, 1996)

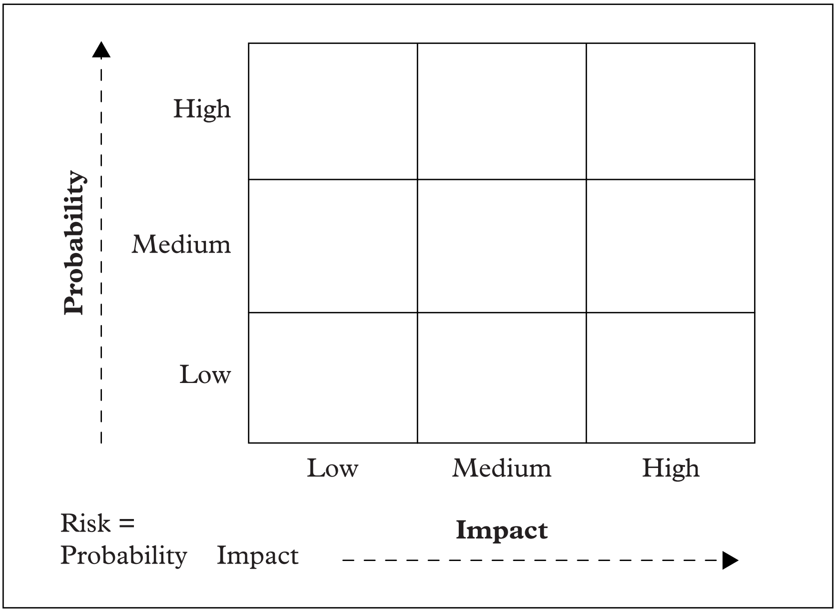

Fig. 11.5: Risk Matrix/Map

causes and the consequences. For instance, the assumption of randomness of the causes of hazardous events is particularly problematic for low frequency high consequence events. In a similar vein, the calculation of the consequences of an accident can also be highly subjective. Furthermore, any valid tool for risk analysis requires that the boundaries, components, and functioning of the system is well established but this is not always evident in the context of port operations given the combination of several elements related to internal (facility, equipment, communication, labour, etc) and external (ships, cargo, external vehicles, etc) factors.

2 RISKS AND SAFETY INDICATORS

Key to any effective safety management system is the use of safety indicators as a tool of mitigation and prevention measures. Most countries use accidents as the primary indicator of port safety, for example the number of accidents per traffic volume or per working hours. The use of reliable accident data has certain advantages. For instance, accidents may be categorised according to their severity into fatal and non-fatal accidents. Accident rates may also be compared over time or between ports for the purpose of achieving safety benchmarks. However, the use of accidents as safety indicators also has a number of shortcomings. In particular, in ports with few fatal accidents over a period of time, one major fatality has the ability to skew the statistics over a number of years. Further difficulties arise when undertaking international comparisons of accident rates.

Precursors are another useful type of safety indicators. A broad definition of precursors may involve any internal or external condition, event, sequence, or any combination of these that precedes and ultimately leads to adverse events. More focused definitions reduce the range of precursors to specific conditions or limit their scope to a specified level of an accident's outcome. For instance, the US nuclear regulatory commission (NRC) defines a precursor as "*any event that exceeds a specified level of severity*", while other organisations incorporate a wider range of severities. In either case, a quantitative threshold may be established for the conditional probability of an incident given a certain precursor, with events of lesser severity considered either as non-precursors with no further analysis or as non-precursors that need categorisation and further investigation.

A particular aspect of precursor analysis is the so-called *near miss* also referred to as the near hit, the close call, or simply the *incident*. The *near miss* is similar to an accident except that it does not necessarily result in a serious injury or damage. It is a particular kind of precursor with elements that can be observed in isolation without the occurrence of an accident. Basing safety indicators on serious and minor incidents is useful because the causal pathways of the latter are similar to those leading to an accident. This argument is even made stronger

	2005–2006	2006–2007	2007–2008
Docks			
Fatal	0	4	3
Major	155	142	174
Over-3-day	709	742	751
Cargo handling			
Fatal	0	1	1
Major	51	43	62
Over-3-day	338	369	414
Other supporting water activities			
Fatal	0	3	0
Major	68	59	76
Over-3-day	260	259	240

Table 11.2: Recent statistics concerning UK port accidents (HSE, 2009)

with much of the literature on reported transport accidents confirming that near misses have usually preceded the actual incidents. Furthermore, the incident rate is particularly useful for organisations with little or no history of major incidents.

Unlike for ship accidents, there is no reliable data on global port accidents. This is largely due to the lack of consistency between ports and countries on the definition and categorisation of port accidents and on how to record, measure, and report them. In the UK, port accidents are published by the Health and Safety Executive (HSE), which collates reported accidents[1] from ports to estimate and categorise accident rates. Other countries have similar national safety agencies, for instance the US National Transport Safety Board and the Australian Transport Safety Bureau.

From the above tables, it is clear that risks and hazards in ports are numerous and may stem from different factors including ships, cargoes, equipment, labour, vehicles, internal standards and procedures. External factors such as earthquakes, typhoons, and heavy weather conditions can also lead to injuries and safety accidents. On the other hand, the losses and damages due to safety

1. HSE covers cargo handling and landside operations, the Maritime and Coast Guard Agency (MCA) deals with issues on board ships and for crew member, and the Marine Accident Investigation Branch (MAIB) investigate accidents at sea. Similar institutional arrangements exist in other countries, eg Australia, Canada, China, Germany, Japan, and the USA.

	Total fatalities	Event or exposure					
		Transport incidents	**Assaults and violent acts**	**Contact with objects/ equipment**	**Falls**	**Exposure to harmful substance or environment**	**Fires and explosions**
Port and Harbour Operations	**4**	**3**	–	–	–	–	–
Marine Cargo Handling	**11**	**8**	–	–	–	–	–
Navigational Services to Shipping	7	**4**	–	–	–	–	–

Table 11.3: Fatal occupational injuries in US ports in 2007 (Bureau of Labour Statistics, 2008)

Cause	**Fatal**	**Serious**	**Minor**	**Total**
Machinery or mechanical appliances	0	1	2	3
Explosion or fire	0	0	1	1
Hot or corrosive substances	0	0	1	1
Electricity	0	0	1	1
Falls of person	1	16	19	36
Stepping on or striking objects or slipping	0	1	50	51
Falling or swinging objects	0	23	67	90
Manual handling	0	0	21	21
Hand tools	0	0	1	1
Foreign bodies in eyes	0	0	2	2
Towing or mooring	0	0	1	1
Defective equipment	0	0	0	0
Boarding or disembarking vessels	0	1	4	5
Gassing, poisonous or toxic substances	0	0	0	0
Miscellaneous, unknown or unclassifiable	0	0	7	7
Total	**1**	**42**	**177**	**220**

Table 11.4: Casualties in cargo handling accidents in Hong Kong 2008 (Hong Kong Marine Department, 2009)

accidents include, in addition to human injuries and fatalities, operational, socio-economic and environmental losses.

Most studies have shown that the majority of safety accidents are attributed to human error. However, there is no detailed taxonomy or consistent hierarchy of human errors that contributes to the occurrence of injuries or damages in ports and terminals. Despite this, factors such as inadequate safety plans and procedures, adverse working conditions, poor safety training, and inappropriate safety cultures are widely recognised as common causes of major incidents across different types of ports and terminals. Further discussion on employer's safety perception and corporate social responsibility is provided in Chapter 14 of this book.

However, unlike ship safety, there is no comprehensive international convention on port safety although some international conventions targeting specific port and cargo operations already exist, for instance the International Convention for Safe Containers (CSC), the International Maritime Dangerous Goods

Cargo	Description	Associated hazards
General	Forest products, steel, scrap etc	Falls from cargo, hatches, unfenced non-working dock/wharf edges, unsafe lifting operations, collapse of load, transport, access-egress
Bulk-solid	Coal, grain, aggregate, fertiliser including ammonium nitrate	Dust, transport, falls from ships' hold access, unguarded machinery, confined spaces, access, explosion of badly stored ammonium nitrate
Bulk-liquid	LPG, oil	Fire, explosion, confined spaces, access
Containerised load on/load off (lo-lo)	Containers lifted by crane on/off ship	Transport especially in container terminal, falls from containers, unsafe cargo securing (aka lashing) points on ship, MSD in crane operators, exposure to fumigants in containers, struck by doors or goods of overstuffed containers
Containerised roll on/roll off (Ro-Ro)	Containers taken by tug and trailer or LGV on/off ship-cars also transported on Ro-Ro vessels	As above, also transport on ramp and during lashing, noise, struck by over-tensioned lashings, exposure to vehicle fumes in older ships
Passenger ferries and cruise liners		Baggage manual handling at cruise terminals. Transport, especially segregation of passengers/traffic. Ro-Ro vessels also often carry passengers.

Table 11.5: Hazards associated with cargo types and operations (HSE, 2009)

Code (IMDG Code), the Code of Safe Practice for Cargo Stowage and Securing (CSS Code), and a series of regulations and guidelines for carrying out port state control (PSC) as outlined in the IMO procedures for PSC. PSC, as opposed to flag state control, is an effective tool for carrying out safety and environmental inspections on foreign ships in host ports and there are various Memoranda of Understanding (MoUs) which cover almost all sectors and regions of maritime trading. Otherwise, numerous regulatory programmes and safety guidelines for port and terminal operations exist at both national and regional levels (see for instance the UK Port Marine Safety Code of 1995).

3 VALUING PORT SAFETY

3.1 Value of Preventing Human Losses and Injuries

An important element in any valuation method of decision making is the cost of preventing a fatality (CPF) and other principal losses in transport and infrastructure, a key component of which stems from human casualties, that is fatalities and injuries. In most countries, specific regulatory frameworks set out the value of preventing a fatality (VPF) and other values for the prevention of injuries on transport infrastructure. Broadly, the purpose of VPF is to provide a means of valuing the benefits of accident savings in the cost benefit analysis of transport projects. For example, the UK currently operates with a VPF of just over £1.38 million while the USA uses a VPF figure of around $6 million. This variation may stem from different methods of calculations, social priorities and values, or other reasons.

However, since the value of preventing these losses are based on life saving rather than observable market transactions of risk reduction, most economists believe that these valuations should be based on the preferences of those who benefit from safety measures and who also pay for them, either directly or through taxation. These do not correspond to the value of a life or to the amount that the public is willing to pay to save the life of an unknown or specific individual.

In the context of casualty prevention, these preferences are often measured using the *willingness to pay* (WTP) approach, that is the amount that the average member of the general public is willing to pay to reduce the level of risk to the average victim. The WTP approach has been extensively used in the context of road safety, but little literature exists on the use of the methodology in the context of port safety.

There are two major empirical approaches to estimating WTP values for risk reductions, namely the *revealed preference method* (RPM) and the *stated preference method* (SPM). RPM involves identifying situations where people (or society) actually trade off money against risk, such as when they may buy safety (or security) measures or when they may take more or less risky jobs for more or less wages. SPM on the other hand involves asking people more or less directly about their hypothetical willingness to pay for safety/security measures that give them specified reductions in risk in specified contexts. In either case, the assessment of the weights of different types of harm should reflect the views and perceptions of both the general public and the people affected. In the first case, generic assessments are conducted to establish a baseline based on measuring society's attitude to safety. In the second case, targeted assessments are conducted because the concerns of specific members of the society would not be adequately reflected in the results of general engagement.

In the UK, VPF figures have been published since 1969. This was primarily for the assessment of highway schemes benefits, but was then extended to include road and rail safety measures, and the same values are applied to other modes of transport. Figure 11.6 plots the VPF for roads, which is also valid for

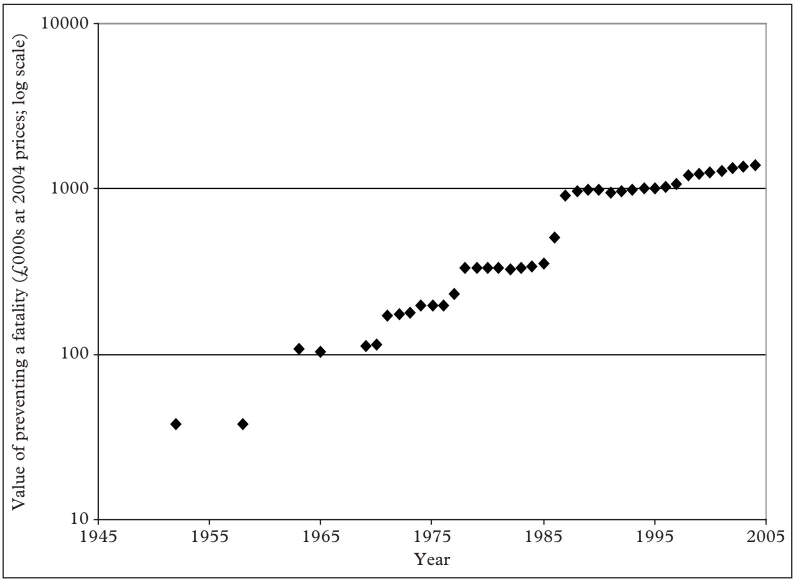

Fig. 11.6: UK valuations of preventing a road fatality at constant 2004 prices (Evans, 2006)

port and maritime transport, since 1952 at constant 2004 prices; the original current prices are re-valued using the RPI (retail prices index). It can be seen that the pattern is one of occasional sharp upward jumps at particular dates, with the last important change being made in 1987, when the WTP principle was adopted and the VPF was set at £500,000 at current prices.

3.2 Wider Effects of Accidents

In addition to casualties, accidents cause damage, disruption and investigation costs. All these direct effects have costs, and the benefits of reducing accidents include avoiding these costs. These benefits should obviously be included in safety appraisals.

It is also possible that accidents may have wider effects than these direct effects. The two obvious possibilities are:

- the public might change their behaviour and perhaps cease to use a transport system that had had an accident, and
- one or more of the involved organisations (operators, government, regulators, etc) might make decisions that they would not make except in the aftermath of an accident.

Both of these involve costs which could have been avoided if the accident had been avoided in the first place. Therefore, it is arguable that the benefits of avoiding accidents should include the avoidance of these indirect costs.

CHAPTER 12

PORT SECURITY

1 SCOPE AND NATURE OF SECURITY THREATS TO PORTS

1.1 New Dimensions to Port Security under the Threat of Terrorism

Just as past maritime disasters (Exxon Valdez, Erika, etc) have fostered further changes to environmental management, the 9/11 attack has led to an increase in maritime security:

- First, physical assets of the transport and logistics system are perceived not only as targets but also as means to carry out terrorist attacks. Vehicles and ships, goods and cargo, equipment and facilities can all serve as weapons of destruction and terrorism. The same applies to non-physical components, such as information and payment flows that can be used as communication and financial resources by terrorists. The latter aspect is essential in the context of risk analysis since it adds on a new dimension to maritime security.
- Second, with domestic issues being increasingly linked to international terrorism, previously perceived differential risk levels have now been equated and altered up to the maximum global scale. As it has been revealed recently, drug smuggling, cargo theft, piracy, illegal immigration and human trafficking are all used by inter-connected local cells as a means of financial, operational, and organisational structuring of international terrorism. Ports throughout the world need therefore to perceive and manage security threats by integrating local/domestic threat levels into a global awareness level.
- Third, the response to a large security attack should not only remind us of the wider impacts on international trade and transport, but also on global logistics and production systems. For instance, the immediate US response to the 9/11 attack (closing borders, shutting down the traffic system and evacuating government/company buildings) has caused huge delays and disruptions; with many domestic companies purchasing, outsourcing, manufacturing, and selling products and services on a global and worldwide basis. The economic and financial cost of such disruptions will be

overwhelmingly high if an attack is to involve strategic cargoes such as oil and gas supplies, or target key networks such as busy ports (transhipment, network or multimodal ports) and maritime links (e.g straits of Gibraltar and Malacca, Suez and Panama canals).

- Last, but not the least, as the threat of international terrorism is far from being over, firms should manage and organise their logistics and supply chains under increased risk and uncertainty. Companies should acknowledge the vulnerability of terrorism to both in-house logistics and shared supply chain networking systems and thus rely more on agile and collaborative relationships. This is to suggest that the traditional fragmented and conflicting channel relationships in ports and shipping must be replaced by closer partnership arrangements.

1.2 Security Threats and Risk Factors in Ports

Ports throughout the world have developed in different ways with a combination of economic, spatial, political, social, and even cultural and military influences, and thus no clear pattern of institutional or functional attributes of ports was produced. However, in the context of international shipping and logistics, ports are identified as key locations where various members of the logistics and trade system can meet and interact and thus they are the most likely to be targeted by terrorists. Moreover, due to their close spatial interactions with large city agglomerations and seashore tourist attractions, ports may also be the subject of large environmental disasters or deliberate maritime/inter-modal accidents, hence adding extra security threats and further complicating security and risk management systems. Two main components should be examined while assessing risk factors in ports: physical assets and facilities versus non-physical flows and processes.

1.2.1 Assets, facilities and physical movements of cargo

The first set includes vessels, inland vehicles and their equipment, port assets and facilities (both infrastructure and superstructure), goods and cargo (both in ports and onboard ships and vehicles), shore and ship-based personnel as well as other individuals within the port estate (operators, users, etc). Apart from cargo, none of the other assets (vessels and vehicles, people, equipment and facilities) pose a serious threat to security if systematically and safely monitored. Assuming that ports effectively invest in and successfully implement integrated security systems, then any potential risk can be identified and properly dealt with when applicable. In addition to enhancing security plans and procedures, ports can also undertake a number of measures to lower or cancel out security threats; ranging from regularly checking and reviewing port facilities to detaining ships or denying access to port premises.

Cargo and cargo movement, on the other hand, pose a higher security threat to ports than all other assets combined. Transported cargo may be in different forms (liquid, dry bulk, break bulk, unitised, etc), and can also change form while in ports or at inter-modal interfaces. Cargo also entails a high volume of complex movements and operations while in ports, including loading and discharging operations, trans-shipment, storing and warehousing, logistics services and value-added activities. As in the case of Less than Container Load (LCL) consignments, goods are handled, stored and shifted many times before being shipped to or from the port, thus generating complex and highly vulnerable cargo-flow patterns and processes.

1.2.2 Non-physical flows and processes

The second set of risks refers to non-tangible flows associated with vehicle/cargo movement and operations in and around ports. Apart from physical flows of cargo, capital, payment and information flows are all common to commercial-cargo ports, and thus they can all be used as a means of financing, communicating, and/or providing logistical support by and for terrorists. The major challenge is that the derived risk is usually perceived at different levels amid supply chain members, including ports. While some shippers strive to secure highly integrated supply chains, for instance by heavily investing in secure IT and communication systems; many manufacturers still trade at arms' length arrangements, hence running higher vulnerability and risk exposure. But even when relatively good levels of protection are put in place, shippers cannot always ensure highly secured distribution channels; with many of their shipments nowadays being trans-shipped, temporarily stored, and/or mixed with other cargo before reaching the ultimate customer. The role of ports in gathering and detecting all these flow types is central to security-risk analysis, and thus much emphasis should be placed on assessing the interactions in ports of non-tangible flows and processes.

2 OVERVIEW OF PORT SECURITY PROGRAMMES

The security of international shipping and port operations had 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 set 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 11 September 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 Organization (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 levels with the US-led 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, 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 (hereafter referred to as the 24-hour rule), the Customs and Trade Partnership against Terrorism (C-TPAT), the Operation Safe Commerce (OSC), the Transportation Worker Identification Credential (TWIC) programme, the mega-port initiative and the Secure Freight Initiative (SFI). Except for the 24-hour rule, these programmes and others have later been codified into the US Safe Port Act.

Initiatives have also emerged from the European Commission (EC) in the guise of EC Regulation 725/2004 on enhancing ship and port facility security, Regulation 884/2005 laying down procedures for conducting Commission inspections in maritime security, the Directive 2005/65/EC extending security measures from the ship–port interface to the entire port facility, and the Authorised Economic Operator (AEO). Outside the EU, regional initiatives that are worth mentioning include the US–Canada–Mexico Free and Secure Trade (FAST) initiative, the ASEAN/Japan Maritime Transport Security, and the Secure Trade in the APEC Region (STAR) for Asia Pacific. The Secured Export Partnership (SIP) is a bilateral customs security arrangement designed to protect cargo exported from New Zealand to the USA against tampering, sabotage, smuggling of terrorists or terrorist-related goods, and other transnational crime, from the point of packing to delivery. On the national level, new security programmes include Canada's and Mexico's own 24-hour rules, the Swedish Stair-Sec initiative and the New Zealand Secured Export Partnership (SEP).

A third set of security initiatives consists of primarily industry-led and voluntary programmes. Initiatives under this category include the Secured Export Partnership (SEP) programme, the ISO/PAS 28000:2005 standard (specification for security management systems for the supply chain), the Technology Asset Protection Association (TAPA) initiative, a series of Partnership in Protection (PIP) arrangements, 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 port network.

2.1 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 (ie 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. Unlike ship security where the ISPS Code requires an international independent certification every five years—the ISPS Code for ports, the accreditation and period of validity for PFSA and the statement of compliance of PFSP are decided by contracting governments.

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 (*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 also provide 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. Table 12.2 shows a ship's ISPS pre-arrival information pro-forma in UK ports, while Appendix 1 provides the list of port security equipment required by the ISPS Code.

Table 12.1: Outline of ISPS code and selected US-led port and maritime security measures

	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 and drills. 5. Nominate designated authority and RSO. Approve, review and certify SSP, PFSP/PFSA. Set and notify appropriate security levels. Issue CSR. Issue and verify ISSC. Exercise compliance measures. Communicate information to IMO	1/2. ISSC issued by flag-state government or RSO (eg 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 and inspection	Validation process and risk assessment mechanism (updated regularly)
	24-hour 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/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

AIS: Automated Identification System, AMS: Automated Manifest System, ACS: Automated Commercial System, ATS: Automated Targeting System, CBP: US Customs and 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.

1	Name of Ship			
2	IMO Number			
3	Registered Flag State			
4	Date of ship's last visit to UK			
5	Dangerous Goods carried (over 10 kg) and UN Class No.			
6	Does the ship have a valid ISSC? If this is the 1st visit to this Port, provide a copy of the ISSC	YES	NO—detail why? Does it have an approved SSP?	
7	What security level is the ship operating at?	1	2	3
8	What were the last 10 ports of call and what were the security levels of the ship during those ship/port interfaces? Start with No. 1 as the most recent port visited.	Port and country	Date visited	Security level
		1		SL =
		2		SL =
		3		SL =
		4		SL =
		5		SL =
		6		SL =
		7		SL =
		8		SL =
		9		SL =
		10		SL =
9	Have any special security arrangements been taken by the ship during ship/port interface at the last 10 ports of call?	YES—detail location and date		NO
10	Have appropriate security procedures been followed during any ship/ship activity during the last 10 ports of call, for example have these interactions been governed by the security requirements in the SSP?	NO—please detail location and date		YES
11	Any other practical security-related information, for example have you witnessed any suspicious activity during the voyage?	YES—detail location and date		NO

Table 12.2: Standard ship's ISPS pre-arrival information pro-forma in UK ports

2.2 The US 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 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 to 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 12.3).

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

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	Antwerp, Zeebrugge (Belgium); Piraeus (Greece); Rotterdam (Holland); Bremerhaven, Hamburg (Germany); Le Havre, Marseille (France); Gothenburg (Sweden); La Spezia, Genoa, Naples, Gioia Tauro, Livorno (Italy); Felixstowe, Liverpool, Thames-port, Tilbury, Southampton (UK); Algeciras, Barcelona, Valencia (Spain); Lisbon (Portugal)
Asia and the East	Singapore (Singapore); Hong Kong, Shenzhen, Shanghai (China); Yokohama, Tokyo, Nagoya, Kobe (Japan); Busan (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)

Table 12.3: Active participating ports in the US CSI as of 30/03/2007 (*Source:* CBP, 2007).

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 was recently deployed in three container ports namely 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.

2.3 The US 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 analyse the containers' content information and identify potential terrorist threats before the 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.

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 harmonised 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

Table 12.4: Data required for electronic reporting under the US 24-hour rule (CBP, 2007)

Under the 24-hour rule, 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 12.4). 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 12.1. The 24-hour rule was enforced on 4 May 2003 and was fully implemented in 99% of the ports with direct export traffic to the USA in January 2005. The 24-hour rule has since then expanded to countries such as Canada and Mexico. 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, as against the originally targeted June 2009 start date.

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. Figure 12.2 describes the US CBP screening process for inbound container cargo and

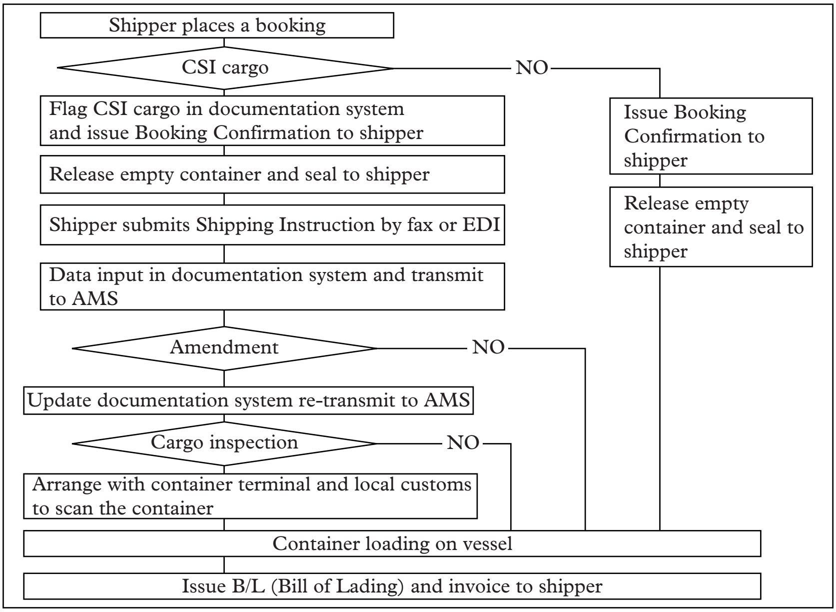

Fig. 12.1: A decision support system to implement the 24-hour rule (Bichou *et al.*, 2007a,b)

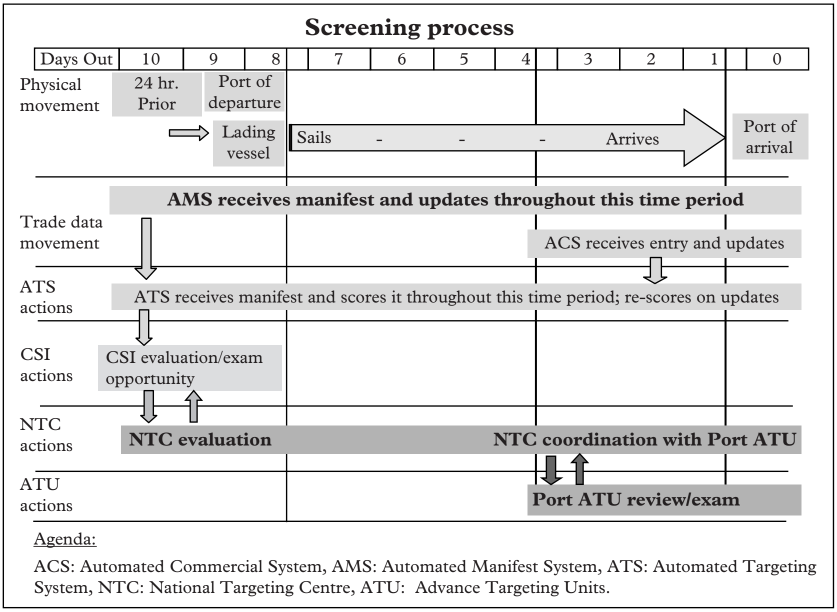

Fig. 12.2: The screening process combining actions from the 24-hour rule and the CSI (adapted from Hercules, 2006)

provides a basis for understanding the relationship between the CSI and the 24-hour rule. 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.

2.4 Customs-Trade Partnership against Terrorism (C-TPAT)

The US Customs-Trade Partnership against Terrorism (C-TPAT) is a joint government-business initiative to build cooperative relationships that strengthen overall supply chain and border security. Under a C-TPAT partnership agreement, participants must provide reliable and verifiable security information about their suppliers in exchange for preferential treatment during customs inspections and expedited procedures. Initially, only importers and carriers based in the USA were eligible to participate in this programme, but this has been extended to both non-importers and foreign supply chain members. As shown in Table 12.5, CBP specifies 10 enrolment categories for C-TPAT par-

1.	US. Importer of Record
2.	US/Canada Highway Carrier
3.	US/Mexico Highway Carrier
4.	Rail Carrier
5.	Sea Carrier
6.	Air Carrier
7.	US Marine Port
8.	Authority/Terminal Operator
9.	US Air Freight Consolidator
10.	Ocean Transportation Intermediary, or Non-Vessel Operating Common Carrier

Table 12.5: The CBP enrolment categories for C-TPAT participation
(*Source:* CBP, 2007).

ticipation including for ship owners and operators. C-TPAT participants must sign an agreement that commits them to the followings:

- Conduct a comprehensive self-assessment of supply chain security, using C-TPAT security guidelines. The latter encompass such areas as procedural security, physical security, personnel security, education and training, access controls, manifest procedures, conveyance security.
- Submit a supply chain security profile questionnaire to CBP.
- Develop and implement a programme to enhance the security throughout the supply chain in accordance with C-TPAT guidelines.
- Communicate C-TPAT guidelines to other companies within the supply chain and work towards building the guidelines into the relationships with these companies.

Under C-TPAT, foreign-based marine port authority and terminal operators (MPTO) may be eligible for membership of the C-TPAT scheme but only following an invitation from CBP to join. The terminal must handle cargo vessels departing to the US and have a designated company officer who will be the primary cargo security officer responsible for C-TPAT. ISPS and MTSA compliance are a prerequisite for C-TPAT MPTO membership, and only terminals in compliance with the applicable ISPS code requirements may be utilised by C-TPAT members. At the time of writing this book, DP World was the only international non-US operator to be certified as C-TPAT compliant.

2.5 The EU Authorised Economic Operator (EAO)

This designates the status that customs authorities of European member states should grant to reliable traders established in the European Community.

AEOs will be able to benefit from facilitations for customs controls or simplifications for customs rules or both, depending on the type of AEO certificate. However, such benefits will not be fully realised until the requirements for pre-arrival and pre-departure are introduced in July 2009 and the changes linked to the Modernised Customs Code are introduced, probably sometime in 2010. The AEO programme specifies three certificate types:

- *Customs Simplifications*: AEOs will be entitled to benefit from simplifications provided for under the customs rules.
- *Security and Safety*: AEOs will be entitled to benefit from facilitations of customs controls relating to security and safety on the entry of the goods into the customs territory of the Community, or when the goods leave the customs territory of the Community.
- *Customs Simplifications/Security and Safety*, a combination of (a) and (b): AEOs will be entitled to benefit from both simplifications provided for under the customs rules and from facilitations of customs controls relating to security and safety.

2.6 The Swedish Stair-Sec Programme

This is a new module introduced to the Swedish Customs programme Stairway (originally created to facilitate customs processes for compliant traders). This module makes it possible to provide quality assurance for operators within the Stairway not only for quality in their customs routines but also for the security measures they have taken to prevent terrorists from using the operators commercial flow of goods for transporting weapons of mass destruction.

2.7 The US–New Zealand Secured Export Partnership

This is a New Zealand-based programme designed to protect cargo against tampering, sabotage, smuggling of terrorists or terrorist-related goods, and other trans-national crime, from the point of packing to delivery. Exporters from New Zealand are eligible and encouraged to participate, especially those moving goods to the US. The programme emphasises that security measures are customisable depending on the applicant's situation.

2.8 Industry-led Programmes

In addition to statutory programmes, a number of primarily industry-led and voluntary initiatives have been introduced since the events of 11 September 2001. Relevant initiatives include the Smart Security Trade-lanes (SST) programme, the Business Anti-Smuggling Coalition (BASC) scheme, the Secured Export Partnership (SEP) programme, the ISO/PAS 28000:2005 standard for supply chain security, and the Technology Asset Protection Association (TAPA) initiative. Although some of these programmes have not been fully implemented as yet, it is believed that they will yield a more effective framework and a higher level of security assurance across and beyond the maritime network.

2.8.1 Smart and secure trade-lanes (SST)

The SST programme was launched in October 2002 by the strategic council on security technology (SCST). SST's objective is to provide physical security and real-time visibility for tracking global container movements through the incorporation of a range of automatic identification technologies such as anti-intrusion sensor devices, Radio Frequency. In May 2003, the International Organization for Standardization (ISO) formally became involved with the SST programme to gain insight into set international supply chain security and visibility standards. As of mid-2004, SST has had 72 company participants worldwide.

2.8.2 Business alliance for secured commerce (BASC)

BASC, formerly known as the Business Anti-Smuggling Coalition, is a cooperation programme between the private sector and national and international organisations created to promote secure and legitimate global trade and supply chain systems with particular emphasis on anti-smuggling procedures. BASC procedures require a security program which consists of a number of operating measures adopted to protect an organisation, its assets, properties, employees and customers.

2.8.3 ISO 28000 for supply chain security

The ISO 28000 (Specification for security management systems for the supply chain) was developed by the International Standards Organization (ISO) to complement the WCO Framework of Standards without attempting to cover specific customs' agency requirements. ISO 28000 was launched in November 2005 as a publicly available specification (PAS) and is now a fully fledged ISO standard. Other relevant ISO standards include:

- ISO 28001:2007 "Security management systems for the supply chain—Best practices for implementing supply chain security—Assessments and plans"
- ISO 28003:2007 "Security management for the supply chain—Requirements for audit and certification of supply chain management security systems"
- ISO 28004:2007 "Security management for the supply chain—Guidelines for the implementation of ISO/PAS 28000"
- ISO 20858:2007 "Ship and marine technology—Maritime PFSAs and security plan development"

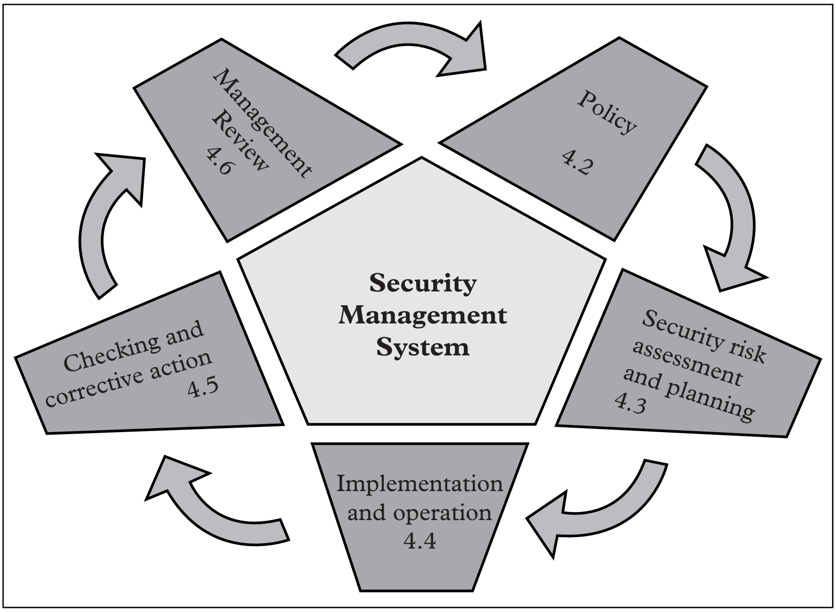

Fig. 12.3: Continual improvement under a supply chain security management system

The ISO 28000 standard is applicable to all sizes and types of organisations at any stage of the supply chain process. It outlines the procedures for an organisation to implement and maintain a security management system with the objective of assuring the security of critical aspects in the supply chain including the financing, manufacturing, information management, warehousing and transportation of goods and services across modes and locations. The key sections in the ISO 28000 are the security risk assessment process, the operational control process and the emergency preparedness process. The standard relies on the principle of continual improvement through management review as shown in Figure 12.3.

3 RISK APPROACH TO PORT SECURITY

3.1 Current Approaches to Port Security

The primary aim of port security assessment models is to assess the level of security within and across the port network. When introducing the risk factor, the concept and measure of uncertainty are to be considered. For risk identification and assessment, ETA and FTA are the two main tools generally used (see Chapter 11). An example of applying ETA (FTA) to port security in relation to the ISPS code would be to categorise and grade scenario-risks

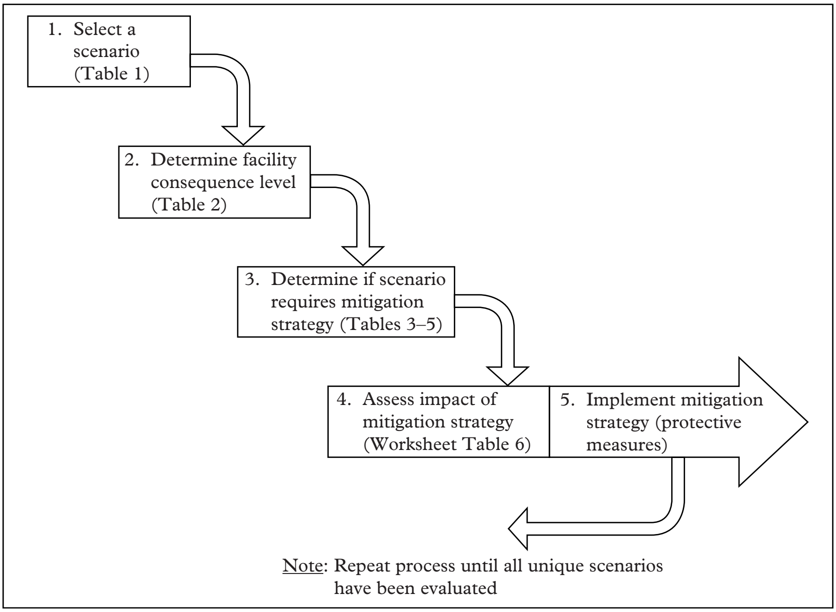

Fig. 12.4: The NVIC risk assessment model

(accidents) according to their overall threat (impact) potentials using a rating scale system from (1) for minor to (3) for severe to fit into the ISPS provisions of MARSEC levels.

Prior to considering the development, application and adequacy of standard risk assessment and management techniques to maritime security, it is important to recognise the nature and limitations of the regulatory context in which the maritime industry works and operates, especially at the international level. In principle, international regulatory instruments provide general guidelines for compliance and implementation, while the development and management of detailed risk-based models are entrusted down to governmental agencies, authorised organisations by them such as classification societies and RSOs in the case of the ISPS code, and/or industry participants. When managing risk through legislation, regulatory assessment models are undertaken to examine the impact of policy options in terms of the costs, benefits and risks of a regulatory proposal. For the ISPS code, examples of regulatory risk assessment models include the US National Risk Assessment Tool (N-RAT) and the UK Regulatory Impact Assessment (RIA) (see Appendix 2).

A typical example of port security risk models based on system's safety is the widely accepted Navigation Vessel Inspection Circular (NVIC) No. 11-02 "*Recommended Security Guidelines for Facilities*" published by the US Coast Guard, and indicated in Figure 12.4. In the UK, the processes which should be taken in order to formalise PFSA and PFSP provisions are depicted in Figure 12.5.

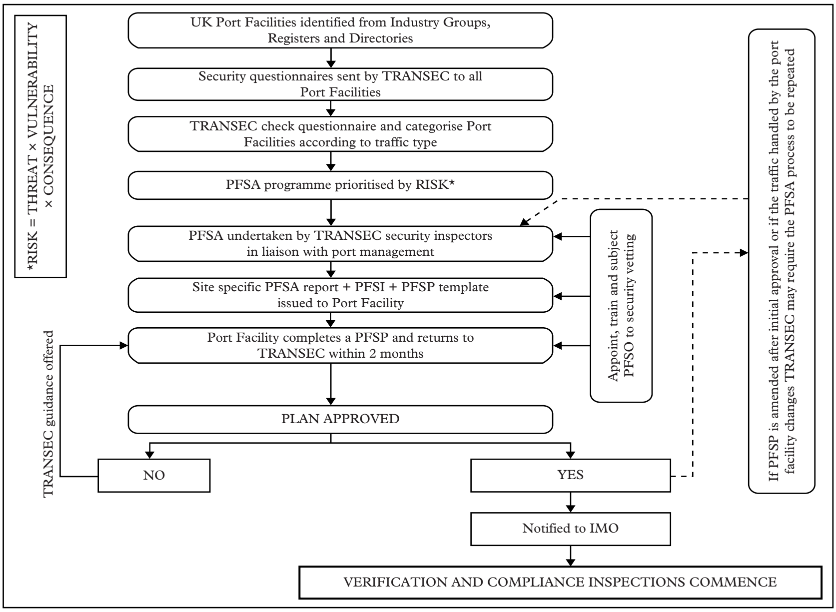

Fig. 12.5: PFSA and PFSP processes
(*Source:* TRANSEC).

3.2 Shortcomings of the Conventional Approach to Port Security Risk

The NVIC model and other conventional risk models follow a safety-risk approach but the latter is based on the assumption of unintentional human and system behaviour to cause harm. This is not the case for security incidents stemming from terrorism or other malicious acts. Another major problem with assessing security threats is that much of the assessment process is intelligence-based, which does not always follow the scrutiny of statistical reasoning. Even with a sound intelligence risk approach, there are many uncertainties involved such as in terms of higher levels of noise in background data. An additional instance of inadequacy of conventional risk models to port security is the lack of historical data and data on the scope and levels of externalities given the rarity of occurrence of large-scale terrorist incidents.

A further difficulty stems from the dissimilarity between stakeholders' perceptions as to the allocation and distribution of the costs and benefits associated with a precautionary policy decision or a new regulatory programme. Page (1978) has described some of these problems in the context of environmental risk management, which can also be relevant to the issues related to security risk assessment, including:

- Poor knowledge of the processes that determine the probability and impact of the risk.

- Potential for catastrophic loss in that the occurrence of a terrorist event would engender great individual, corporate and societal losses.
- Combination of low subjective probability, high uncertainty and lack of consensus.
- Rarity of the occurrence of similar events with few estimates based on historical figures.
- Unclear pattern regarding the value, allocation, transfer and distribution of costs and benefits among both participating and non-participating parties.

In addition to the above, two main drawbacks of port security regulations in relation to risk assessment and management are worth discussing: the inconsistencies in the current maritime and port reporting system and the failure to consider the supply chain dimension of security.

3.2.1 Reporting systems and port security

Following the events of 11 September 2001, several organisations have designed and implemented reporting systems for security incidents/accidents with the most recognisable reporting system being the colour alert system used by the US Department of Homeland Security (DHS). Relevant examples in maritime security include the International Maritime Organisation (IMO) reporting system for ISPS compliance and the International Maritime Bureau (IMB) reports of piracy accidents.

A major drawback resulting from the combination of warning thresholds and security event reporting is that the system may depict several flaws and errors. If vulnerabilities are defined too precisely or the threshold is set too high, several risk-significant events may not be reported. On the other hand, setting the threshold for reporting too low may overwhelm the system by depicting many false alarms, and ultimately a loss of trust in the system. Table 12.6 shows the types of errors that may occur given these conflicting approaches. Type I error refers to a false negative and occurs in situations of missed signals when an accident occurs with no warning being issued. Type II error refers to a false positive whereby a false alert is issued, leading for instance to mass evacuation or a general disturbance of the system.

	Significant	**Not significant**
Event reported	True positive (significant event)	False positive *(Type II error)*
Event not reported	False negative *(Type I error)*	True negative (non-significant event)

Table 12.6: Errors resulting from the interplay between threshold settings and event reporting

Another issue arising from reporting security incidents under regulatory constraints relates to the fact that reported data remains in the hands of the regulator. This raises questions about (i) the reliability and validity of information since fears of regulatory actions may discourage organisations from reporting incidents and (ii) the dissemination of reported information given that the regulator may restrict access to data which is considered too sensitive to be shared. The argument here is that the aim of reporting must emphasise organisational learning along with a guarantee of privacy and immunity from penalties for those reporting incidents.

In port security, implementing programmes of security assessment based on incident indicators would have a number of benefits including for such aspects as identifying unknown failure modes and analysing the effectiveness of actions taken to reduce the security risk. Another opportunity from incident rate analysis is the development of trends in reported data, which may be used for the purpose of risk management and mitigation. Despite this, there is no formal categorisation between incident and accident reporting in shipping and ports. Furthermore, we are not aware of any formal precursor programme being implemented in the context of maritime security, except for on-going research into potential security hazards for liquid-bulk and specialised ports such as LNG/LPG terminals.

One of the major changes brought about by maritime and shipping security is that further documentation and screening for the cargo being transported by sea is now required. However, such requirements are not always consistent between regulations or countries. An instance of anomalies in maritime reporting and documentation systems is when ships and their cargoes become exempt from regular customs inspections when sailing between ports of countries belonging to the same trading or economic block such as the EU or NAFTA. In the EU for example, Member States of the European Union enjoy the freedom of moving goods within the Community, which means that as long as consignments originate within the EU, there are no controls concerning their movement. The issue of the exemption of Authorised Regular Shipping Services from Customs Reporting Regimes gives rise to anomalies in the reporting of cargoes, as it is very likely that such vessels are not only carrying goods of EU Origin but also consignments under Community Transit Customs control, or sometimes cargo originating from outside the EU. Unless that cargo is individually reported as being in separate containers or trailers, or the vessel itself is registered within the EU, the cargo may not be declared and its content may be unclear. Vessels sailing in EU territorial waters may also be carrying consignments on a consolidated basis and for which there is only brief summary details referring to the consolidation, and not necessarily for each individual grouped consignment.

To avoid such anomalies, countries such as the USA have introduced detailed documentation and reporting systems such as through the 24-hour rule. However, because of the requirements of such levels of details under the new security regulations, shipping lines and their agents may fail to produce the relevant documentation and related detailed cargo description so as to conform

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 ICT)	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	Ship/port planning Release of empty container Coordination with terminals and customers for cargo inspection

Table 12.7: Potential errors from implementing the 24-hour rule
(*Source:* Bichou *et al.*, 2007).

to the 24-hour rule and other maritime security requirements. A sample of potential errors that might occur in the work processes while satisfying maritime security is provided in Table 12.7.

Even with detailed procedural regulations such as the 24-hour rule, full and accurate information regarding cargo movement and ownership throughout the supply chain may not be readily available to regulators or customs authorities. This is typically the case when using a combination of transport modes (multimodal transportation) and consolidation arrangements. For the latter, the description of LCL consignments in terms such as "*freight of all kinds*" (FAK) creates a vacuum in information transparency and accessibility as far as the carriage of goods on groupage consignment is concerned. A more radical example is that of a consignment described loosely as "Cosmetic Products", which may contain commodities ranging from aromatic oils through soaps to lipsticks and nail varnish. However, the consignment may also include items such as nail varnish remover, which is classed in Hazardous Goods because of its flammable nature, but since the overall groupage consignment description made no mention of this, the specific commodity was overlooked and no specific Dangerous Goods documentation was issued for the nail varnish remover, despite the evident risk involved in the shipment of the consignment.

The nature of the international supply chain demands that information pertaining to cargo is passed down the line from Supplier to Customer in order to ensure the smooth and efficient despatch and delivery of the consignment, and that all authorities and parties within the supply chain, especially from a transportation and national control perspective, are fully informed as to the nature and risk of the consignment in question. Even when no international frontier controls are involved, such as within the European Union, there is still a significant need for such flows of information especially where combined forms of transport are involved. This issue will be examined further in the next section.

A further issue arising from the new requirement for detailed reporting stems from the on-going trend of increase in vessel size. For instance, the wide deployment of new Super Post-Panamax container vessels means that the Cargo Manifest for each vessel becomes larger, with the risk that the computer systems required to analyse the information therein require updating to cover the increased volume of information or may take some time to absorb all the information contained therein. Given the sheer volume of container information in each manifest, it is too cumbersome a task for the Customs Computer or the Customs Officer to analyse each cargo at the time the manifest is submitted, even though containers are selected at random for scanning and examination at the port.

Last, but not least, the issue of container security poses problems as there are as yet no agreed international standards and regulations on the enforcement of container seals, whether mechanical or electronic. Container security consists of a complex system of interrelated activities in information and data capture, physical surveillance of the container, and inquiries into the various actors in the supply chain; but any standardisation process must decide on the privacy of the parties involved and their wiliness to share information with each other.

3.2.2 The supply chain risk dimension of port and maritime security

Since the introduction of the new security regime in shipping and ports, researchers and practitioners alike have questioned the wisdom of having so many regulations. Others have justified the overlap of these programmes in order to establish a multi-layer regulatory system in an effort to fill potential security gaps. The concept of layered security is not entirely new to transport systems and dates back to the 1970s. Prior to the introduction of new maritime security measures, the concept has also been cited in 1997 in the context of aviation security. Figure 12.6 depicts the hierarchy of regulatory programmes by level of security and supply chain coverage. The levels relative to each programme are hypothetical but typical.

Despite the layered approach, several problems pertaining to supply chain security can be detected, including:

- Different approaches to the scope, nature and flow configurations of maritime supply chain linkages.
- Poor understanding of the nature and scope of disruptions, including resilience capabilities, to a system's supply chain following a terrorist incident scenario.

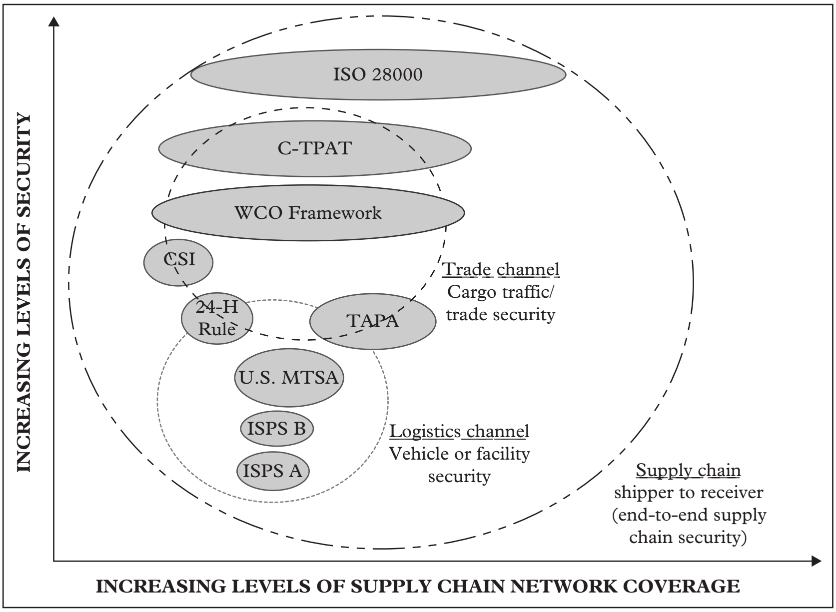

Fig. 12.6: Hierarchy of security measures by level of security and network coverage

- Inadequacy of the traditional approaches (probabilistic, actuarial, historical, etc) to modelling security-risk threats and vulnerabilities, due mainly to the lack of historical data and the irrationality of the terrorist human behaviour.
- Difficulty in quantifying and assigning costs/benefits across supply chain members with different perceptions of and exposures to security-related risks.

4 ECONOMIC EVALUATION OF PORT SECURITY MEASURES

In view of the new security regime, maritime operators have had to implement security measures in order to comply with security initiatives and the route to compliance frequently requires investment in security equipment, 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 and the provisions for detailed reporting, further inspections, and other operational requirements. Therefore, the literature on cost impacts of maritime security may be classified into two main categories: the literature on compliance costs and the literature on procedural and operational costs.

4.1 Compliance Cost of Port Security

4.1.1 Ex ante assessment

Even before the entry in 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 US$1.1 billion for the first year and US$656 million each year up to 2012. Based on these estimates, the Organisation for Economic Co-operation and Development (OECD) 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 12.8. 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 EU operators, would cost port and terminal operators in the EU around 5 million just for audit expenses (DNV Consulting, 2005).

4.1.2 Ex post assessment

Following the entry into force and implementation of the new 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:

- Among the plethora of survey inquiries on the subject, it is worth mentioning the 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 US$0.08 and US$3.6 respectively, of which US$0.03 and US$2 in terms of annual (recurrent) costs respectively (UNCTAD, 2007). However, a recent survey by the World Bank found that the average ISPS compliance costs amount to US$0.22 per ton and US$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),

Table 12.8: Summary of ISPS *ex ante* cost estimates as computed by various regulatory risk assessment impacts

Source of estimates	**Cost items**	**Scope**	**Initial costs***	**Annual costs***	**Total cost* over 2003–2013 @ 7% DFC**
USCG	Total ISPS US ports	226 port authorities, of which 5000 facilities are computed (from Fairplay) (ISPS Parts A and B MARSEC Level 1)	1125	656	5399
	Total ISPS US vessels subject to the regulation	3500 US-flag vessels, as well as domestic and foreign non-SOLAS vessels (ie operating in US waters) (ISPS Parts A and 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 US OCS Facilities under US jurisdiction	3	5	37
	US cost for ISPS implementation	**(ISPS Parts A and B)**	**115**	**884**	**7331**
	Aggregate 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	

(Continued)

Table 12.8: Summary of ISPS *ex ante* cost estimates as computed by various regulatory risk assessment impacts (*Continued*)

Source of estimates	Cost items	Scope	Initial costs*	Annual costs*	Total cost* over 2003–2013 @ 7% DFC
OECD	AIS	Based on 43,291 international commercial fleet of more than 1,000 GT (Passenger and cruise vessels not included), MARSEC 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 and shipping companies		**1279**	**730**	
	PFSA, PFSA, PFSP	2,180 port authorities worldwide, of which 6,500 facilities are computed (from Fairplay) (ISPS Part A 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 and 70 ports, of which 300 port facilities	240 AUD	74 AUD	
Shipowners' association	Total costs for vessels	47 Australian vessels	29,655 AUD		

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.

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

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 of spreading 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 US200,000 initial costs and US113,000 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 1,756 C-TAPAT certified participants, Diop *et al.* (2007) report that C-TPAT implementation and operating costs only amount to US$38,471 and US$69,000, 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. However, other surveys on the subject provide contradictory results—see for instance Lloyd's List (2003) and BDP (2004).
- As with survey inquiries, economic impact studies on the cost of port security also depict inconsistent results. For example, Damas (2001) estimated that the new security measures introduced in the wake of the September 11 terrorist attacks would cost the US economy as much as US$151 billion annually, of which US$65 billion was 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 cost around US$1.6 billion per year, with an extra financing burden of carrying 10% higher inventories at US$7.5 billion per year (IMF, 2001). Such discrepancies are also observable 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 US$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 US$1.7 billion, based on a longer shutdown period of 12 days.

- Cost assessment of regulatory initiatives may also be undertaken through financial and insurance risk modelling. 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. 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 Yemen from their schedules or divert to ports in neighbouring states.
- 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) brought by 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 as either a barrier or an incentive to trade (Raven, 2001). For instance, the OECD (2002) reports that post 9/11 trade security measures would have cost from 1% to 3% of North American trade flows corresponding to a cost between US$60 billion and US$180 billion in 2001 figures. Another trade estimate places the global costs of post 9/11 tighter security at about US$75 billion per year (Walkenhorst and Dihel, 2002).
- Other researchers have looked at the knock-on effect of US port closures on other dependent economies and foreign ports. For example, Saywell and Borsuk (2002) estimated the loss from this disruption to be as high as 1.1% of the combined GDP of Hong Kong, Singapore and Malaysia. In a similar vein, Booz Allen Hamilton (2002) ran a port security game simulation to assess the impacts of a terrorist incident in a US port followed by a nationwide border-crossing closure for eight days. With an estimated cost of US$50 billion on the US economy, their results show inconsistent results with those of previous studies. Pritchard (2002) and Zuckerman (2002) suggest even lower costs than those reported above.
- Another way 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 or from ocean carriers to shippers), and 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 US$6 per shipped container, and up to US$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. Standard practices in the industry suggest that market players try to generate extra profits by transferring costs to each other (Fung *et al.*, 2003), and there is already evidence of similar practices in the recovering of security costs by the port industry (see Table 12.9).

In evaluating the costs and benefits 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.

CBA and alternative approaches such as CEA and SHA (see Chapters 4 and 11) 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

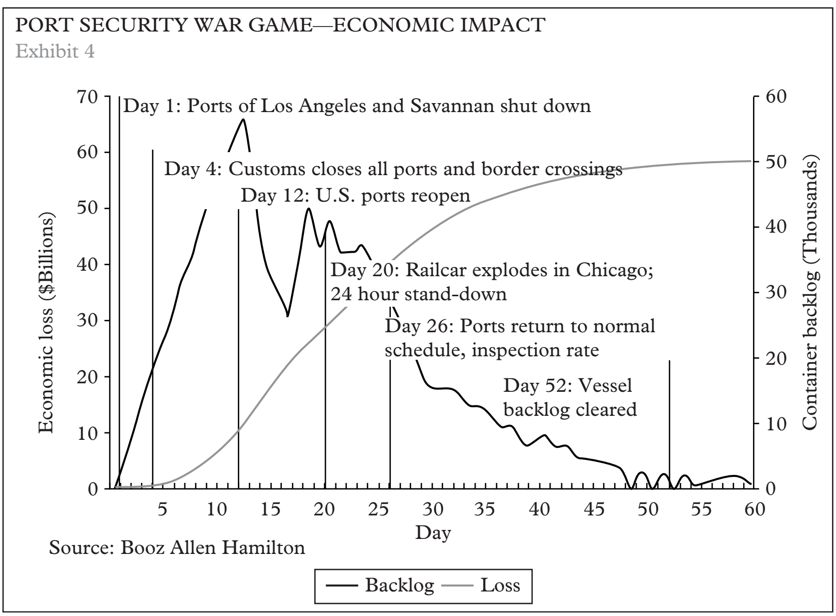

Fig. 12.7: The Booz Allen Hamilton's port security war game simulation (BAH, 2002)

Port or terminal	Security fee $*/TEU
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
Felixstowe, Harwich and Thames port	19 for import and 10 for export
Tilbury	12.7
Charleston, Houston and Miami	5
Gulf seaports marine terminal conference	2
Shenzhen (China)	6.25

Table 12.9: Sample of container ports' security charges (*: expressed in US$ 2006)

valuation methods and their applications in port, maritime and supply chain security. In particular, they pointed out the difficulty in assessing 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). A good discussion on the limitations of survey and economic costing approaches to port security is provided by Bichou (2004).

4.2 Procedural and Operational Cost

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 operational efficiency due to better procedural arrangements:

- On the one hand, many argue that the procedural requirements of the new security regime act against operational and logistical efficiency. Proponents of this standpoint list a number of potential inefficiencies ranging from direct operational redundancies, such as lengthy procedures and further inspections, to 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 the 24-hour will 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 days or more 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 $5,000 for the first time and USD $10,000 thereafter in case they submit missing or inaccurate data to CBP. A detailed review of the 24-hour 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 analytical research on procedural security impacts uses modelling techniques to predict the operational costs and benefits of security. Lee and Whang (2005) have developed a mathematical model to assess the benefits of reduced lead times and inspection levels in the context of Smart and Secure Trade-lanes (SST). White (2002) also used mathematical modelling by developing a min-depth heuristic 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 recovery cycle for the US container terminal of Virginia.

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 and 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

(Continued)

Appendix 1: (*Continued*)

ISPS part/ reference	Port facility security plan topic	ISPS category	Equipment category	Equipment required
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 and 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, eg 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 and 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 the 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 alert, alarm system/gate/ 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

(*Continued*)

Appendix 1: (*Continued*)

ISPS part/ reference	Port facility security plan topic	ISPS category	Equipment category	Equipment required
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 and visual alarms	Intrusion detection devices/audio and 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 and 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 and devices whose carriage is not authorised from entering the port/ship facility	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

(Continued)

Appendix 1: (*Continued*)

ISPS part/ reference	Port facility security plan topic	ISPS category	Equipment category	Equipment required
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 unaccompa-nied baggage	Screening equipment	X-ray

(*Continued*)

Appendix 1: (*Continued*)

ISPS part/ reference	Port facility security plan topic	ISPS category	Equipment category	Equipment required
B.16.8.7	At all security levels, procedures to assess the continuing effectiveness of security measures, procedures and equipment, including identification of and response to equipment failure or malfunction	Monitoring security of port facility	Backup systems	
B.16.51	The plan should establish procedures 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 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 and 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 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 and continuous communication between port facility security personnel and ships and 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

(Continued)

Appendix 1: (*Continued*)

ISPS part/ reference	Port facility security plan topic	ISPS category	Equipment category	Equipment required
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 and obtaining waterside patrols and specialist search teams including bomb and 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 unauthorised access or disclosure	Monitoring security of port facility	Data security	Fireproof 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

(*Continued*)

Appendix 1: (*Continued*)

ISPS part/ reference	Port facility security plan topic	ISPS category	Equipment category	Equipment required
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	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 and 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 and 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

(Continued)

Appendix 1: (*Continued*)

ISPS part/ reference	Port facility security plan topic	ISPS category	Equipment category	Equipment required
B.16.25.2	Restricted areas may include: embarkation and disembarkation areas, passenger and ship's personnel holding and 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 and telecommunication, water and 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 and port control buildings, including security and surveillance control rooms	Restricted areas	Signage/ security control room	Control systems

Appendix 2: N-RAT Assessment Exercise Report

The following is extracted from the N-RAT assessment exercise as reported in the Federal Register//Vol. 68, No. 204, October 22, 2003 (pp. 60464–6046)

The Coast Guard used the National Risk Assessment Tool (N-RAT) to assess benefits that would result from increased security for vessels, facilities, OCS facilities, and areas. The N-RAT considers threat, vulnerability, and consequences for several maritime entities in various security-related scenarios. Using the N-RAT, we determined that significant public benefit accrues if a transportation security incident is avoided or the effects of the transportation security incident can be reduced. These public benefits include human lives saved, pollution avoided, and "public" infrastructure, such as national landmarks and utilities, protected. For this benefit assessment, the Coast Guard used a team to calculate a risk score for each entity and scenario before and after the implementation of required security measures. The difference in before and after scores indicated the benefit of the proposed action. We determined annual risk points reduced for each of the six final rules using the N-RAT. Table A presents the annual risk points reduced by the final rules. As shown, the final rule for vessel security reduces the most risk points annually. The final rule for AIS reduces the least.

Once we determined the annual risk points reduced, we discounted these estimates to their present value (7% discount rate, 2003–2012) so that they could be compared to the costs. We presented the cost effectiveness, or dollars per risk point reduced, in two ways: First, we compared first-year cost to first-year benefit, because first-year cost is the highest in our assessment as companies develop security plans and purchase equipment. Second, we compared the 10-year present value cost to the 10-year present value benefit. The results of our assessment are presented in Table B.

Maritime entity	**Vessel security**	**Facility security**	**OCS facility security**	**AMS**	**AIS**
Vessels	778,633	3,385	3,385	3,385	1,317
Facilities	2,025	469,686		2,025	
OCS facilities	41		9,903		
Port areas	587	587		129,792	105
Total	781,286	473,658	13,288	135,202	1,422

Table A: Annual risk points reduced by final rules

Items	Vessel	Facility	Off-shore facility	AMS	AIS
First-year cost (millions)	218	1,125	3	120	30
First-year benefit	781,285	473,659	13,288	135,202	1,422
First-year cost effectiveness ($/risk point reduced)	279	2,375	205	890	21,224
10-year present value cost (millions)	1,368	5,399	37	477	26
10-year present value benefit	5,871,540	3,559,655	99,863	1,016,074	10,687
10-year present value cost effective-ness ($/risk point reduced)	233	1,517	368	469	2,427

Table B: Annual risk points reduced by final rules

The study also looks at the potential economic impacts of the new security regulations on small businesses and maritime entities, and found that the cost-implications of the regulations will be insignificant with a less-than-3% impact on 73% of small businesses owning non-SOLAS vessels in the first year it is in effect. Approximately 88% have a less-than-10% impact.

CHAPTER 13

PORT ENVIRONMENTAL MANAGEMENT

As with other areas of port operations and management, environmental management in ports cuts across several topics such as planning, operations, policy and regulation. Furthermore, because the environmental impacts of port projects and activities have both socio-economic (land use, city planning, economic development, social and cultural resources, etc) and eco-system (air and water quality, coastal systems and estuaries, landscape, fisheries and habitats, etc) dimensions, environmental management and sustainability in ports interacts with new research fields that are outside the traditional port literature including subjects such as earth sciences, history, ecology, marine biology, urban development and sociology.

The international community has responded with a series of regulatory and procedural frameworks in the wake of environmental disasters at sea and in ports. More recently, the global climate agenda and increased public awareness about environmental issues have put more pressure on port and terminal operators to integrate environmental sustainability as a key element in port planning and operations. This chapter outlines the main legal, operational and scientific tools used for environmental assessment and management within and around ports.

1 ENVIRONMENTAL PRINCIPLES OF PORT OPERATIONS

1.1 Environmental Risks and Impacts

Planning for port development requires feasibility studies that must consider not only the technical, financial and economic aspects but the environmental factors and impacts as well. Environmental factors associated with port development include land reclamation, dredging, construction, maintenance, and any related activity such as the disposal of materials waste and release of contaminants. On the other hand, nautical and cargo handling operations can also create negative environmental externalities. Sources of environmental degradation caused by ships in port areas include ship stress and vibration, emissions and noise, waste production and disposal, storm and discharge of ballast waters, spill and leakage, paint and anti-fouling substances, grounding and collision. For cargo handling operations, environmental risks include dust, toxic and hazardous materials from cargo, emissions, noise, and vibration from handling equipment and vehicles, spills and leakages from pipelines and storage tanks, and any adverse impact or accident during cargo handling, storage and distribution. Tables 13.1 and 13.2 depict the main environmental factors and adverse impacts of port development and operations.

In addition to the factors mentioned above, other factors not directly associated with port development and operations can also impact the environmental sustainability of ports and adjacent marine and urban areas. Examples include different types of pollution and waste stemming from military, domestic, agricultural, industrial, tourism, and off-shore activities. Finally, environmental risks may also stem from external factors such as safety and security incidents, earthquakes and seismic events, storms, hurricanes and similar adverse weather conditions. However, port development also creates positive environmental and wider effects by facilitating a shift from highly polluting land transport services to the more environmental friendly maritime transport services or by generating socio-economic benefits such as job creation and urban regeneration.

Despite this, environmental risks and impacts depend largely on the levels of environmental awareness and perception of port stakeholders and users. Table 13.3 shows the shifts in top 10 environmental issues as identified by European ports in two recent ESPO surveys undertaken in 1996 and 2003, respectively.

Factor	**Impact**
Construction and dredging	Coastal erosion and subsidence, sediment excavation and turbidity, changes in waves, tide and current patterns, shifts in sea-bed morphology, degradation of fisheries and marine ecosystems, degradation of water quality, changes in socio-economic environment, etc
Land reclamation	Degradation of estuaries, coastal flora and fauna, loss of habitats and endangered species, aesthetic and visual pollution, loss of cultural resources, impacts on land use, etc
Ships and navigation	Degradation of water and air quality, water pollution, climate change effects, noise and vibration, aesthetic and visual pollution, etc
Cargo handling/ terminal operations	Injuries and fatalities, air pollution, climate change effects, noise and vibration, degradation of wetlands adjacent to ports, impacts on adjacent residential and urban areas, aesthetic and cultural impacts, impacts on land use, etc

Table 13.1: Environmental factors and impacts in ports

Category of pollution	Pollutants	Monitoring
Marine and water, including soil and sediments	Halogenated hydrocarbons Petroleum and its derivatives Other organic chemicals Nutrient chemicals Inorganic chemicals Suspended solids (including garbage) Radioactive substances Thermal waste	Currents, waves and tide, water temperature, salinity, nutrient levels and dissolved oxygen Turbidity and sediments Ships' waste, disposal, safety and environmental records, Accidents and oil spills
Air	Green gas Carbon dioxide (CO_2) Oxides of nitrogen (NO_x) Sulfur oxides (SO_x) Hydrocarbons (HC) Particulate (PM)	Air temperature, atmospheric pressure, humidity, rainfall, wind speed and direction Dust, nitrogen oxide, sulphur oxide, carbon dioxide and other chemical pollutants
Noise	Ships, trucks, handling equipment, etc	Calculating levels of noise

Table 13.2: Category of pollution in ports

1996 survey	2003 survey
1. Dust	1. Garbage and waste
2. Dredging disposal	2. Dredging disposal
3. Port development (land)	3. Dredging operations
4. Dredging operations	4. Dust
5. Garbage and waste	5. Noise
6. Port development (water)	6. Air quality
7. Noise	7. Bunkering
8. Water quality	8. Port development (land)
9. Traffic volume	9. Ship discharge (bilge)
10. Hazardous cargo	10. Hazardous cargo

Table 13.3: Top ten environmental issues as identified by EU ports (ESPO, 1996; 2003)

1.2 Regulatory Framework for Environmental Management

With respect to regulating environmental activities and geographical areas of ports, there are multiple policy instruments and a range of regulatory actors involved in the regulation of a single, global industry. The list below outlines the main measures and the requirements targeted at environmental management and monitoring in ports, but it is neither exclusive nor exhaustive.

- The IMO Maritime Pollution Convention (MARPOL 73/78) covers six chapters as Annexes: I-Pollution by Oil, II-Chemical, III-Harmful Substances in Packaged Form, IV-Sewage, V-Garbage, and Annex VI-Air Pollution. The amendments of 1998 require the issuing of detailed standards on packing, labelling, marking, documentation, storage, quantity limitations, expectations and notifications for preventing or minimising pollution by harmful substances.
- The IMO Safety of Life at Sea (SOLAS) Convention as adopted in 1974, and amended in 1996. For instance, regulation 1 of part A requires each contracting Government to issue, or cause to be issued, detailed instructions on the safe packing and storage of dangerous goods which shall include the precautions necessary in relation to cargo. The other six regulations of part A deal with the packing, identification, marking, labelling and placarding of dangerous goods; the documentation which is to be provided; storage and segregation requirements; the carriage of explosives on board passenger ships; and the reporting of accidents involving dangerous goods.
- The United Nations Convention on the Law of the Sea (UNCLOS) of 1982.
- The IMO Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention, in force since 1975).
- The IMO Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC90).
- The IMO Convention on Facilitation of International Maritime Traffic (FAL) 1976, which covers the use of a declaration standard form of documents for transport of goods.
- The IMO Convention on Hazardous and Noxious Substances (HNS) introduces strict liability for the ship owner, higher limits of liability than the present general limitation regimes and a system of compulsory insurance and insurance certification.
- The IMO Convention for Safe Containers (CSC) aims at maintaining a high level of safety of human life, as well as uniform international safety regulations in the transport and handling of containers, by providing generally acceptable test procedures and related strength requirements, including procedures for dangerous cargo carriage in container freight.
- The IMO International Maritime Dangerous Goods Code (IMDG Code) covers dangerous goods in packaged form and provides guidelines on classification, terminology, identification, packing and packaging, marking, labelling and placarding, documentation and marine pollution aspects.
- The Code of Safe Practice for Cargo Stowage and Securing (CSS Code) where the principal thrust is the provision of an international safe standard for cargo handling and stowage arrangements.

- The International Ship Management (ISM) Code ensures that shipping companies develop safety and environmental plans for each ship.
- Other related regulatory instruments exit both at national or regional levels. For instance, EU environmental regulation in ports includes a raft of directives ranging from the water framework directive, the wild birds and habitats directives, the dangerous substances directive and the waste reception facilities directive. In the USA, the Environmental Protection Agency (RPA) website lists over 20 legislations directly related to port planning and operations.

In addition to the above regulations, several initiatives and instruments provide guidelines on environmental assessment and management in and around ports:

- The United Nations Framework Convention on Climate Change (UNFCCC or FCCC), including the 1997 Kyoto Protocol.
- The UN/ECE/ILO/IMO Guidelines for Packing of Cargo Transport Units (CTU).
- OECD Guiding Principles for Chemical Accidents (OECD/IMO Port supplement).
- UNEP Awareness and Preparedness for Emergencies at the Local Level (APELL).
- The IMO Manual on Oil Pollution.
- Procedures for the Control of Ships and Discharges.
- The IMO/UNEP Intergovernmental Panel on Climate Change (IPCC),
- IMO Guidelines on the Provision of Adequate Reception Facilities in Ports.
- The IMO Crude Oil Washing Guidelines (COW Systems).
- The International Chamber of Shipping (ICS) Guidelines on International Safety Guide for Oil Tankers and Terminals (ISGOTT).
- The IAPH Guidelines on Port Safety and Environmental Control.
- The UN Recommendations on the Transport of Dangerous Goods (Orange Book) across Modes.

In the case of industry-led programmes, two on-going programmes are worth mentioning:

- The Ecoports programme, an EU scheme allowing ports to make a self-assessment of their environmental conditions (Self Diagnosis Methodology (SDM)) with a view of certification. The SDM consists of a list of questions which are then analysed by the Eco-Ports technical team. The result is a colour-coded return identifying a port's individual strengths and weaknesses and providing confidential comparisons with the rest of the industry. Completion of the SDM can lead to qualification for a Port Environmental Review System (PERS) certificate. Certificates are awarded by the Lloyd's Register which carries out an independent audit of the application. A major benefit of PERS is that it can be used as a basis for further accreditation under ISO 140001.

- The Clean Air Action Plan (CAAP) underway in the San-Pedro region in the USA. In 2006, the ports of Long Beach and Los Angeles in the USA, in cooperation with the EPA and California Air Resources Board (CARB), adopted the CAAP to cut pollution by 45% by 2012.

Elements of CAAP
• Clean trucks programme • Clean vessels programme • Vessel speed reduction • Alternative fuels • Shore-side power for ships • Clean locomotives programmes • Clean cargo handling equipment • Clean harbour craft • Tariff changes • Incentives/voluntary measures • Alternative technology programme • Reduce pollution by 45% within five years

Table 13.4: Tools and objectives of CAAP

Table 13.5: Regulations and procedures on ship's emissions

Ships and other port equipment are significant sources of air pollution. For cargo equipment, no direct method or international standard to extract emissions for specific cargo handling equipment exist. For ships, it is estimated that they have emitted 1,046 million tonnes of CO_2 in 2007, which corresponds to 3.3% of the global emissions during 2007. Other emissions such as NO_x and SO_x have been mentioned in the description of the new Annex VI to MARPOL. The following table contains an estimation of ships' emissions in 2008 as published by the IMO:

	Ship exhaust	**Refrigerant**	**Transport of crude oil**	**Total**
CO_2	1050	–	–	1050
CH_4	0.10	–	0.14	0.24
N_2O	0.03	–	–	0.03
HFC	–	0.0004	–	0.0004

(Continued)

Table 13.5: (*Continued*)Regulations and procedures on ship's emissions

PFC	–	–	–	–
SF_6	–	–	–	–
NO_x	25	–	–	25
NMVOC	0.8	–	2.3	3.1
CO	2.5	–	–	2.5
PM	1.8	–	–	1.8
SO_x	15	–	–	15

The IMO emission standards are commonly referred to as Tier I, II and III standards. Tier I standards were defined in the 1997 version of Annex VI, while the Tier II/III standards were introduced by Annex VI amendments adopted in 2008. The amendments include caps on the sulphur content of fuel oil as a measure to control SOx emissions, and indirectly PM emissions:

Global Fuel Sulphur Cap

- *4.50% m/m prior to 1 January 2012;*
- *3.50% m/m on and after 1 January 2012; and*
- *0.50% m/m on and after 1 January 2020.*

Emission Control Area (eg Economic Exclusive Zone) Fuel Sulphur Cap

- *1.50% m/m prior to 1 July 2010;*
- *1.00% m/m on and after 1 July 2010; and*
- *0.10% m/m on and after 1 January 2015.*

For NO_x emissions, existing regulations require that engines be tested at three different loads and use a weighted averaged to compare with an overall emission standard. Ship emission standards for NO_x are categorised in terms of a three-tier standard or threshold depending on the rated engine speed and the year of construction/entry into service.

Tier	**Year**	**n < 130 rpm**	**13 rpm < n < 200 rpm**	**n ≥ 200 rpm**
I	2010	17	45* $n^{(-0.2)}$	9.8 g/kW-h
II	2011	14.4	44* $n^{(-0.23)}$	7.7 g/kW-h
III	2016	3.4	9* $n^{(-0.2)}$	2.0 g/kW-h

Annexes I, II, IV and V in MARPOL 73/78 cover the specific requirements regarding the handling and discharge of ship-generated wastes, and the IMO has published a comprehensive manual on port reception facilities. Ships of ≥400 GRT and those certified to carry ≥15 persons must both have a garbage management plan. The ship operator/owner must assess all aspects of waste generation, handling and disposal and plan ahead on how best to manage them.

Most ports require an advance notification from the ship of its intention to use port reception facilities. Typically, the notice should contain the following:

- Ship particulars (Name, GRT, IMO number, owner, flag state, etc)
- Voyage and port particulars (former and next port of calls, ETA, berth number, etc)
- Type and amount of waste for discharge to facility (type, substance category, quantity, etc)
- Pump rate of ships discharge equipment
- Shipboard disposal problem (if any)

Ballast water reception needs a special facility (large amount and low oil content). The principle would be the same as above. Tanks are usually cleaned with hot water with the possible addition of detergents. Prewash must be discharged to a reception facility. Main washes may be discharged to a reception facility, although usually they are discharged at sea. If discharged to a reception facility, then the port must accept the discharge.

The process of treatment at a facility is almost the same as for Annex I products. Usually chemical wastes will be incinerated. Basically equipment for handling and collect garbage in a port should be able to: 1) receive; 2) segregate; 3) store; and 4) arrange for transport of the waste to be processed somewhere else. In order to collect wastes the most common receptacles used are: containers, bins or dumpsters. Receptacles used for recycling should be easy to distinguish from those used for non-recyclable waste.

For final disposal, there are three options: incineration, land farming, or landfill.

Table 13.6: Regulations and procedures on ship's waste and reception facilities in ports

2 PRINCIPLES AND PROCEDURES OF ENVIRONMENTAL MANAGEMENT IN PORTS

2.1 Impact Assessment

Environmental impact assessment (EIA) is a broad concept which covers a variety of tools and procedures aimed at the assessment and monitoring of the impact of a project, an activity, or an incident on the environment. Today, most countries have established mandatory EIA frameworks for project design and

EIA Procedures
Description of environmental conditions *Geophysical environment* *Climate* *Hydrographical conditions* *Sediment transport* *Sediment quality* *Water quality* *Air, noise, and vibration* *Biological environment* *Marine ecology and fisheries*
Socioeconomic environment *Land use* *Employment* *Traffic* *Recreation and heritage*
Alternative analysis *Alternative harbour locations* *Alternative layouts*
Mitigation measures

Table 13.7: General framework for an EIA port project

implementation across several sectors including port planning, development and operations. EIA requirements and procedures may vary from country to country, but standard and uniform guidelines may be adopted by several countries such as in the case of member countries of the EU or for projects funded by international agencies such as the European Investment Bank, the World Bank and the Asian Development Bank.

The EIA is an important and useful tool for the administrations responsible for the protection of the environment because its application in advance to the activities to be developed in the country will allow the detection of impacts possible to be corrected or irreversible impacts which will require the adoption of an alternative solution to the proposed project. The EIA is also a useful tool to promote activities which can originate a relevant impact on the environment because the EIA will detect and evaluate such impact in advance. This early evaluation will suggest that the promoter should adopt other alternatives which will avoid the installation of expensive equipment to reduce pollution to the level required by the legislation. The public also receives the benefits of an EIA because in general their environment is better preserved and in particular they are invited to express their opinion through the consultations with the community concerned usually considered in the EIA preparation.

2.2 Mitigation Plans and Emergency Preparedness

Emergency response planning is an established tool to contemplate different levels of emergencies and establish the corresponding contingency plans. Different emergency plans (eg port-related, provincial-related) may be used and coordinated between different agencies to establish a tiered response depending on the area of application and the size of the emergency. As far are ports are concerned, three types of plans may be needed:

The basic elements of a contingency plan include, but are not limited to, the following:

- basic information on port installations and inventory, substances handled, resources and personnel at risk;
- definition of institutional and work responsibilities, terminal or facility contingency plan;
- guidelines and recommendations for action;
- actions and operations: assignment of resources, for example response equipment, personnel, financial contingencies, and so on;
- strategy for action: scope and objectives, risk analysis, applicable legislation and regulations, etc;
- integration with other contingency plans; and
- emergency evaluation.

CHAPTER 14

PORT LABOUR AND HUMAN RESOURCE MANAGEMENT

1 HISTORY AND ORGANISATION OF PORT LABOUR

Early ship and cargo handling activities were relatively simple. Dock and port labour was largely casual and labourers were hired either individually or as part of a gang or a pool for one day or for the entire period of a job task. However, this combination of labour-intensive operations and an untrained port work force resulted in poor and unsafe working conditions. This was followed by a number of governmental and union schemes, such as the US/Canada International Long-shore and Warehouse Union (ILWU) and the UK National Dock Labour Scheme (NDLS), with a view to providing a stable and more organised labour force and ensuring safer and improved working conditions. Similar union and government schemes have taken place across most countries and port regions.

Following the advances in ship technology (eg containerisation) and the increases in port mechanisation and automation, port operations became more capital intensive and less dependent on labour and workforce. Furthermore, recent reforms through port deregulation and privatisation have brought about a new breed of private and global operators whose aim is to achieve greater rationalisation and operational efficiency. As a result, several labour and employment reforms were introduced. In the UK, the NDLS was abolished in 1989 with an estimated 6,500 registered dockers (over 70% of the former total) made redundant under the provisions of the (three-year) dock labour compensation scheme (DLCS).

Other countries have followed suit and established redundancy compensation and labour reform schemes during periods of privatisation and institutional restructuring. Globally, it has been reported that port deregulation has resulted in job losses ranging from 40% to 60% (Zarocostas, 1996). Labour reform plans were not always successful as they faced strong resistance from port unions and labour representatives.

With the advent of globalisation and port concentration practices, the labour market was opened to international competition which meant greater opportunities for labour flexibility and mobility as well as new possibilities of

	Number of port workers		
	1970	**1985**	**1992**
Britain	70,000	20,000	8,500
USA	95,000	26,000	12,000
Australia	30,000	6,500	3,184

Table 14.1: Port job losses in the UK, the US and Australia (compiled from Hensen, 1996 and Greenwald, 2004)

Country	**Year**	**Compensation per worker (in nominal $US)**
Chile	1981	14,300
Colombia	1982	6,250
Venezuela	1991	14,800

Table 14.2: Redundancy compensation of port workers in selected countries (compiled by the author)

	Average % increase of cost per worker	**Average % increase of productivity per worker**
Marseille	21.3	12
Le Havre	22.1	21.2
Dunkirk	29.4	18.2
Rouen	28.6	30.3
Nantes	27.7	5.7

Table 14.3: Comparison between the cost and productivity of French port workers between 1985 and 1997

contracting out core functions. This was seen by several labour representatives as a threat to job stability and national port unions responded by forming the International Dockworkers Council (IDC) or joining existing international unions such as the International Transport Workers Federation (ITWF). International solidarity is seen by unions as an important strategy to go beyond national industrial relations legislation. Global port operators have become more aware of the need to employ and retain well-qualified and motivated port personnel. As a result, new HR policies were introduced with a particular focus on the improvement of productivity through labour management, advanced training and education programmes, and formalised paths for career promotion and development.

Regulators and international agencies were also aware of the safety and training challenges imposed by a rapidly changing port market. Enhanced national safety and health occupancy regulations were introduced in several countries (see, for instance, the port marine safety act in the UK). Other countries have embodied international instruments in force for occupational safety and health in dock work and for cargo handling in ports with national certification standards for safety and occupational health. Among the international instruments developed in the field of port safety and working practices, a number of conventions and codes of practices developed by UN organisations (ILO, IMO, WHO, etc) as well as by the International Organization for Standardization (ISO), as outlined below. Despite this, no global standards or internationally certified best practices on ship and cargo handling operations in ports exist. The lack of standardised and harmonised port practices remains one of the main issues in international port management.

- ILO Dock Work Convention (No. 137), 1973: Convention Concerning the Social Repercussions of New Methods of Cargo Handling in Docks.
- ILO Occupational Safety and Health (Dock Work) Convention (No. 152), 1979
- ILO Code of Practice on Safety and Health in Ports (2005)
- ILO/IMO Code of Practice on Security in Ports (2004)
- ILO Port Safety and Health Audit Manual (2005)
- A number of ISO standards for containers, container seals, etc.

2 PORT TRAINING AND EDUCATION

Recent structural and technical changes taking place in the port industry offer great opportunities for port development and globalisation, but they can only work if operated by competent and well-trained specialists and workforce. On the one hand, new developments in port operations and technology require well-qualified and technically skilled and updated workforce. On the other hand, port managers traditionally recruited from ex-seafarers and maritime pools may not be suitable to manage modern and complex logistics and technological port systems. Unfortunately, there are no global standards for port education and training despite several international organisations being heavily involved in port training and related capacity building programmes.

Faced with this situation, industry associations as well as public authorities have developed a range of occupational standards and qualification frameworks for port and terminal workers at entry levels. For instance, the UK Port Skills and Safety (PSSL) and its predecessor (the British Ports industry Training—BPIT) have developed five national occupancy standards for the port industry: harbour masters, marine pilots, port operations, supervision of port operations, and vessel traffic system (VTS) operations. PSSL have also

Fig. 14.1: Examples of port jobs requiring NVQ qualifications

developed a range of port apprenticeships at national level qualifications (NVQ) 2 and 3. Unlike occupational standards, apprenticeships are formalised qualification programmes leading to the award of a school degree which can be accepted as an entry qualification for undergraduate university education in the UK.

International organisations have also developed training programmes for port workers. Among these, it is worth mentioning the ILO Port-worker Development Programme (PDP) and the UNCTAD's port training and train-for-trade programmes. Some of these programmes are delivered online or are based on distance learning. Contemplating the delivery of standardised training packages through distance learning has opened the door to port workers from remote and developing countries to access the latest qualifications and gain the necessary knowledge for safe and efficient port operations.

Port education has also been integrated into national schemes of further education by transport and logistics departments in mainstream universities and academic institutions across Europe and Asia, while in the USA port programmes are delivered mainly by maritime academies and other affiliated colleges. This has provided experienced port workers with the opportunity to obtain higher academic degrees for personal development and greater career promotion and mobility. Equally, this has enabled students with little or no relevant experience in port operations and management to have a career in the port industry. Over recent years, the enrolment in port education programmes has been overwhelmingly high. As a result, there has been a mushrooming of port-related training and education programmes although the design, content and objectives of such programmes are not always consistent.

However, the influence that new academic offerings have had on the training of port labour and the influence that a changing port industry exerts on such training seem to have led to contradictory results. Port operators tend to prefer training that focuses on planning, operations, logistics and technology and this is not usually available in traditional postgraduate university programmes (see Table 14.5). Furthermore, one of the main criticisms of postgraduate courses is that they usually overlook the practical dimension of port operations and

C.1:1 Container terminal operations C.1.2: Container ship loading and discharging operations C.1.3: The container terminal quay transfer operation C.1.4: The container yard: the storage operation C.1.5: The container terminal receipt/delivery operation C.1.6: Container freight station operations C.2.1: Container ship construction C.2.2: Container ship stowage plans C.2.3: Container securing systems C.2.4: Container ship loading discharge lists and work plans C.3.1: Container construction C.3.2: Container numbering and marking C.3.3: Container inspection C.3.4: Packing of goods in containers: 1. principles and planning C.3.5: Packing of goods in containers: 2. Working practices C.4.1: Safe working on containers terminals C.4.2: Safe working aboard container vessels	C.6.1: The container terminal and international trade C.6.2: Measuring container terminal performance C.6.3: Analysis and review of container terminal performance P.3.1: Handling dangerous cargoes in ports S.1.1: The port supervisor: organisational status S.1.2: The port supervisor: tasks and duties S.1.3: The port supervisor: supervisory skills S.1.4: The port supervisor: personal attributes S.2.1: Supervision of container ship discharge and loading S.2.2: Supervision of container terminal quay side transfer operation S.2.3: Supervision of the container yard operations S.2.4: Supervision of the container terminal receipt/delivery operation S.2.5: Supervision of container freight stations

Table 14.4: List of PDP units
(*Source:* ILO).

management, and this is mainly due to the lack of practical experience from a part of the teaching and research staff.

To overcome this issue and others, several port operators have developed tailored programmes for graduate training and executive education, usually targeted at their own personnel and workforce. The main programmes currently running include the PSA's management associate programme (MA), APM Terminals' global terminal development programme (GTDP), HPH's port executive programme (PEP), ABP's graduate management training, and more recently DP World's global organisational leadership development programme (GOLD) programme. Some operators such as PSA have established separate training institutions (eg the PSA Institute) providing both in-house and exter-

UNIVERSITY		
Liverpool John Moores *MSc Port Management*	**Cardiff** *Diploma in Port and Shipping Administration*	**Plymouth** *MSc International Port Management*
Core modules Port management Logistics and supply chain management International trade and logistics Maritime transports systems Research methods **One optional module from:** Maritime pollution control Marine and offshore safety Maritime IT Marine insurance **Research project**	**Three core modules** Port policy and management E-commerce and IT Law of carriage of goods by sea Law of marine insurance Shipping economics International shipping policy **Research project**	**Core modules** Port policy and management Research skills Finance and business modelling Logistics and maritime commerce Business systems and methods **One optional module from:** International supply chains Shipping finance, management and law International logistics management **Research project**

Table 14.5: Example of postgraduate taught courses in port management in the UK

nal training programmes for outside participants. The objective of these programmes is to identify and train port personnel who either possess or have the potential to develop the knowledge and skills required to carry out operational and management port tasks. Typically, the programmes last between 12 to 24 months during which the trainee is placed in one or several terminals and attends a series of short courses and workshops. After the training period, and subject to satisfaction, the candidate is offered a permanent position and may be deployed or relocated to other terminals and workplaces.

3 HR SYSTEMS AND JOB TYPES IN PORTS

The port industry strongly depends on human resources who have to be highly qualified because of the heavy responsibilities for safety and environmental

GTDP Modules	
Module 0	Introduction to Container Terminal Operations
Module 1	Health and Safety
Module 2	Security
Module 3	Maintenance for Operators
Module 4	Yard Planning
Module 5	Vessel Planning
Module 6	Gate Operations
Module 7	Rail Operations
Module 8	People Management

Table 14.6: Outline of GTDP modules
(*Source:* APM Terminals.)

sustainability, expensive equipment and vehicles, and tonnes of goods and cargo. This requires appropriate planning and implementation of human resources (HR) capable of operating and managing a continuously changing and challenging port environment.

Due to the complex and constantly changing port environment, terminal and port organisations today have difficulties in defining and delimiting various job tasks in port operations and management. Furthermore, one of the widely observed shortcomings in traditional port organisations is the inappropriate allocation and composition of the port's workforce across various operational and management divisions. In 2005, the UK DfT had commissioned a study with the primary aim of estimating port employment and accident rates in the UK. The study has also revealed the variety of job categories related to port operations and management (see Table 14.7).

Modern organisations categorise port activities in terms of planning, execution, and monitoring functions, and this has helped them streamline specific tasks and responsibilities while ensuring transparency and quality assurance in port employment. The type and range of job profiles and classifications in ports not only denote the nature and labour intensity of port operations, but they also reflect the extent of institutional structuring and reform as well as changes in working conditions and culture (working hours, shift systems, wages and incentives, skills and training, occupational safety and health, etc). The examples shown in Figures 14.2 and 14.3 below show how both the organisation and description of port jobs and functions must be integrated into an overall system of port performance monitoring and development.

Table 14.7: Categories of port job employment in the UK (DfT, 2005)

Direct	Indirect	Partially related	Unrelated
Port management and administration Cargo handling, storage, warehousing Berthing, mooring, towing Technical support and maintenance Lock operations Shipping operators on port pilots Tug operators Lighter operators Line/shipping agents Forwarding agents (for sea or mainly sea transport) Bunkering Ship chandlers Ship repair and maintenance Tank cleaning Waste disposal waste oil reception Port police, security Customs and immigration Health and safety, environmental protection Marine surveys Salvage activities Dredging Importers/exporters Fishing, on port Ship brokers Ship classification, Ship surveyors Marine engineers Underwater maintenance and engineering Specialist equipment hire/sales Fuel supply Charterers	Cleaners Catering staff Construction/ demolition Sales of general products and services	This is defined as employment by businesses located on port because it is convenient for their operation, for example they may import raw materials or export finished goods and wish to have a manufacturing base close to the reception of raw materials or export of goods. Manufacturing Fish processing/sales	Marinas Ship builders Boat yards Hotels Restaurants Taxi services Car parking, car hire Museums Yacht clubs Yacht sales Sail makers Sailing school Estate agents (not port-related property) Haulage Warehousing off port Forwarding agents (land or mainly land transport)

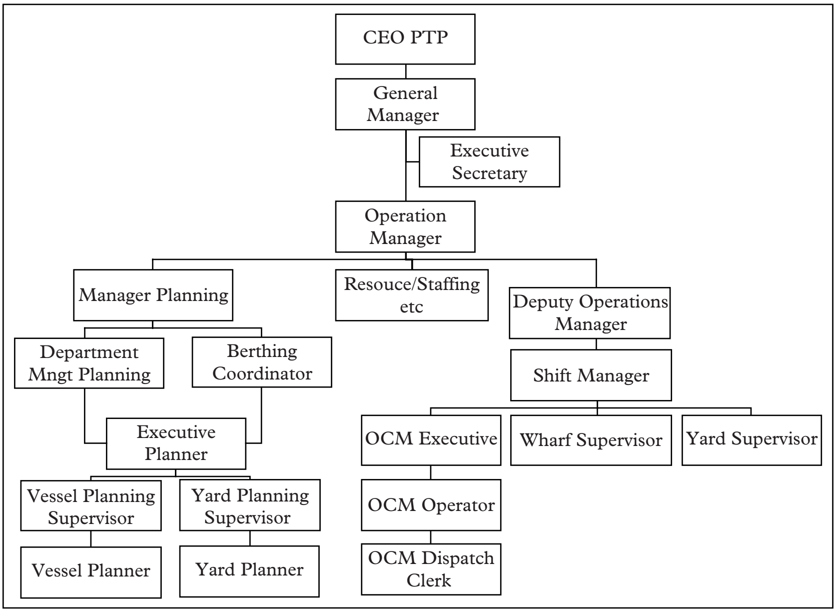

Fig. 14.2: Organisation of Tanjung Pelepas container terminal (with consent from APMT)

APM TERMINALS

Subject	JOB DESCRIPTION				
Prepared by	Controlled by	Approved by	Revision no.	Revision date	Ref. Dept
	CENAPMT		1.0	01/01/2006	

Department: Operations
Title: Operations Manager
Reports to: Terminal Manager
Name:

Position Summary

Direct the activities of the operations team through the reporting managers and supervisors. Ensure that the team is never satisfied with status quo and will continuously strive to improve the service to internal and external customers.

It is expected to make constant process improvement and empower others to take action with due regard to safety, quality, cost, and productivity, while ensuring maximum production levels and efficient utilization of labor, equipment and space.

Critical Success Factors

1. Achieve average gross moves per quay crane of 37 GMPH.
2. To meet the berth production targets as established in the terminals/shipping line contracts.
3. Achieve average 30-minute truck turn-round time
4. Grow a second to none operations team with an environment that is supportive of learning, training and developing, whilst minimizing staff tumover.

Major accountabilities

No.	Priority	Time
1	Manage, motivate, coach and instruct all operational team members, structure tasks and goals, establish efficient courses of action, set priorities, organize information, efficiently execute with following considerations. • Staffing levels for management and labor • Terminal Productivity • High-level Operational Strategy • Long-term Equipment needs • Long-term Capacity needs • Customer and Service requirements • Safety requirements	25 %
2	Ensure safe working conditions are kept at all times.	20 %
3	Ensure cost awareness is filtered throughout organization.	10 %
4	Provide regular process control checks and initiate and support performance improvement activities.	10 %
5	Set and maintain performance criteria for reporting personnel. Ensure personal development plans are developed, reviewed, and carried out.	5 %
6	Perform periodic scheduled performance review with reporting personnel.	5 %
7	Maintain and enhance relationships between departments. Promote goodwill among external/internal customers and vendors.	10 %
8	Participate in accident investigations and disciplinary hearings.	5 %
9	Together with the Business Process Analysis, drive and support in KPI analysis, process design, process redesign, and implementations of new processes.	5 %
10	Facilitate the daily operations meeting.	5 %

APM Terminals

Fig. 14.3: APMT detailed description of the operations manager's tasks

APM TERMINALS

Subject	JOB DESCRIPTION				
Prepared by	Controlled by	Approved by	Revision no.	Revision date	Ref. Dept
	CENAPMT		1.0	01/01/2006	

Skills and Abilities Required in Position

Skill	Implication	Weight
Customer and Quality Focused	Makes decisions and acts in a way that leads to meeting customer requirements: contributes to the advancement of customer goals; focuses on best practices and continuous improvement: seeks out personal improvement opportunities.	5
Leadership	Provides vision and empowers others to take action. Guides and inspires others to accomplish goals. Establishes high standards for performance. Commands attention and conducts self in a professional manner.	5
Thinking	Analyses market, industry and dynamics of the company and its competitors. Forward thinking; understands implications of decisions.	4
Problem Solving	Anticipates problems; manages prevention; recognizes the key issues in problems and creates contingency plans and alternative solutions. Evaluates solution for both long-and short-term benefit. Exhibits sound judgment. Measures results and takes corrective action when needed.	4
Cost focused	Demonstrates cost consciousness in all areas of work; strives to improve terminal's cost position. Able to work within constraints of budget.	4
Change Management	Initiates change: educates and influences others to accept change.	4
Communication	Creates an environment where staff can communicate across functional boundaries. Shares knowledge, ideas and information openly. Influences others. Communicates in a clear and concise manner; conducts effective meetings; keeps people informed; solicits input from associates. Fluent in English, both written and oral.	5
Drive/ Energy	Generates high volumes of relevant work: able to sustain high level of activity and energy over long hours when necessary. Works with a business like approach to daily challenges. Makes a difference every day at work. "No detail too small, no effort too great."	5
Process Management	Provide and create a process driven organization, which supports continual process improvement though the optimal design of work flows, organizational structure, and technology.	5

Work hours:
Office Hours

Signature / date

Signature Manager / date

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REFERENCES AND FURTHER READING

Accorsi, R, Apostolakis, G and Zio, E, 1999, Prioritising stakeholder concerns in environmental risk management, *Journal of Risk Research*, 2(1), 11–29

Angeloudis, P, Bichou, K and Bell, MGH, 2007, Security and reliability of the liner container-shipping network: analysis of robustness using a complex network framework, in: Bichou, K, Bell, MGH and Evans, A (eds), *Risk Management in Port Operations, Logistics and Supply Chain Security*, Informa: London, 95–107

Arrow, KJ and Debreu, G, 1954, Existence of equilibrium for a competitive economy, *Econometrica*, 22(3), 265–290

Asia Pacific Economic Commission (APEC), 1999, *Assessing APEC Trade Liberalisation and Facilitation: 1999 Update*, Economic Committee, APEC Publications: Singapore

A.T. Kearney, Inc., 1984, *Measuring and Improving Productivity in Physical Distribution: The Successful Companies*, The National Council of Physical Distribution Management: Chicago, IL

Australian Productivity Commission, 2003, *International Benchmarking of Container Stevedoring*, Research Report, Australian Government: Canberra, Australia

Aversa, R, Botter, RC, Haralambides, HE and Yoshizaki, HTV, 2006, A mixed integer programming model on the location of a hub port in the east coast of South America, *Maritime Economics & Logistics*, 7, 1–18

Babione, R, Kim, CK, Rhone, E and Sanjaya, E, 2003, *Post 9/11 Security Cost Impact on Port of Seattle Import/Export Container Traffic*, University of Washington, GTTL 502 Spring Session 2003

Ball, J, 1998, Process analysis tools for process improvement, *TQM Magazine*, 10(5), 342–354

Banker, RD and Cooper, W, 1994, Validation and generalization of DEA and its uses, *TOP*, 2(2), 249–314

Banker, RD and Maindiratta, A, 1992, Maximum likelihood estimation of monotone and concave production frontiers, *Journal of Productivity Analysis*, 3, 401–415

Banomyong, R, 2005, The impact of port and trade security initiatives on maritime supply-chain management, *Maritime Policy and Management*, 32(1), 3–13

Barke, M, 1986, *Transport and Trade*, Oliver & Boyd: Edinburgh

Barletta, G and Bichou, K, 2007, Planning and implementing RFID technologies to enhance security in port operations, in: Bichou, K, Bell, MGH and Evans, A (eds), *Risk Management in Port Operations, Logistics and Supply Chain Security*, Informa: London, 63–82

Barros, CP, 2003, Incentive regulation and efficiency of Portuguese port authorities, *Maritime Economics and Logistics*, 5, 55-69

Barros, CP and Athanassiou, M, 2004, Efficiency in European seaports with DEA: evidence from Greece and Portugal, *Maritime Economics and Logistics*, 6, 122–140

Battese, GE and Coelli, TJ, 1995, A model for technique inefficiency effects in a stochastic frontier production function for panel data, *Empirical Economics*, 20, 325–332

Beamon, BM and Ware, TM, 1998, A process quality model for the analysis, improvement and control of supply chain systems, *International Journal of Physical Distribution and Logistics Management*, 28, 704–715

Bechtel, C and Jayaram, J, 1997, Supply chain management: a strategic perspective, *The International Journal of Logistics Management*, 8, 15–34

Bedford, T and Cooke, R, 2001, *Probabilistic Risk Analysis: Foundations and Methods*, Cambridge University Press: Cambridge

Bell, MGH, 2007, *City Logistics*, Working Paper, Imperial College London

Bell, MGH and Bichou, K, 2008, Port efficiency and the stability of container liner schedules, *Maritime Economics & Logistics*, 10(1), 23–56

Bell, MGH, Kanturska, U and Schmocker, JD, 2008, Attacker-defender models and road network vulnerability, *Philos Transact A Math Phys Eng Sci*, 366, 1893–1906

Ben-Akiva, ME and Lerman, SR, 1985, *Discrete Choice Analysis: Theory and Application to Travel Demand*, MIT Press: Cambridge, MA

Bendall, H and Stent, A, 1987, On measuring cargo handling productivity, *Maritime Policy and Management*, 14, 337–343

Bhimani, A and Jordan, MA, 2003, *A Few Facts about Jumbo Cranes*, Proceedings of the 2003 TOC Americas Conference, Panama, 1–15

Bichou, K, 2004, The ISPS code and the cost of port compliance: an initial logistics and supply chain framework for port security assessment and management, *Maritime Economics and Logistics*, 6(4), 322–348

Bichou, K, 2005a, *Maritime Security: Framework, Methods and Applications*, Report to UNCTAD, UNCTAD: Geneva, June 2005

Bichou, K, 2005a, *Port Inland Interface Assessment: Operations and Strategies*, Report for UNCTAD, UNCTAD: Geneva

Bichou, K, 2006, Review of performance approaches and a supply chain framework to port performance benchmarking, in Brooks, M and Cullinane, K (eds), *Devolution, Port Governance and Port Performance*, in *Research in Transportation Economics (Volume 17)*, Elsevier: London, 567–599

Bichou, K, 2008, Security of ships and shipping operations, in: Talley, W (ed.), *Ship Piracy and Security*, Informa: London, 73–88

Bichou, K, 2009, *A Benchmarking Study of the Impacts of Security Regulations on Container Port Efficiency*, Imperial College Working Paper

Bichou, K and Bell, MGH, 2007, Internationalization and consolidation of the container port industry: assessment of channel structure and relationships, *Maritime Economics & Logistics*, 9(1), 35–51

Bichou, K and Evans, A, 2007, Maritime security and regulatory risk-based models: review and critical analysis, In: Bichou, K, Bell, M G H and Evans, A, 2007, *Risk Management in Port Operations, Logistics and Supply Chain Security*, Informa: London, 265–280

Bichou, K and Gray, R, 2004, A logistics and supply chain management approach to port performance measurement, *Maritime Policy and Management*, 31(1), 47–67

Bichou, K and Gray, R, 2005a, A critical review of conventional terminology for classifying seaports, *Transportation Research A*, 39, 75–92

Bichou, K and Gray, R, 2005b, A logistics and supply chain approach to seaport efficiency -an inquiry based on action research methodology, in: Kotzab, H, Seuring, S, Müller, M and Reiner, G (eds), *Research Methodologies in Supply Chain Management*, Physica: Heidelberg, 413–428

Bichou, K, Bell, MGH and Evans, A, 2007a, *Risk Management in Port Operations, Logistics and Supply Chain Security*, Informa: London

Bichou, K, Lai, KH, Venus Lun, YH and Cheng, TCE, 2007b, A quality management framework for liner shipping companies to implement the 24-hour advance vessel manifest rule, *Transportation Journal*, 46(1), 5–21

Bier, VM, 1993, Statistical methods for the use of accident precursor data in estimating the frequency of rare events, *Reliability Engineering and System Safety*, 42, 267–280

Bird, FE and Germain, GL, 1996, *Practical Loss Control Leadership*, Det Norske Veritas: Alberta

Bird, J, 1980, *Seaports and Seaport Terminals*, Hutchinson University Library: London

Bish, EK, Leong, TY, Li, CL and Simchi-Levi, D, 2001, Analysis of a new vehicle scheduling and location problem, *Naval Research Logistics*, 48, 363–385

Blonigen, BA and Wilson, WW, 2006, *Port Efficiency and Trade Flows*, IWR Report 06-NETS-R-11, US Army Corps of Engineers, 1–44

Bonilla, M, Medal, A, Casaus, T and Salas, R, 2002, The traffic in Spanish ports: an efficiency analysis, *International Journal of Transport Economics*, 19(2), 237–253

Booz Allen Hamilton, 2002, *Port Security War Game*, available at www.boozallen.com

Bosk, LB, 2006, *Port and Supply-Chain Security Initiatives in the United States and Abroad*, Policy Research Project Reports Series 150, Lyndon B Johnson School of Public Affairs, University of Texas at Austin, 1–238

Bostel, N and Dejax, P, 1998, Models and algorithms for container allocation problems on trains in a rapid transhipment shunting yard, *Transportation Science*, 32(4), 370–379

Bowersox, DJ and Closs, DJ, 2002, Supply chain sustainability and cost in the new war economy, *Traffic World*, April 1, 2002

Bowlin, WF, 1998, Measuring performance: an introduction to data envelopment analysis, *Journal of Cost Analysis*, 12, 3–27

Breautigam, R, Daughety, A and Tornquist, M, 1984, A firm specific analysis of economies of density in the US railroad industry, *Journal of Industrial Economics*, 33, 3–20

Brockett, P, Cooper, W, Shin, W and Wang, Y, 1998, Inefficiency and congestion in Chinese production before and after the 1978 economic reforms, *Socio-Economic Planning Sciences*, 32, 1–20

Brooks, MR and Button, KJ, 2005, Market structures and shipping security, *Proceedings of the 2005 Conference of International Association of Maritime Economists*, Limasol, Cyprus, June 2005

Brooks, MR and Button, KJ, 2006, Market structures and shipping security, *Maritime Economics and Logistics*, 8, 100–120

Bureau d'Enquêtes et d'Analyse pour la Sécurité de l'Aviation Civile (BEA), 2002, *Rapport sur l'Accident de Air France Concorde F-BTSC ayant lieu le 25 Juillet 2000 à la Platte d'Oie*, Ministère de l'Equipement, du Transport et du Logement: Paris

Bureau of Transportation Statistics (BTS), 2002, Project 6 overview: Develop better data on accident precursors or leading indicators, in: *Safety Numbers Conference Compendium*, BTS: Washington, DC

Burgess, DF, 1974, A cost minimization approach to import demand equations, *The Review of Economics and Statistics*, 56(2), 225–234

Caplice, C and Sheffi, Y, 1995, A review and evaluation of logistics performance measurement systems, *International Journal of Logistics Management*, 6(1), 61–74

Charnes, A, Cooper, WW and Rhodes, E, 1978, Measuring the efficiency of decision making units, *European Journal of Operational Research*, 2, 429–444

Chen, T, 1999, Yard operations in the container terminal—a study in the 'unproductive moves", *Maritime Policy and Management*, 26(1), 27–38

Cheung, RK, Li, CL and Lin, W, 2002, Interblock crane deployment in container terminals, *Transportation Science*, 36(1), 79–93

Choi, Y S, 2005, *Analysis of Combined Productivity of Equipment at Container Terminal*, Working Paper, Korea Maritime Institute, 1–24

Choi, HR, Kim, HS, Park, BJ, Park, NK and Lee, SW, 2003, An ERP approach for container terminal operating systems, *Maritime Policy and Management*, 30(3), 197–210

Chou, C-C, 2007, A fuzzy MCDM method for solving marine transhipment container port selection problems, *Applied Mathematics and Computation*, 186(1), 435–444

Christopher, M, 1998, *Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service*, Financial Times-Pitman Publishing: London, England

Clark, X, Dollar, D and Micco, A, 2002, *Maritime Transport Costs and Port Efficiency*, World Bank Policy Research Working Paper 2781

Clark, X, Dollar, D and Micco, A, 2004, *Port Efficiency, Maritime Transport Costs and Bilateral Trade*, NBER Working Paper 10353, National Bureau of Economic Research: Cambridge, MA

Cochrane, R, 2007, The effects of market differences on the throughput of large container terminals with similar levels of efficiency, *Proceedings of the Annual Conference of the International Association of Maritime Economists*, Athens, Greece, June 2007

Coelli, T, Prasada-Rao, DS and Battese, GE, 1998, *An Introduction to Efficiency and Productivity Analysis*, Kluwer: Boston and London

Colquhoun, GJ, Baines, RW and Crossley, R, 1993, A state of the art review of IDEF0, *International Journal of Computer Integrated Manufacturing*, 6(4), 252–264

Cooper, WW, Deng, H, Seiford, LM and Zhu, J, 2004, Congestion: its identification and management with DEA, in: *Handbook on Data Envelopment Analysis*, Springer: New York, 177–201

Coto-Millan, P, Banos-Pino, J and Rodriguez-Alvarez, A, 2000, Economic efficiency in Spanish ports: some empirical evidence, *Maritime Policy and Management*, 27(2), 169–174

Council of Logistics Management, *What Is It All About?* Council of Logistics Management: Oak Brook, IL, 1986

Cuadrado, M, Frasquet, M and Cervera, A, 2004, Benchmarking the port services: a customer oriented proposal, *Benchmarking: An International Journal*, 11(3), 320–330

Cullen, WD, 2000, *The Ladbroke Grove Rail Inquiry*, Her Majesty's Stationary Office: Norwich

Cullinane, KPB and Song, DW, 2003, A stochastic frontier model of the productive efficiency of Korean container terminals, *Applied Economics*, 35(3), 251–267

Cullinane, K and Toy, N, 2000, Identifying influential attributes in freight route/mode choice decisions: a content analysis, *Transportation Research E*, 36, 41–53

Cullinane, KPB, Song, DW and Gray, R, 2002, A stochastic frontier model of the efficiency of major container terminals in Asia: assessing the influence of administrative and ownership structures, *Transportation Research Part A*, 36, 743–762

Cullinane, KPB, Song, DW, Ji, P and Wang, TF, 2004, An application of DEA windows analysis to container port production efficiency, *Review of Network Economics*, 3(2), 186–208

Cullinane, KPB, Ji, P and Wang, TF, 2005, The relationship between privatization and DEA estimates of efficiency in the container port industry, *Journal of Economics and Business*, 57, 433–462

Cullinane, KPB, Wang, TF, Song, DW and Ji, P, 2006, The technical efficiency of container ports: comparing data envelopment analysis and stochastic frontier analysis, *Transportation Research Part A: Policy and Practice*, 40, 354–374

D'Este, G, 1992, Frameworks for understanding the behaviour of purchasers of general cargo shipping services, in: *World Conference on Transport Research*, Lyons, France

D'Este, G and Meyrick, S, 1992, Carrier selection in a Ro/Ro ferry trade—Part 2: Decision factors and attitudes, *Maritime Policy and Management*, 19(2), 115–126

Daganzo, CF, 1989, The crane-scheduling problem, *Transportation Research B*, 23(3), 159–175

Dally, HK (ed.), 1983, *Container Handling and Transport*, CS Publications: Surrey

Damas, P, 2001, Supply chains at war, *American Shipper*, November, 17–18

Darren, P, 2004, Smart and safe borders: the logistics of inbound cargo security, *The International Journal of Logistics Management*, (15) 2, 65-75

De, P and Ghosh, B, 2003, Causality between performance and traffic: an investigation with Indian ports, *Maritime Policy and Management*, 30 (1), 5–27

De Monie, G, 1987, Measuring and evaluating port performance and productivity, *UNCTAD Monographs on Port Management No. 6*, UNCTAD: Geneva

Defilippi, E, 2004, Intra-port competition, regulatory challenges and the concession of Callao port, *Maritime Economics and Logistics*, 6, 279–311

Dharmalingam, K, 1987, Design of storage facilities for containers—a case study of Port Louis harbour, Mauritius, *Ports and Harbors*, September, 27–31

Dio, M, Tiwari, P and Itoh, H, 2001, A computable general equilibrium analysis of efficiency improvements at Japanese ports, *Review of Urban and Regional Development Studies*, 13(3), 187–206

Diop, A, Hartman, D and Rexrode, D, 2007, *C-TPAT Partners Cost/Benefit Survey*, CBP: Washington, DC

DNV Consulting, 2005, *Study on the Impacts of Possible European Legislation to Improve Transport Security*, Report 40008032-6-2 for European Commission DG TREN, Final report: Impact Assessment, EC: Brussels

Drewry Shipping Consultants, 2006, *Annual Review of Global Container Terminal Operators*, Drewry Shipping Consultants: London, UK

Ertay, T, Ruan, D and Tuzkaya, UR, 2006, Integrating data envelopment analysis and analytical hierarchy for facility layout design in manufacturing systems, *Information Systems*, 176, 237–262

Estache, A, González, M and Trujillo, L, 2002, Efficiency gains from port reform and the potential for yardstick competition: lessons from México, *World Development*, 30(4), 545–560

Fernández, JE, De Cea, J and Fernández, JM, 1999, Port privatization in developing countries: the case of container terminals. *International Journal of Transport Economics*, 26(2), 293–314

Fink, C, Mattoo, A and Neagu, IC, 2000, *Trade in International Maritime Services: How Much Does Policy Matter?* World Bank: Washington, DC

Fourgeaud, F, 2000, *Measuring Port Performance*, World Bank, PF/TWUTD, 1–18

Frankel, EG, 1987, *Port Planning and Development*, John Wiley & Sons: New York

Frankel, EG, 1991, Port performance and productivity measurement, *Ports and Harbours*, 36(8), 11–13

Fung, MK, Cheng, LK and Qiu, LD, 2003, The impact of terminal handling charges on overall shipping charges: an empirical study, *Transportation Research Part A*, 37(8), 703–716

Ghobadian, A and Husband, T, 1990, Measuring total productivity using production functions, *International Journal of Production Research*, 28(8), 1435–1436

Gstach, D, 1998, Another approach to data envelopment analysis in noisy environments: DEA+, *Journal of Productivity Analysis*, 9, 161–176

Guy, E and Urli, B, 2006, Port selection and multi-criteria analysis: an application to the Montreal-New York alternative, *Maritime Economics and Logistics*, 8(2), 169–186

Hall, PV, 2004, Mutual specialization, seaports and the geography of automobile imports, *Tijdschrift voor Economische en Sociale Geografie*, 95(2), 135–146

Hamilton, GL, Ramsussen, D and Zeng, X, 2000, *Rural Inland Waterways Economic Impact Kit: User Guide*, Institute for Economic Advancement, University of Arkansas at Little Rock: Little Rock, Arkansas, 1–34

Harrald, JR, Stephens, HW and Van-Drop, JR., 2004, A framework for sustainable port security, *Journal of Homeland Security and Emergency Management*, 1(2), 1–13

Hayuth, Y, 198, Containerization and the load centre concept, *Economic Geography*, 57(2), 160–176

Hercules, R, 2006, Cargo security strategy in the post 9/11 era, *Conference Proceedings of the 2006 International Forum of the Writing Instrument Manufacturers Association*, San Francisco, California

Hoffmann, J, 2001, Latin American ports: results and determinants of private sector participation, *International Journal of Maritime Economics*, 3, 221–230

Hummels, D, 2001, *Time as a Trade Barrier*, Mimeo, Purdue University, 1–40

Imai, A, Nishimura, E and Papadimitriou, S, 2001, The dynamic berth allocation problem for a container port, *Transportation Research B*, 35, 401–417

ISEMAR (Institut Supérieur d'Economie Maritime), 1999

Jansson, JO, 1984, *Transport System Optimization and Pricing*, John Wiley & Sons: Chichester

Jara-Díaz, S, Martinez-Budría, E, Cortes, C and Basso, L, 2002, A multi-output cost function for the services of Spanish ports' infrastructure, *Transportation*, 29(4), 419–437

Keebler, JS, Manrodt, KB, Dutshe, DA and Ledyard, DM, 1999, *Keeping Score: Measuring the Business Value of Logistics in the Supply Chain*, University of Tennessee and the Council of Logistics Management

Kessides, I, 2004, *Reforming Infrastructure: Privatization, Regulation, and Competition*, World Bank and Oxford University Press

Kim, KH and Moon, KC, 2003, Berth scheduling by simulated annealing, *Transportation Research Part B*, 37, 541–560

Kim, KH and Park, YM, 2004, A crane scheduling method for port container terminals, *European Journal of Operational Research*, 156, 752–768

Kim, KH, Lee, SJ, Park, YM, Yang, C and Bae, K, 2006, Dispatching yard cranes in port container terminals, *Proceedings of the Transportation Research Board 85th Annual Meeting*, Washington, DC

Kim, M and Sachish, A, 1986, The structure of production, technical change and productivity in a port, *Journal of Industrial Economics*, 35(2), 209–223

Kite-Powell, H, 2005, *Economic Implications of Possible Reductions in Boston Port Calls due to Ship Strike Management Measures*, Report produced for NOAA National Marine Fisheries and MASSPORT

Kruk, B and Donner, ML, 2008, *Review of Cost of Compliance with the New International Freight Transport Security Requirements*, World Bank Transport Papers, TP 16, 1–58

Kwak, SJ, Yoo, SH and Chang, JI, 2005, The role of the maritime industry in the Korean national economy: an input-output analysis, *Marine Policy*, 29, 371–383

Lawrance, D and Richards, A, 2004, Distributing the gains from waterfront productivity improvements, *Economic Record*, 80, 43–52

Lee, HL and Whang, S, 2005, Higher supply chain security with lower cost: lessons from total quality management, *International Journal of Production Economics*, 96(3), 289–300

Legato, P and Mazza, RM, 2001, Berth planning and resources optimisation at a container terminal via discrete event simulation, *European Journal of Operational Research*, 133, 537–547

Léonard, P, 1989, *Les Indicateurs de la Politique Maritime*, Paradigme: Caen, France

Leontief, W, 1936, Quantitative input-output relations in economic system of the United States, *Review of Economics and Statistics*, 18(3), 105–125

Lirn, TC, Thanopoulou, HE and Beresford, AKC, 2003, Transhipment port selection and decision-making behaviour: analysing the Taiwanese case, *International Journal of Logistics: Research and Applications*, 6(4), 229–244

Liu, Z, 1995, The comparative performance of public and private enterprises: the case of British ports, *Journal of Transport Economics and Policy*, 29(3), 263–274

Lloyd's List, 2003, *Lines Take on Extra Staff to Cope with US Cargo Clamp*, Lloyd's List 05/03/2003

Louviere, JJ, Hensher, DA and Swait, J,2000, *Stated Choice Methods: Analysis and Applications in Marketing, Transportation and Environmental Valuation*, Cambridge University Press: Cambridge

Lyridis, D, Fyrvik, T, Kapetanis, GN, Ventikos, N, Anaxagorou, P, Uthaug, E and Psaraftis, HN, 2005, Optimizing shipping company operations using business process modelling, *Maritime Policy and Management*, 32(4), 403–420

Malchow, MB, 2001, *An Analysis of Port Selection*, Dissertation submitted to the Department of Civil Engineering, Institute of Transportation Studies, University of California at Berkeley

Malchow, MB and Kanafani, A, 2004, A disaggregate analysis of port selection, *Transportation Research Part E*, 40, 317–337

Mangan, J, Lalwani, C and Gardner, B, 2002, Modelling port/ferry choice in RoRo freight transportation, *International Journal of Transport Management*, 1, 15–28

Martin Associates, 2001, *Economic-Impact Study of the Great Lakes St. Lawrence Seaway System*, Report prepared for the US St. Lawrence Seaway Development Corporation, Lancaster, 1–78

Martinez-Budría, E, Díaz-Armas, R, Navarro-Ibañez, M and Ravelo-Mesa, T, 1999, A study of the efficiency of Spanish port authorities using data envelopment analysis, *International Journal of Transport Economics*, 16, 37–53

Meersmans, JM and Wagelmans, PM, 2001, Dynamic scheduling of handling equipment at automated container terminals, *Econometric Institute Report EI-2001 33*, Erasmus University: Rotterdam, 1–20

Meifeng-Luo and Grigalunas, TA, 2003, A spatial economic multimodal transportation simulation model for US coastal container ports, *Maritime Economics & Logistics*, 5(2), 158–178

Menachof, D and Talas, R, 2009, The efficient trade off between security and cost for sea ports: a conceptual model, *International Journal of Risk Assessment and Management*, 13(1), 46–57

Micco, A and Perez, N, 2001, Maritime transport costs and ports efficiency, *Inter-American Development Bank Annual Meeting*, Santiago

Murphy, P, Dalenberg, D and Daley, J, 1988, A contemporary perspective of international port operations, *Transportation Journal*, 28(2), 23–32

Narasimhan, A and Palekar, U-S, 2002, Analysis and algorithms for the transtainer routing problem in container port operations, *Transportation Science*, 36(1), 63–78

Notteboom, T, 2003, Thirty-five years of containerisation in Antwerp and Rotterdam: structural changes in the container handling market, in: Loyen, R (ed.), *Struggling for Leadership: A Century and a Half of Antwerp-Rotterdam Port Competition (1870–2000)*, Physica-Verlag: New York, 117–142

Page, T, 1978, A generic view of toxic chemicals and similar risks, *Ecology Law Quarterly*, 7, 204–244

Paik, S and Bagchi, P, 2000, Process reengineering in port operations: a case study, *The International Journal of Logistics Management*, 11(2), 59–72

Pritchard, J, 2002, Firms, consumers tally losses now that West Coast ports see peace, *Associated Press State and Local Wire*, 26 November

Rios, LR and Gastaud Mecada, AC, 2006, Analysing the relative efficiency of container terminals of Mercosur using DEA, *Maritime Economics and Logistics*, 8, 331–346

Robinson, R, 1976, Modelling the port as an operational system: a perspective for research, *Economic Geography*, 52(1), 71–86

Robinson, R, 1999, *Measurements of Port Productivity and Container Terminal Design: A Cargo Systems Report*, IIR Publications: London

Rodrigue, JP, Comtois, C and Slack, B, 1997, Transportation and spatial cycles: evidence from maritime systems, *Journal of Transport Geography*, 5(2), 87–98

Rothengatter, W, 2003, Marginal cost and other pricing principles for user charging in transport, *Transport Policy*, 10(2), 121–130

Saywell, T and Borsuk, R, 2002, The fallout of the Bali bombings on regional economies: the neighbourhood takes a hit, *Far Eastern Economic Review*, Hong Kong, 24 October

Seiford, LM and Zhu, J, 1998, Stability regions for maintaining efficiency in data envelopment analysis, *European Journal of Operational Research*, 108(1), 127–139

Sengupta, JK, 1988, *Efficiency Analysis by Production Frontiers: The Nonparametric Approach*, Theory and Decision Library/Series B, Kluwer Academic Publishers: Dordrecht, The Netherlands

Song, DW, Cullinane, K and Roe, M, 2001, *The Productive Efficiency of Container Terminals: An Application to Korea and The UK*, Ashgate: Aldershot

Stavins, RN (ed.), *Economics of the Environment*, 4th Edition, Norton & Co: New York, NY, 378–393

Steenken, D, Voss, S and Stahlbock, R, 2004, Container terminal operation and operations research- a classification and literature review, *OR Spectrum*, 26(1), 3–49

Taaffe, EJ, Merrill, RL and Gould, PR, 1963, Transport expansion in underdeveloped countries: a comparative analysis, *Geographical Review*, 53, 503–529

Talley, WK, 1994, Performance indicators and port performance evaluation, *Logistics and Transportation Review,* 30(4), 339–352

Tongzon, J and Heng, W, 2005, Port privatisation, efficiency and competitiveness: some empirical evidence from container ports (terminals), *Transportation Research Part A: Policy and Practice*, 39(5), 405–424

Tongzon, JL and Sawant, L, 2007, Port choice in a competitive environment: from the shipping lines' perspective, *Applied Economics*, 39, 477–492

Tuna, O and Silan, M, 2002, Freight transportation selection criteria, an empirical investigation of Turkish liner shipping, *IAME Panama 2002 Proceedings*

UNCTAD, 1976, *Port Performance Indicators*, UNCTAD: Geneva

UNCTAD, 1985, *Port Development Handbook*, UNACTAD: Geneva

UNCTAD, 1999, The fourth generation port, *UNCTAD Ports Newsletter*, 19: 9–12

UNCTAD, 2007a, *Maritime Security: ISPS Implementation, Costs and Related Financing*, Report by the UNCTAD secretariat, UNCTAD: Geneva

UNCTAD, 2007b, *Review of Maritime Transport 2007*, UNCTAD: Geneva

UNCTAD, 2008, *Review of Maritime Transport 2008*, UNCTAD: Geneva

US Bureau of Customs and Border Protection, 2004, available at www.cbp.gov, visited on 01/03/04

US Customs and Border Protection (CBP), 2006, available at www.cbp.gov, visited on 12/03/2006

US Customs and Border Protection (CBP), 2007, available at_www.cbp.gov, visited on 12/12/2007

US Federal Register, 2003, N-RAT assessment exercise, *Federal Register*, 68(204)

US Maritime Administration—MARAD, 2005, *Public Port Finance Survey for the Financial Year 2004*, MARAD: Washington, DC

Valentine, VF and Gray, R, 2001, The measurement of port efficiency using data envelopment analysis, *Proceedings of the 9th World Conference on Transport Research*, Seoul, South Korea, 22–27 July

Van der Linden, JA, 1998, *Interdependence and Specialisation in the European Union: Inter-country Input-Output Analysis and European Integration*, Labyrint: Capelle IJssel

Van der Linden, JA, 2001, The economic impact study of maritime policy issues: application to the German case, *Maritime Policy and Management*, 28(1), 33–54

Veldman, SJ and Buckmann, EH, 2003, A model on container port competition: an application for the West European container hub-ports, *Maritime Economics and Logistics*, 5, 3–22

Verbeke, A and Debisschop, K, 1996, A note on the use of port economic impact studies for the evaluation of large scale port projects, *International Journal of Transport Economics*, 13(3), 247–258

Vis, IFA and De Koster, R, 2003, Transshipment of containers at a container terminal: an overview, *European Journal of Operational Research*, 147(1), 1–16

Vis, IFA and Harika, I, 2004, Comparison of vehicle types at an automated container terminal, *OR Spectrum*, 26, 117–143

Vitale, MR and Mavrinac, SC, 1995, How effective is your performance measurement system? *Management Accounting*, 77(2), 43–73

Wakabayashi, H and Iida, Y, 1992, Upper and lower bounds of terminal reliability of road networks: an efficient method with Bollean algebra, *Journal of Natural Disaster Science*, 14, 29–44

Walkenhorst, P and Dihel, N, 2002, *Trade Impacts of the Terrorist Attacks of 11 September 2001: A Quantitative Assessment*, Workshop on the Economic Consequences of Global Terrorism, DIW/German Institute for Economic Research: Berlin

Walter, I, 1956, *Location and Space-Economy: General Theory Relating to Industrial Location, Market Areas, Land Use, Trade, and Urban Structure*, MIT Press and Wiley: Cambridge

Wang, JJ, 1998, A container load centre with a developing hinterland: a case study of Hong Kong, *Journal of Transport Geography*, 6(3), 187–201

Wang, TF, Cullinane, KBP and Song, DW, 2005, *Container Port Production and Economic Efficiency*, Palgrave: New York

Wang, TF, Xie, X and Yang, Z, 2006, Container terminal efficiency: a context-dependent data envelopment analysis approach, *Proceedings of the International Association of Maritime Economists Annual Conference*, Melbourne, 12–14 July

Wanhill, SRC, 1974, Further analysis of optimum size seaport, *Journal of Waterways and Harbors*, 100, 377–383

Waters, RC, 1974, Role crises in America's ports, *Transportation Journal*, 14(2), 37–40

Wheelwright, SC, 1978, Reflecting corporate strategy in manufacturing decisions, *Business Horizons*, February, 57–66

White, CC, 2002, *Transportation Security and Efficiency*, Presentation at the Sloan Annual Industry Centers Meeting, Boston, 6 December

Wilmsmeier, G, Hoffmann, J and Sanchez, R, 2006, The impact of port characteristics on international maritime transport costs, *Research in Transportation Economics*, 16, 117–140

Wilson, J, Mann, C and Otsuki, T, 2003, Trade facilitation and economic development: measuring the impact, *The World Bank Economic Review*, 17, 367–389

Yang, T, Chen, MC and Hung, CC, 2007, Multiple attribute decision-making methods for the dynamic operator allocation problem, *Mathematics and Computers in Simulation*, 73(5), 285–299

Zuckerman, S, 2002, Shutdown not so bad after all, *San Francisco Chronicle*, 18 October

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